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June 14, 2018

John Tippets, Director
Idaho Department of Environmental Quality
1410 North Hilton
Boise, ID 83706

Richard Whitman, Director
Oregon Department of Environmental Quality
700 NE Multnomah Street, Suite 600
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Subject: Idaho Power Company, Hells Canyon Complex
FERC Project No. 1971
Application for Certification under Clean Water Act § 401

Dear Messrs. Tippets & Whitman:

On November 22, 2017, the Idaho Power Company withdrew and concurrently resubmitted a new application for Clean Water Act Section 401 certification for its Hells Canyon Complex hydroelectric project (FERC Project No. 1971). Discussions between Governors Otter and Brown regarding fish passage have been ongoing since April 2017 and necessitate Idaho Power withdrawing its application for § 401 certification at this time. Idaho Power concurrently is resubmitting a new, complete application for § 401 certification. Given the progress made to-date on the § 401 certification proceedings, Idaho Power is hopeful complete certifications can be issued by the end of the year.

Because of the interrelationship among water quality standards, the § 401 certification, and aquatic species and the Endangered Species Act, we have provided a courtesy copy of this letter to NOAA Fisheries and the USFWS.

IPC very much appreciates the input and cooperation of IDEQ and ODEQ staff with the development of this § 401 application. We look forward to continuing such efforts in the proceedings on the current § 401 application.

Sincerely,

Brett Dumas

Brett Dumas
Director, Environmental Affairs

cc: NOAA Fisheries, USFWS

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Section 401 Water-Quality Certification Application

Hells Canyon Complex
FERC No. 1971

June 2018

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Section 401 Water-Quality Certification Application

Hells Canyon Complex, FERC Project No. 1971

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation/ Acronym	Definition
°C	degrees Celsius
7DAM	7-day average maximum
7Q10	10-year, 7-day discharge
A/C	air conditioning
AIR	additional information request
AME	absolute mean error
ATU	accumulated thermal unit
biocriteria	biological criteria
bkcal	billion kilocaleries
BL	baseline
BLM	United States Bureau of Land Management
BOD	biochemical oxygen demand
BSP	bacteria secondary production
CFD	computational fluid dynamic
CFR	Code of Federal Regulations
cfs	cubic feet per second
CFU	colony-forming units
cm	centimeters
COD	chemical oxygen demand
CWA	*Clean Water Act of 1972* (formerly known as the *Federal Water Pollution Control Act of 1948*, as amended)
DART	Data Access in Real Time
DBOD	dissolved biochemical oxygen demand
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DN	dissolved nitrogen
DO	dissolved oxygen
DOC	dissolved organic carbon
E. coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
ESA	*Endangered Species Act of 1973*
ESPA	Eastern Snake Plain Aquifer
FEIS	final environmental impact statement
FERC	Federal Energy Regulatory Commission
FLA	final license application

Abbreviation/ Acronym	Definition
FPA	*Federal Power Act of 1935*, as amended
FPC	Federal Power Commission
FWS	United States Fish and Wildlife Service
g	grams
GBT	gas-bubble trauma
HAB	harmful algal bloom
HART	Oregon Hydroelectric Application Review Team
HCC	Hells Canyon Complex
HCD	Hells Canyon Dam
HCNRA	Hells Canyon National Recreation Area
HPS	hypolimnetic pumping system
HUC	hydrologic unit code
IDAPA	*Idaho Administrative Procedures Act*
IDEQ	Idaho Department of Environmental Quality
IDFG	Idaho Department of Fish and Game
IDHW	Idaho Department of Health and Welfare
IDWR	Idaho Department of Water Resources
IIHR	Iowa Institute of Hydraulic Research
IPC	Idaho Power Company
kg	kilogram
m	meter
m^2	square meter
m^3	cubic meter
m/s	meters per second
MDN	Marine Derived Nutrients
mg	milligram
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
ml	milliliters
mm	millimeters
msl	mean sea level
MW	megawatt
MWMT	maximum weekly maximum temperature
NA	not available
NCC	Natural Conditions Criteria
ng/L	nanograms per liter
NHC	Northwest Hydraulic Consultants

Abbreviation/ Acronym	Definition
NOAA	National Oceanic Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NSTP	natural seasonal thermal pattern
NTU	nephelometric turbidity units
O&M	operation and maintenance
OAR	Oregon Administrative Rules
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
OHA	Oregon Health Authority
OP	orthophosphate
OPHD	Oregon Health Authority Public Health Division
OPUC	Public Utility Commission of Oregon
ORS	Oregon Revised Statute
OWRD	Oregon Water Resources Department
PAH	dimethylnaphthalene
PBOD	particulate biochemical oxygen demand
pH	hydrogen ion
PME	protection, mitigation, and enhancement
PMF	probable maximum flood
PNV	potential natural vegetation
POC	particulate organic carbon
PP	particulate phosphorus
PUSP	Provisional Unified State Position
RM	river mile
ROWQIP	Riverside Operation Water-Quality Improvement Project
RV	recreational vehicle
SCADA	Supervisory Control and Data Acquisition
SED	first-order sediment oxygen demand
SOD	sediment oxygen demand
SR–HC TMDL	Snake River–Hells Canyon Total Maximum Daily Load
SRFC	Snake River fall Chinook
SRPM	Snake River Planning Model
SRSP	Snake River Stewardship Program
SU	standard unit
SWDHD	Southwest District Health Department
SWG	Settlement Working Group
TAC	Technical Advisory Committee

Abbreviation/ Acronym	Definition
TCS	temperature control structure
t-DDT	dichlorodiphenyltrichloroethane (total-DDT)
TDG	total dissolved gas
TDS	total dissolved solids
TMP	*Temperature Management Plan*
TFT	The Freshwater Trust
THEP	Tributary Habitat Enhancement Plan
TIC	total inorganic carbon
TL	total length
TMDL	total maximum daily load
TOC	total organic carbon
TOM	total organic matter
TP	total phosphorus
TSS	total suspended solids
TVA	Tennessee Valley Authority
µg/L	micrograms per liter
µm	micrometer
U.S.	United States
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USC	United States Code
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
VSS	volatile suspended solids
WMA	Wildlife Management Area
WMT	weekly maximum temperature
WQ	water quality

1. INTRODUCTION

Pursuant to the *Federal Power Act of 1935*, as amended (FPA), Idaho Power Company (IPC) filed an application with the Federal Energy Regulatory Commission (FERC) in July 2003 for a new license authorizing the continued operation and maintenance (O&M) of the Hells Canyon Complex (HCC), a 3-dam hydroelectric project comprised of the Brownlee Project, Oxbow Project, and Hells Canyon Project (collectively, FERC Project No. 1971-079). In the application, IPC proposed protection, mitigation, and enhancement (PME) measures to address effects associated with the HCC.

The HCC is located on the Snake River in Oregon and Idaho. Because the HCC is located on a border river between Oregon and Idaho, IPC is applying for *Clean Water Act of 1972* (CWA) § 401 certification from the Oregon Department of Environmental Quality (ODEQ) and Idaho Department of Environmental Quality (IDEQ) to certify any discharges originating in their respective states that may result from the continued operation of the HCC will comply with applicable water-quality standards. IPC is filing this as a joint application for Idaho and Oregon with the understanding that the ODEQ and IDEQ intend to coordinate their respective certification proceedings to avoid conflicts or inconsistencies in the issued certifications. Consistent with applicable law, each state’s CWA § 401 certification will only include conditions relating to discharges within that state.

IPC first filed a CWA § 401 certification application (§ 401 application) with the ODEQ and IDEQ in July 2003. IPC has subsequently withdrawn and filed amended § 401 applications with both states in accordance with the requirements of CWA § 401. The last application was filed in November 2018 and updated in February 2018. This current application is being filed on June 14, 2018.

1.1. HCC

1.1.1. Location Description

Hells Canyon is situated in west central Idaho and northeastern Oregon on the Snake River, a major tributary to the Columbia River and a border water of Oregon and Idaho. The HCC is in the southern part of Hells Canyon and forms 3 reservoirs: Brownlee, Oxbow, and Hells Canyon. A more detailed description of the HCC location is available in Exhibit A of the *New License Application: Hells Canyon Hydroelectric Complex*.

The FERC project boundary for the HCC extends from just above Porter Island (river mile [RM] 343), within Malheur County in the State of Oregon, approximately 5 miles northwest of Weiser, Idaho, to Hells Canyon Dam (HCD) (RM 247.6) in Wallowa County, Oregon (Figure 1.1-1). (Figure E.6-2, Panels 1–11, of the *New License Application: Hells Canyon Hydroelectric Complex*, provides an area view at a larger scale.) The length of the project boundary extends just over 95 river miles. The width of the project boundary is typically several hundred feet and is generally defined as the distance between the average high-water lines on each bank of the reservoir. Exceptions to this typical width occur in the few specific areas where IPC owns larger areas of property. Notable exceptions are on the lower Burnt River, near the

Spring Recreation Area; Sturgill Creek; Daly Creek and the upper end of the Powder River pool; and at the Brownlee and Oxbow operators' villages (Brownlee Village and Oxbow Village, respectively).

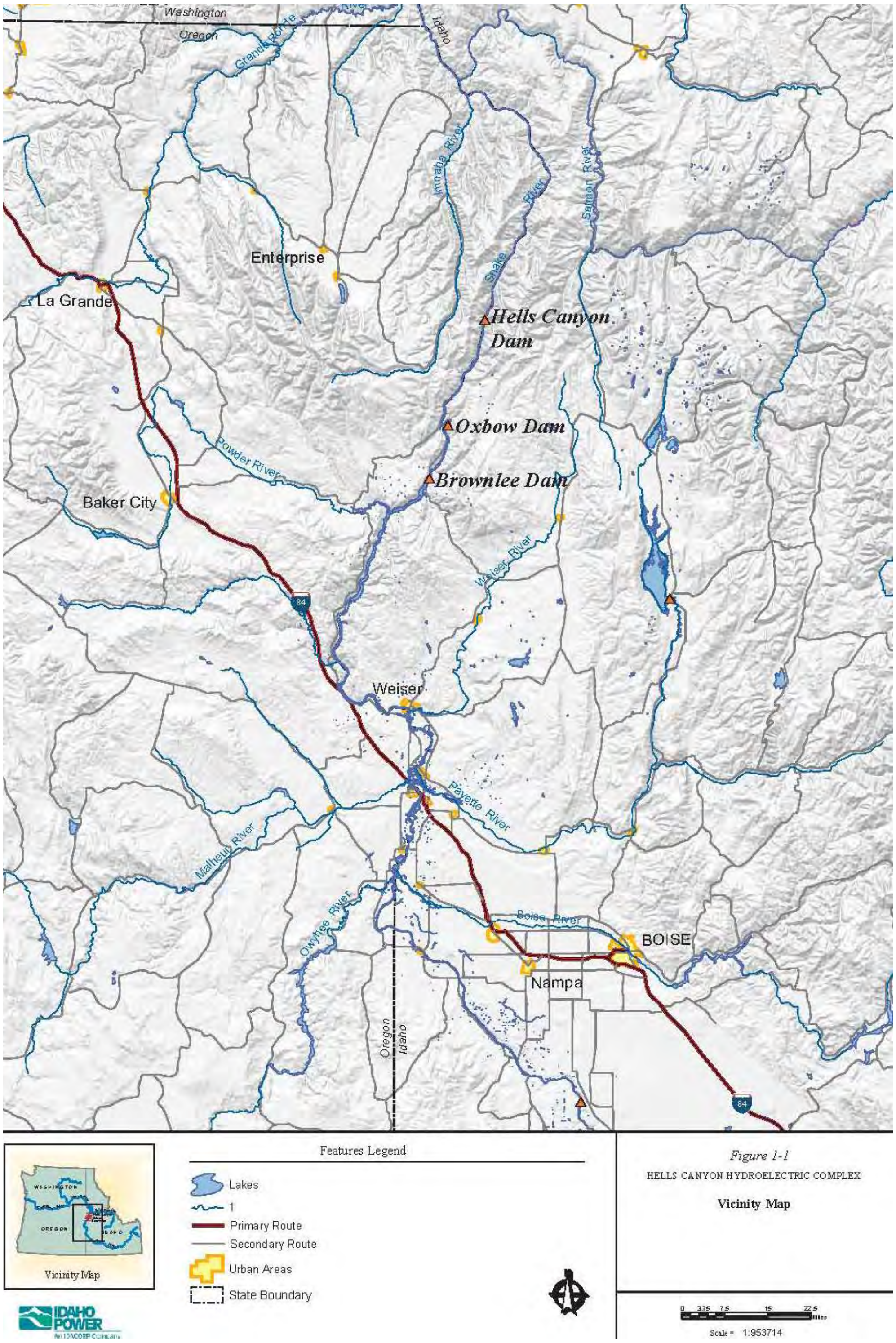

Figure 1.1-1
Vicinity map of IPC's HCC

The HCC is situated within and across the political boundaries of Malheur, Baker, and Wallowa counties in Oregon and Adams and Washington counties in Idaho; the HCC forms the border between these states. In Oregon, the upper approximately 10 miles of the project area (from just above Porter Island to the south side of Farewell Bend State Park) lie in Malheur County. Within this reach, approximately 10 islands in the Snake River lie entirely within Oregon. From the state park northward to approximately 12 miles below Oxbow Dam, the project area lies within Baker County. The remainder to the north (approximately 13 miles) is within Wallowa County and is also almost completely within the Wallowa–Whitman National Forest and the Hells Canyon National Recreation Area (HCNRA). The delineation between Adams and Washington counties in Idaho occurs near Brownlee Dam.

1.1.2. Construction History

IPC started access and site preparation work for Brownlee Dam on November 10, 1955. Brownlee Dam was substantially completed, and reservoir filling commenced on, May 9, 1958. Excavation for Oxbow Dam began on December 11, 1957. Oxbow Dam was completed, and reservoir filling commenced on March 12, 1961. Excavation for HCD began on August 27, 1964. HCD was completed, and reservoir filling commenced on, October 10, 1967.

The first Brownlee Project generating unit went into operation on August 27, 1958. The last Hells Canyon Project generator went into service on December 28, 1967. An additional turbine, Brownlee Project Unit No. 5, was constructed and placed in service on March 31, 1980. More details on project benchmarks and dates are available in Exhibit C of the *New License Application: Hells Canyon Hydroelectric Complex*.

1.1.3. Features of Interest

Prominent features of interest within the HCC in Oregon include Oxbow Dam and HCD. The Oxbow Village and Copperfield Park (RM 269.5) include the major developed areas for the HCC workforce. The village and park lie at the intersection of Oregon State Highway 86 (Oregon 86) and IPC’s road along Oxbow and Hells Canyon reservoirs. Approximately 20 residences, a kitchen and dining facility, bunkhouse, classroom facility, school, post office, and a 72-space park comprise the village. Approximately 0.25 to 0.5 miles upstream from Oxbow Village is the Oxbow shop complex (Oxbow Shop) and the Oxbow fish hatchery. Continuing upstream, shortly before reaching the bridge near Brownlee Dam (RM 283.9), the Brownlee Village and trailer park accommodate a smaller number of the HCC workforce (approximately 10 residences). The trailer park served as a camp during the construction of Brownlee Dam. A number of other United States (U.S.) Bureau of Land Management (BLM), state, and county recreation facilities; private residences; and recreational concessions are located in Oregon within the project boundary. These include a BLM facility at Copper Creek; private residences in the Homestead area; Hewitt and Holcomb parks (Baker County) on the Powder River arm (RM 7.5); a number of residences and cabins on the Powder River arm; residences in the Douglas Creek area; BLM’s Spring Recreation Area at the Burnt River (RM 326.7); the State of Oregon’s Farewell Bend State Park (RM 333.5); and the privately owned Snake River Recreational Vehicle (RV) and Oasis Campground, as well as the adjoining BLM Oasis site (RM 340).

On the Idaho side of the river, several additional points of interest are IPC's Brownlee Dam and power plant (RM 284.6), Woodhead Park (139 spaces) and the caretaker's house (RM 287.3), McCormick Park (34 spaces and tent camping) (RM 283.3), and Hells Canyon Park (24 spaces and tent camping) and the caretaker's house (RM 263.5). Other developments on the Idaho side not associated with IPC include the privately owned Mountain Man Lodge (RM 310.5); Steck Park (RM 327.9), cooperatively owned and run by the BLM and Idaho Department of Fish and Game (IDFG); and several private residences.

1.2. Existing License

1.2.1. Year Issued

The Federal Power Commission (FPC), predecessor agency to FERC, originally issued the license for the 3-dam hydroelectric project, known today as the HCC, on August 4, 1955. The license issued was for 50 years.

1.2.2. Year Expires

The original HCC license expired July 31, 2005. The project currently operates under an annual license.

1.3. New License Filing Schedule

1.3.1. Intent to File

A notice of intent to file a new license application for the HCC was filed by IPC in July 2000.

1.3.2. Draft License Application

IPC distributed a draft license application for the HCC to federal and state resource agencies, Indian tribes, and other interested parties in September 2002.

1.3.3. Final License Application

IPC filed a final license application (FLA) for the HCC with FERC on July 21, 2003 (*New License Application: Hells Canyon Hydroelectric Complex*).

1.3.4. Additional Information Request Filings

On May 4, 2004, IPC received additional information requests (AIR) from FERC relative to water-quality issues. More detail on operational scenarios is available in the *New License Application: Hells Canyon Hydroelectric Complex*, AIR OP 1; on DO augmentation in AIR WQ 1; and temperature control in AIRs WQ 2a, WQ 2b, and WQ 2c. The measures related to temperature control were reviewed by FERC in the 2007 *Final Environmental Impact Statement*

(FEIS)[1] in conjunction with a recommendation by several parties, including the Nez Perce and Umatilla tribes, that IPC investigate the installation of a temperature control structure (TCS) in Brownlee Reservoir to meet CWA numeric and narrative criteria to support downstream fisheries. FERC concluded the installation of a TCS was not warranted due to the high cost of the measure and the potential for adverse effects on Snake River fall Chinook (SRFC) salmon from increased temperatures during the summer migration season and the release of hypolimnetic water that is low in DO and high in concentrations of ammonia, mercury, and organochlorine compounds (FERC, 2007, p. 649–50).

2. CWA CERTIFICATION PROCESS

CWA § 401 (33 United States Code [USC] § 1341) requires that any person applying for a federal license or permit to conduct any activity including, but not limited to, the construction or operation of facilities that may result in any discharge into navigable waters, provides the licensing or permitting agency a certification from the state in which the discharge originates stating any such discharge will comply with applicable provisions of the CWA. FERC regulations require an applicant to also file with FERC a copy of the request for CWA § 401 certification pursuant to the U.S. Code of Federal Regulations (CFR) (18 CFR § 16.8(f)(7)).

The ODEQ is the agency of the State of Oregon designated to carry out the certification functions prescribed by CWA § 401 for Oregon waters. The IDEQ is the agency of the State of Idaho designated to carry out the certification functions prescribed by CWA § 401 for Idaho waters.

2.1. Oregon

The Oregon Environmental Quality Commission adopted Oregon Administrative Rules (OAR) 340-048-0005 through 340-048-0055 to prescribe the procedures for receiving, evaluating, and taking final action on a § 401 application. OAR 340-048-0020(2) identifies the information that must be included in an application for CWA § 401 certification.

In addition, Oregon Revised Statute (ORS) Chapter 543A prescribes procedures for coordination among state agencies regarding the reauthorization of federally licensed hydroelectric projects, including the state certification of water quality. The Oregon Hydroelectric Application Review Team (HART) is tasked with this responsibility, though the ODEQ has the lead responsibility on CWA § 401 certification.

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[1] A CD with a complete copy of the FEIS has been submitted to the ODEQ and IDEQ in conjunction with previous filings of the § 401 application.

2.2. Idaho

The Idaho Board of Environmental Quality has not adopted rules specific to the CWA § 401 certification process. However, the IDEQ has developed *Idaho Section 401 Certification Guidance* (IDEQ 2012) to foster a consistent statewide approach to CWA § 401 certification.

2.3. Other Potentially Applicable State Laws

CWA § 401 (d) requires any certification issued to set forth such limitations necessary to ensure compliance with applicable water-quality standards and “any other appropriate requirements of state law.”[2] OAR 340-048-0020(j) requires a § 401 application filed with the ODEQ to identify and describe “other requirements of state law applicable to the activity that have any relationship to water quality.” IPC provides the following in compliance with OAR 340-048-0020(j).

2.3.1. HART

ORS 543A establishes a Hydroelectric Authorization Review Team (HART) process for developing a coordinated state position in governmental proceedings related to the reauthorization of existing hydroelectric projects. Pursuant to ORS 543A, the HART process will include a reauthorization of IPC’s water rights for the project and consideration of impacts to fish and wildlife habitat and resources; recreation; scenic and aesthetic values; historic, cultural, and archaeological sites; and botanical resources. HART for the HCC is composed of the following Oregon agencies: ODEQ; Oregon Department of Fish and Wildlife (ODFW); Public Utility Commission of Oregon (OPUC); Oregon Department of State Lands; Oregon Water Resources Department (OWRD); Department of Geology and Mining Industries; Oregon Marine Board; and the Oregon Parks and Recreation Department.

The HART issued a Provisional Unified State Position (PUSP) for the HCC licensing on April 25, 2003, and a Second Unified State Position (SUSP) on December 12, 2016, as part of a package of draft state approvals, including a draft ODEQ section 401 certification, an ODEQ Evaluation and Findings Report, and a draft OWRD proposed final order approving new draft water rights certificates. The SUSP and OWRD documents will undergo additional review in response to this revised application.

Over the course of the HART and 401 process, IPC has submitted comments restating its long-standing concerns regarding the nature, scope and applicability of the HART process to the HCC relicensing due to FERC’s regulatory jurisdiction over the project under the Federal Power Act and its unique location on the navigable, interstate boundary waters between Oregon and Idaho. Notwithstanding those concerns, IPC elected to seek concurrent FERC relicensing and state reauthorization pursuant to ORS 543A.071 because of the opportunity it afforded for cooperation and coordination among the various Oregon agencies and the FERC process. IPC, however, has consistently reserved the option to contest the applicability of the HART process and, pursuant to

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[2] 33 USC 1341(d). Because there are no federal requirements, such as effluent limitations or new source performance standards, applicable to hydroelectric projects, ODEQ certification conditions will be based solely on state law.

ORS 543A.071(4), withdraw from the Oregon reauthorization process at any time prior to issuance of a final water right certificate, should it determine such action necessary to protect IPC's interests.

2.3.2. Laws Administered by the ODEQ and IDEQ

ORS 454.605, et seq., and OAR Chapter 340, Divisions 71 and 73, contain requirements to govern the on-site disposal of sewage. The purpose of such rules is to prevent health hazards and protect the quality of surface water and groundwater. The ODEQ contracts with local governments to administer the program pursuant to state rules.

IPC has received 2 permits for sewage disposal associated with the HCC. Permit number ID0020907 was originally issued, in part, for treated sanitary sewage at the Brownlee Project. This discharge was permanently eliminated on May 26, 2001, and replaced with a new, upland on-site disposal (septic) system permitted through the Idaho Department of Health and Welfare (IDHW), Southwest District Health Department (SWDHD). The ODEQ has permitted (OR-002727-8) a sewage holding tank for the Hells Canyon Project. As such, no treated or untreated sewage is disposed directly to surface waters of Oregon or Idaho.

IPC has 3 National Pollutant Discharge Elimination System (NPDES) permits issued for the disposal of non-contact cooling water and sump discharges: ID-002090-7, OR-002728-6, and OR-002727-8 at the Brownlee, Oxbow, and Hells Canyon projects, respectively. The constituents typically monitored and reported include flow rate, water temperature, oil and grease, hydrogen ion (pH), and total suspended solids (TSS).

Associated with the HCC, IPC maintains several comfort stations that include showers, restrooms and vault toilets, and RV dump stations (Table 2.3-1). IPC also contracts the placement of 30 portable toilets from April through October. In addition, there is a fish-cleaning station at Woodhead Park on Brownlee Reservoir. There is no treated or untreated wastewater discharged directly to surface waters of Oregon or Idaho. The largest facility, Woodhead Park, developed in 1994, disposes effluent by a land-application treatment system meeting IDEQ standards.

Table 2.3-1
Number of comfort stations (includes showers), restrooms and vault toilets, and RV dump-station treatment type by project in the HCC

Project	Location	Comfort Stations	Restrooms and Vault Toilets	RV Dump-Station Treatment Type
Brownlee	Woodhead Park	2	4	Wastewater treatment lagoon
Oxbow	McCormick Park	1	0	Drain field
	Carters Landing	0	1	Pump-out
	Oxbow Boat Launch	0	1	Pump-out
Hells Canyon	Copperfield Park	1	0	Drain field
	Hells Canyon Park	1	0	Drain field

IPC will improve and expand the recreational facilities in the HCC as part of the new license issuance. The McCormick Park comfort station will be replaced, increasing capacity, and another comfort station will be added at Hells Canyon Park. A camp host septic will be added at the Spring Recreation Site on Brownlee Reservoir, and IPC will rebuild the associated fish-cleaning station. Additionally, IPC will take over the maintenance of 18 vault toilets and add another 7 throughout the HCC.

2.4. IPC State Water Rights

IPC has vested rights to use the waters of the Snake River in connection with the Hells Canyon Project pursuant to water rights issued by Oregon and Idaho. The CWA does not supersede or abrogate rights to quantities of water that have been established by either state (CWA § 101(g), 33 USC § 1251(g)). By filing this application, IPC does not waive any vested state water rights.

2.4.1. Oregon Water Rights

IPC holds vested water rights to use the waters of the Snake River in Oregon pursuant to the terms and conditions of Oregon License No. 189 for the Hells Canyon Dam development, issued April 22, 1968, for the period ending December 31, 2017. Similarly, under Oregon License No. 161, issued December 19, 1961, IPC has a vested right to use the waters of the Snake River in connection with the Oxbow Project, pursuant to the terms and conditions of such license, for the period ending December 31, 2017. Finally, under Oregon License No. 188, issued June 5, 1961, as amended January 20, 1981, IPC has a vested right to use the waters of the Snake River in connection with the Brownlee Project, pursuant to the terms and conditions of such license, for the period ending December 31, 2017. Under ORS 543A.150(2), expiration dates in hydropower water rights for which the HART reauthorization process is pending shall be extended. IPC has requested that the OWRD issue an extension for HE 189, HE 161 and HE 188. IPC requests that ODEQ include appropriate conditions in its certification that recognize and protect IPC’s vested water rights under Oregon law.

2.4.2. Idaho Water Rights

IPC holds vested water rights in Idaho in connection with each of the 3 reservoirs that comprise the HCC. For Brownlee Reservoir, IPC has the following Idaho state water rights: 03-02018, 03-02023, 03-02024, and 03-07018. For Oxbow Reservoir, IPC has the following Idaho state water rights: 03-02019, 03-02025, and 03-10246. For Hells Canyon Reservoir, IPC has the following Idaho state water rights: 03-02017, 03-02020, 03-10184, and 03-10247.

3. CONCURRENT WATERSHED WATER-QUALITY PROCESSES

IPC supports the watershed approach used to develop and implement a total maximum daily load (TMDL) for the Snake River as an appropriate mechanism to improve the water quality of the Snake River and considers it particularly relevant to the CWA § 401 certification process. As such, IPC supported the development of the Upper Snake–Rock Creek TMDL (commonly referred to as the Middle Snake River TMDL), the King Hill–C. J. Strike Reservoir

TMDL, the Middle Snake–Succor Creek TMDL, and the Snake River–Hells Canyon TMDL (SR–HC TMDL) and continues to actively participate in their implementation.

The SR–HC TMDL includes the reach of the Snake River associated with the HCC. The IDEQ and ODEQ issued the SR–HC TMDL in July 2003, with revisions in June 2004 (IDEQ and ODEQ 2004). The U.S. Environmental Protection Agency (EPA) approved the individual bacteria, pH, pesticides, and TDG TMDLs in March 2004 and the rest of the TMDLs in September 2004.[3]

3.1. A Watershed-Based Approach

CWA § 303 requires that states adopt water-quality standards necessary to protect designated beneficial uses, including fish, wildlife, and recreation. Subsection 303(d) establishes requirements for states to identify and prioritize water bodies that are water-quality limited or impaired (i.e., water bodies that do not meet applicable water-quality standards). Oregon and Idaho's *Integrated Report* lists these waters, as well as the current condition of all state waters (CWA § 305(b)). For waters identified in Category 5 of the *Integrated Report*, states must develop a TMDL for each of the pollutants for which water-quality standards are exceeded.

TMDLs define the amount of a particular pollutant that can be present in a water body without causing an exceedance of applicable water-quality standards or non-attainment of beneficial uses. TMDLs also define, based on the best available science, the amount of a pollutant a water body can receive from all sources and still meet applicable water-quality standards. Natural sources of pollutants, as well as releases from point and nonpoint sources (anthropogenic sources), are taken into consideration in the development of TMDLs. Pollutant loads are then allocated or budgeted to the identified sources (including natural sources) in a manner that describes the total amount of pollutant load that can be released to the water body by each identified source without causing applicable water-quality standards to be exceeded. In this way, the IDEQ and ODEQ (2004) stated, "responsibility for improving water quality lies on the shoulders of everyone who lives, works or plays in a watershed that drains into an impaired waterbody."[4] A key objective of the TMDL process was to "establish load allocation mechanisms that will allow attainment of the water quality targets through (to the extent possible) fair and equitable distribution of the identified pollutant loads, and result in productive implementation without causing undue hardship on any single pollutant source."[5]

In connection with the development of TMDLs, water-quality management plans (referred to as implementation plans in Idaho) are also developed to identify actions to achieve the TMDL load

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[3] On October 7, 2003, IPC filed a petition for judicial review in the Circuit Court for Baker County, Oregon, Case No. 03-678, challenging those portions of the SR–HC TMDL that impose a temperature load allocation on the HCC. This petition is still pending; it has been extended annually by agreement between IPC and the State of Oregon and approval of the court. This notwithstanding, IPC will propose PME measures as part of the § 401 application process that address temperature effects of the HCC downstream of HCD.

[4] SR–HC TMDL, p. 4.

[5] SR–HC TMDL, p. 18.

and waste load allocations and improve the water quality of a listed water body. In Oregon, these management plans must be submitted to the EPA with a draft TMDL for approval. In Idaho, implementation plans are to be developed within 18 months of the EPA's approval of the TMDL. The implementation of these management plans, which generally includes periodic reviews and revisions, is expected to result in the attainment of water-quality standards for a CWA § 303(d) listed water body.

3.2. Development of TMDLs in the Watershed

Segments of the Snake River, upstream and downstream of the HCC, are listed by Oregon and Idaho as water-quality limited under § 303(d) of the CWA. Information on the segments listed and the water-quality standards exceeded can be accessed on the ODEQ and IDEQ websites.

Consistent with these listings, TMDL processes and related management plans are in place or are being developed for most of the upstream waterways, including the Weiser, Payette, Malheur, Owyhee, and Boise watersheds, as well as the Snake River upstream through American Falls Reservoir. The Snake River TMDLs include the Middle Snake–Succor Creek, King Hill–C. J. Strike Reservoir, Middle Snake, Upper Snake–Rock Creek, Lake Walcott, and American Falls. The management or implementation plans associated with these TMDL efforts contain mechanisms specifically targeted to reduce, among other pollutants, bacteria, sediment, nutrients, DO, and temperature impacts to tributary watersheds and the Snake River. In many cases, implementation plans have already begun upstream and are demonstrating positive results. While the ODEQ and IDEQ expect that water quality in the Snake River will improve with the implementation of the TMDLs and that these improvements will lead to corresponding water-quality benefits in the HCC, the agencies also note that, due to the size of the watershed and the complexities involved, an extended period of time will be required to achieve the water-quality targets (IDEQ and ODEQ 2004). According to the SR–HC TMDL:

> For watersheds that have a combination of point and nonpoint sources where pollution reduction goals can only be achieved by including some nonpoint source reduction, a reasonable assurance that reductions will be met must be incorporated into the TMDL (EPA, 1991). The SR–HC TMDL will rely on nonpoint source reductions to meet the load allocations to achieve desired water quality and to restore designated beneficial uses. The State of Oregon Water Quality Management Plan and the State of Idaho Implementation Plan (Section 6.0) contain more detailed information on implementation programs that will provide reasonable assurance of implementation.[6]

For purposes of this application, reasonable assurance of compliance with the water-quality standards assumes full implementation of TMDLs.

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[6] SR–HC TMDL, p. 475.

3.3. The SR–HC TMDL

In addition to the TMDL processes referenced previously, the ODEQ and IDEQ initiated a TMDL process in 2000 involving the reach of the Snake River associated with the HCC. This process was in response to CWA § 303(d) listings by Oregon or Idaho for bacteria, sediment, pesticides, DO, nutrients, pH, temperature, and mercury. Additionally, TDG was assessed during the TMDL process, and Idaho added TDG and removed bacteria and pH as pollutants impairing reaches of the Snake River and the HCC. The SR–HC TMDL and *Water Quality Management Plan* were issued by the IDEQ and ODEQ in July 2003 and revised in June 2004. The EPA approved pesticide and TDG TMDLs in March 2004 and nutrients, sediment, DO, and temperature TMDLs in September 2004. The SR–HC TMDL covers the mainstem Snake River from RM 409 near the town of Adrian, Oregon, to the inflow of the Salmon River at RM 188.2 and includes Brownlee, Oxbow, and Hells Canyon reservoirs.

The EPA added chlorophyll *a* in 2012 to Oregon's CWA § 303(d) list as impairing reaches of the Snake River and the HCC outside of the irrigation season.

IPC actively participated in the SR–HC TMDL process as part of a larger watershed water-quality approach initiated by the ODEQ and IDEQ because improvement in water quality in the Snake River depends on water-quality improvements throughout the Snake River watershed. Water quality within the HCC reservoirs, as well as the water quality of releases from those reservoirs, is largely a function of the quality of the Snake River water flowing into Brownlee Reservoir. The ODEQ and IDEQ also recognize the interrelationship of the TMDL efforts on the Snake River with the HCC licensing and CWA § 401 certification processes (IDEQ and ODEQ 2004).

The IDEQ and ODEQ (2004) describe the available database on water-quality conditions in the lower Snake River and Hells Canyon reaches of the Snake River as "robust" (much of the data being the result of the IPC's study and data-collection efforts associated with the licensing of the HCC). However, the states recognize that achieving water-quality standards in a river as complex as the Snake River would require an iterative and extended process that will require several decades to respond completely to implementation projects and changes in management. The SR–HC TMDL specifically notes the following:

> As demonstrated by the size and diversity of the issues addressed in this document, the SR–HC TMDL reach is a highly complex system and will no doubt yield unexpected results as implementation and further data collections proceeds. The challenges encountered in determining designated beneficial use support and system impairment are an outgrowth of this complexity and will require additional assessment and revisitation as our understanding of the system evolves. Additionally, due to the complexity encountered and the enormous geographic scope of the effort, an extended time period for implementation and system response will be required.[7]

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[7] SR–HC TMDL, p. 481–482.

With regard to temperature specifically, the SR–HC TMDL states it is difficult to determine what natural temperature conditions are for such a highly regulated system or precisely how altered current conditions are from natural conditions (IDEQ and ODEQ 2004). To address this, it suggested a site-potential analysis in part to assess the influence of the HCC on water temperatures downstream and develop a temperature load allocation for the project using inflow temperatures measured at Brownlee Reservoir as an estimate of site potential in the Snake River downstream of the HCC.

IPC disagreed with the site-potential standard because it allows upstream temperatures to exceed the applicable numeric temperature criterion. The site-potential standard effectively supersedes the upstream numeric criterion of 19 degrees Celsius (°C) (previously 17.8°C at the time of the SR–HC TMDL), even though the SR–HC TMDL determined elevated temperatures upstream of the HCC are due in part to anthropogenic sources, such as upstream and tributary impoundments, water withdrawals, channel straightening and diking, and the removal of streamside vegetation that cannot be precisely quantified. This is not consistent with the ODEQ's definition of "natural conditions" for purposes of applying the ODEQ's Natural Conditions Criteria (NCC). See OAR 340-041-0002(41) and 340-041-0028(8). While the TMDL provided that this estimate of site potential should not be interpreted as natural conditions, the elevated site-potential temperatures supplant the applicable numeric criteria upstream of the HCC.[8] IPC generally concurred that natural-condition temperatures for the Snake River prior to Euro-American settlement could not be precisely determined. However, during the public comment period to the 2001 draft SR–HC TMDL, IPC asserted that the SR–HC TMDL temperature analysis improperly ignored upstream anthropogenic effects on water temperature (IPC 2002).

Despite that assertion, IPC considered the IDEQ's and ODEQ's 2001 approach to temperature in the draft TMDL to be acceptable because "…it has treated all anthropogenic temperature influences in the watershed equally and has not attempted to make-up for the ignored effects of these influences by allocating additional, disproportional load allocations to specific anthropogenic influences, including the HCC."[9] IPC also commented that the manner in which the IDEQ and ODEQ addressed temperature in the SR–HC TMDL was consistent with prior TMDLs developed in Idaho:

> The manner in which the DEQs approach the temperature issue in this Draft TMDL is similar to the approach used by IDEQ in the Payette watershed. In the EPA approved Payette TMDL, IDEQ acknowledged that while water temperatures in the watershed exceeded water quality standards for cold water biota and salmonid spawning (as in the Snake River), other factors, including habitat modification and flow alteration, were significant causes of beneficial use impairment. IDEQ further found that another condition that

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[8] While the concept of site potential may not be representative of natural conditions, it may suffer from the same legal infirmities of the Oregon NCC that was struck down by the Court in *Northwest Environmental Advocates v. EPA et al.*, 855 F.Supp.2d 1199 (D. Or. 2012) (*NWEA II*). The EPA subsequently withdrew its approval of Oregon's NCC for temperature by letter to the ODEQ dated August 8, 2013.

[9] IPC letter to Tonya Dombrowski (IDEQ) dated April 19, 2002.

> precluded the development of a temperature TMDL in the Payette watershed was warm water temperatures upstream of Black Canyon Reservoir. IDEQ therefore concluded in the Payette TMDL "because of these conditions, it is recommended that temperature TMDL not be developed due to external sources of warm water temperatures and habitat modification." IPC recommends that the current approach in this Draft TMDL be maintained, as it is consistent with IDEQ's prior practice and is otherwise fundamentally fair.

The EPA also submitted comments to the 2001 draft SR–HC TMDL. In those comments, the EPA expressed concern that increased fall temperatures below the HCC should be considered in the temperature TMDL because "the fall period in question includes one of the most critical time periods for SRFC, which spawn below HCD. Allocations should be established to ensure temperature criteria are attained during the spawning and incubation periods."[10] IPC also addressed the fall spawning period in its 2002 comments:

> Fall Chinook spawning downstream of Hells Canyon Dam is currently supported under the existing thermal regime… Nonetheless fall Chinook spawning water temperature criteria (13°C and 9°C), as currently established, are difficult to meet below the HCC because the temperature of water flowing into the HCC is well above the temperature criteria. However, reservoir temperature modeling shows that when upstream inflow temperatures meet the applicable target, downstream temperatures are at or near criteria…These results demonstrate that a broad watershed based approach is needed to address temperature problems in the Snake River.[11]

On July 15, 2003, the ODEQ and IDEQ issued the final SR–HC TMDL that imposed a temperature load allocation[12] for the outflow from HCD of no greater than a maximum weekly maximum temperature (MWMT) of 13°C when inflow temperature to Brownlee Reservoir, defined as site potential in the SR–HC TMDL, is less than an MWMT of 13°C or no more than a 0.14°C increase in water temperature when site potential is greater than an MWMT of 13°C.[13] The load allocation applies from October 23 through April 15 for SRFC spawning and November 1 through March 30 for mountain whitefish (*Prosopium williamsoni*) spawning.

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[10] EPA letter to the IDEQ and ODEQ, dated April 24, 2002. In its comments, the EPA also acknowledged that in making determinations regarding natural conditions, "temperatures at the upstream boundary of the TMDL are used as the baseline for the natural condition."

[11] IPC public comments on the draft SR–HC TMDL, April 19, 2002, at p. 7.

[12] Waste load allocations, specific to the 3 NPDES permits issued for the Brownlee, Oxbow, and Hells Canyon powerhouses were also assigned in the SR–HC TMDL.

[13] Oregon has revised standards for allowable anthropogenic increases to 0.3°C. This revision affects IPC's load allocation.

4. PROJECT DESCRIPTION

4.1. Legal Name and Address of Project Owner

Idaho Power Company
1221 W. Idaho St.
P.O. Box 70
Boise, ID 83702
Phone: 208-388-2676

4.2. Legal Name and Address of Owner's Official Representative

James C. Tucker
Lead Counsel
Idaho Power Company
1221 W. Idaho St.
P.O. Box 70
Boise, ID 83702

4.3. Adjacent Lands

4.3.1. Names and Addresses of Contiguous Property Owners

Names and addresses of Oregon contiguous property owners to the HCC are included as Exhibit 4.3-1.

4.3.2. Adjacent Land Use

The project area includes 17,070 acres of land, including lands above and below the normal high-water mark (Table 4.3-1)[14]. Of the total project acreage, 5,600 acres (33%) are federally owned; 340 acres (2%) are state owned; and 11,130 acres (65%) are privately owned. Of the privately owned land in the project area, IPC owns 9,660 acres (57% of the total acreage).

Table 4.3-1
Land ownership (acres) in the HCC project area

Land Ownership	Hells Canyon	Oxbow	Brownlee	Total HCC	% of Total
Total Lands (flooded and non-flooded lands)					
Federal lands					
U.S. Forest Service (USFS)	1,360	–	–	1,360	7.97
BLM	240	570	3,430	4,240	24.84

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[14] IPC has proposed a new project boundary as part of the HCC new license application. Table 4.3-1 is based on the existing project boundary.

Total federal lands	*1,600*	*570*	*3,430*	*5,600*	*32.81*
State lands	0	10	330	340	1.99
IPC lands					
Limited-use rights	30	0	1,140	1,170	6.85
Full-use rights	330	1,100	7,060	8,490	49.74
Total IPC lands	*360*	*1,100*	*8,200*	*9,660*	*56.59*
Other private lands	100	610	760	1,470	8.61
Total acreage in project boundary	**2,060**	**2,290**	**12,720**	**17,070**	**100.00**
Flooded Lands					
Federal lands					
USFS	970	–	–	970	9.49
BLM	220	300	2,180	2,700	26.42
Total federal lands	*1,190*	*300*	*2,180*	*3,670*	*35.91*
State lands	0	0	110	110	1.08
IPC lands	90	120	6,000	6,210	60.76
Other private lands	0	80	150	230	2.25
Total acreage flooded	**1,280**	**500**	**8,440**	**10,220**	**100.00**

Of the total project acreage, 6,850 acres (40%) are above the normal high-water mark. (These acreages are determined by subtracting the flooded lands from the total land values.) Federal and state lands comprise 1,930 acres (28%) and 230 acres (3%), respectively, of the total unflooded acreage. Private lands make up 4,690 acres (68%) of the unflooded lands in the project area. Of these lands, IPC owns 3,450 acres, or half of all unflooded lands in the project area.

At the upstream end of the project area near Weiser, Idaho, agriculture and private ownership are extensive. As the canyon steepens along Brownlee Reservoir, more lands come under federal ownership, primarily managed by the BLM. Significant state ownership associated with the Cecil D. Andrus Wildlife Management Area (WMA) occurs on the Idaho side, just upstream of Brownlee Dam. On the Powder River arm, BLM and private lands are interspersed until agriculture and corresponding private ownership predominate around Richland, Oregon.

Along Oxbow Reservoir, BLM-managed land and private lands continue to be intermixed. IPC's land ownership in fee is focused on Brownlee and Oxbow reservoirs, with several larger parcels on the Powder River arm of Brownlee Reservoir.

On the Idaho side, the Payette National Forest reaches down to Hells Canyon Reservoir just downstream of Oxbow Village and continues on to HCD, where the HCNRA begins. Private ownership predominates the Oregon side of Hells Canyon Reservoir, with a few larger parcels of BLM-managed lands interspersed down to Copper Creek, which forms the boundary of the HCNRA and wilderness area.

Land in the HCC is used for 6 primary purposes: 1) cultivated agriculture, 2) livestock grazing, 3) hydroelectric power generation, 4) recreation, 5) wildlife habitat, and 6) residential and rural residential use. In the past, industrial mining and timber harvest also occurred. Any mining remaining in the area is believed to be recreational rather than industrial. Although timber sales and harvest may still occur at higher elevations, no harvest is known to have recently occurred. Interstate 84 (I 84) passes near the upper end of the project area on the Oregon side. A small area of commercial use occurs adjacent to I 84 at Farewell Bend, Oregon. The distribution of these land uses and the aesthetic character of the area are largely determined by the canyon's geography. More detail on land use throughout the HCC is available in Exhibit E.6 of the *New License Application: Hells Canyon Hydroelectric Complex*.

4.3.3. Evaluation of Consistency of IPC's Project with County Comprehensive Plans

Per Oregon regulations OAR 340-048-0020(2)(i)(A) and (C), an applicant must provide an exhibit that "includes land use compatibility findings for the activity prepared by the local planning jurisdiction" and "discuss the potential direct and indirect relationship to water quality of each finding or land use provision." The HCC is within, or adjacent to, Malheur, Baker, and Wallowa counties in Oregon. Although the FPA may preempt county plans, IPC provides, as Exhibit 4.3-2 to this application, the findings and an evaluation of such plans in accordance with the Oregon regulations.

More detail is available in the *New License Application: Hells Canyon Hydroelectric Complex*. Proposed PME measures are included in Section E.6.4., and the *Hells Canyon Resource Management Plan* is included as Technical Report E.6-1., also summarized in Section E.6.4 of Exhibit E.

4.4. Project Overview

The HCC includes the Snake River from Farewell Bend, Oregon, downstream approximately 95 river miles to HCD. The HCC is comprised of Brownlee, Oxbow, and HCDs and reservoirs. The reservoirs were constructed primarily for power production, although Brownlee Reservoir has operational requirements related to flood control. The 3-dam complex was initiated in 1958 with the construction of Brownlee Dam. The contemporary Oxbow Project was constructed in 1961, and HCD was constructed in 1967. Together, the 3 hydroelectric projects have a total nameplate generating capacity of 1,166.9 megawatts (MW), or enough electric energy to supply 758,485 homes. As such, the HCC is the centerpiece of IPC's generating portfolio and is critical to the economies of Idaho and eastern Oregon. More detail on IPC's hydroelectric resources is available in Exhibit H of the *New License Application: Hells Canyon Hydroelectric Complex*.

The combined water volume of the 3 HCC reservoirs is approximately 1,647,500 acre-feet, while the usable storage is 1,009,198 acre-feet. All of the reservoirs can be characterized as relatively deep, with mean depths ranging from 50 feet (Oxbow Reservoir) to 100 feet (Brownlee Reservoir). The maximum depth in Brownlee Reservoir is 300 feet. More detail on the physical characteristics of the HCC reservoirs is available in Technical Report E.2.2-2 of the *New License Application: Hells Canyon Hydroelectric Complex*. Both Oxbow and Hells Canyon reservoirs have normal water-level fluctuations of approximately 5 feet, with an additional 5 feet for atypical circumstances. In contrast, the water-level fluctuation of Brownlee Reservoir is approximately 100 feet. Most water-level fluctuation in Oxbow and Hells Canyon reservoirs is related to power production, while flood control accounts for most of the annual change in water-surface elevation in Brownlee Reservoir.

Brownlee Reservoir is the largest of the 3 reservoirs, with a total volume of approximately 1,420,000 acre-feet and a usable storage of 975,318 acre-feet. The average annual flow into Brownlee Reservoir is approximately 13,000,000 acre-feet. Despite the large volume of Brownlee Reservoir, retention times are relatively low (approximately 30 days) because of the large amount of flow into the reservoir.

Snowmelt runoff dominates the project area's hydrology. Based on records of U.S. Geological Survey (USGS) gage 13269000, Brownlee Reservoir receives its highest inflows in May (Brennan et al. 2000). The lowest rate of inflow occurs in August when precipitation levels are lowest and irrigation diversions in the Snake River are highest (USBR 1999). This general hydrologic regime is typical of most major tributaries to the HCC. However, this regime probably does not reflect the natural hydrologic processes because many of the tributaries are regulated by reservoirs for flood control, agricultural water supplies, power generation, and recreation (IDWR 1971). Many of the drains discharge small volumes of water (less than 1 cubic meter [m^3] per second) from irrigated cropland adjacent to the Snake River (Myers et al. 1998).

The use of Brownlee Reservoir to meet flood-control requirements may result in slightly higher flows from January through April and slightly lower flows in May and June than would occur without the flood-control requirements. Because Oxbow Reservoir receives flows primarily from Brownlee Reservoir, and Hells Canyon Reservoir, in turn, receives discharged flows primarily from Oxbow Reservoir, the hydrologic regimes of Oxbow and Hells Canyon reservoirs are very similar to that of Brownlee Reservoir.

4.5. Project Operations

The HCC includes the dams, reservoirs, and power plants associated with the Brownlee, Oxbow, and Hells Canyon projects. Operations of the three projects are closely coordinated to generate electricity and serve many other public purposes.

Currently, 534,534 customers rely on IPC's hydroelectric and thermal generation system for power. The HCC is a critical part of IPC's generation system. Its winter and summer operations are particularly important because energy needs are highest during those seasons. In winter, customers need extra electricity for lighting and heating. During the summer, they need extra electricity for air conditioning and irrigation pumping.

IPC operates the HCC to comply with its existing FERC license, as well as voluntary arrangements to accommodate other interests, such as recreational use and environmental resources. Among these arrangements are the *Fall Chinook Interim Recovery Plan and Study* (IPC 1991), voluntarily adopted by IPC in 1991 to protect the spawning and incubation of SRFC salmon below HCD, which are listed as a threatened species under the *Endangered Species Act of 1973* (ESA), and, most recently, the *Hells Canyon Hydroelectric Project Settlement Process Interim Agreement* (2005 Interim Agreement) that IPC entered into with multiple parties relating to the operation of the HCC pending the issuance of a new license. While portions of the

2005 Interim Agreement have expired, other portions remain in effect pending the issuance of a new license for the HCC. Table 4.5-1 summarizes IPC's proposed operations of the Hells Canyon Complex, with comments and explanations to how they relate to IPC's original proposal in the Final License Application (FLA 2003) or FERC Staff Alternatives presented in the Final EIS.

Table 4.5-1
IPC's proposed operations of the Hells Canyon Complex, with comments and explanations to how they relate to IPC's proposal in the Final License Application (FLA 2003) or FERC Staff Alternatives presented in the Final EIS. Footnotes referenced in the table provide further explanation of the proposed operations.

	Brownlee	Oxbow	Hells Canyon	Comment/Explanation
Maximum reservoir elevation (ft msl)	2,077	1,805	1,688	Original IPC Proposal; FLA 2003
Minimum reservoir elevation (ft msl)	1,976	1,800[g]	1,683[h]	Original IPC Proposal; FLA 2003
Flood control	Elevations at or below USACE flood-control mandates	NA	NA	In contrast to IPC's proposed operations, the FERC Staff Alternative (FEIS 2007) - be within 1 ft of April 15 and April 30 required elevations and coordinate refill after April 30 with USACE, ODFW, IDFG, NMFS and interested tribes.
Daily Reservoir Elevations Changes				
January 1–May 20	Not to exceed 3 ft[a]			Original IPC Proposal; FLA 2003
May 21–June 20	Draft not to exceed 1 ft[ab]			Original IPC Proposal; FLA 2003
June 21–July 4	Draft not to exceed 3 ft or go below elevation of 2,069 ft-msl[ab]			Original IPC Proposal; FLA 2003
July 5–Dec 31	Not to exceed 3 ft[a]			Original IPC Proposal; FLA 2003
January 1–December 31		5 ft[g]	5 ft[h]	Original IPC Proposal; FLA 2003
Reservoir Target Elevations				
May 20	2,069 or higher			ODEQ Draft Exhibit A identified a June 7 target elev of 2,069 and target elevation between June 8 - July 5 of 2,075. Alternatively, FERC Staff Alternative (FEIS 2007) refill Brownlee to 2,077 by June 20 & draft 237,000 AF between June 21 - July 31, except as restricted by USACE flood control. IPC would release 150,000 AF no later than July 15, but maintain elevations through July 4 holiday. No refill would occur between June 21 and August 31.
August 7	2,059[c]			
Project Outflows				

	Brownlee	Oxbow	Hells Canyon	Comment/Explanation
Fall Chinook salmon stable flow program second Monday in October through second Friday in December			8,500 cfs to 13,500 cfs[d]	Original IPC proposal FLA 2003 - 8,000 -13,000 cfs; FERC Staff Alternative 8,500 cfs to 13,500 cfs (FEIS 2007)
Hourly ramp-rate restrictions	NA	NA	1 ft per hour - up and down[e]	Original IPC Proposal FLA 2003 FERC Staff Alternative (FEIS 2007) - 4 inch per hour ramp-rate between March 15 and June 15. Through informal ESA consultation with NMFS & USFWS, IPC has developed & implemented a fall Chinook stranding and entrapment monitoring and management plan that Services agree provides greater protection than the 4 inch per hour ramp rate described in the FERC Staff Alternative.
Maximum daily flow fluctuation June 1–September 30	NA	NA	10,000 cfs[f]	Original IPC Proposal FLA 2003
Minimum flow				
• Fall Chinook incubation and rearing period	NA	NA	Dependent upon flow established to protect critical redd[i]	Original IPC Proposal FLA 2003
• Completion of fall Chinook rearing and incubation period to initiation of fall Chinook stable flows			6,500 cfs[j] at Johnson Bar Gage	Original IPC Proposal FLA 2003; FERC Staff Alternative (FEIS 2007) - minimum flow of 8,500 cfs from Memorial Day weekend to Sept. 30 in medium high & extremely high flow years measured at HCD gage. If 3-day moving average inflow to Brownlee is less than 8,500 cfs, the instantaneous minimum release at HC Dam equal to 3-day moving average.
• Year-round at McDuff Gage			13,000 cfs; 11,500 cfs [k]	Not addressed by IPC in 2003 FLA. See footnote k.
Minimum bypass flow	NA	100 cfs	NA	Original IPC Proposal; FLA 2003
Adaptive fish protection operations			Operational protocols established to re-connect entrapment pools or respond to temperature conditions in critical entrapment areas during the fall Chinook	FERC Staff Alternative (FEIS 2007) develop a Stranding and Entrapment Plan & implement a 4 inch per hour ramp-rate March 15 to June 15; Through informal ESA consultation with NMFS & USFWS, IPC has developed & implemented a fall Chinook stranding and entrapment monitoring and management plan that Services agree provides greater protection than the

	Brownlee	Oxbow	Hells Canyon	Comment/Explanation
			salmon rearing period[l]	ramp rate described in the FERC Staff Alternative.

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[a] Except for atypical conditions which are defined as operations needed to: 1) protect the performance, integrity, reliability or stability of the electrical system with which the HCC is interconnected; 2) compensate for any unscheduled loss of generation; 3) provide generation during severe weather or extreme market conditions; 4) inspect, maintain, repair, replace or improve the electrical system or facilities related to the HCC; 5) prevent injury to people or damage to property; or 6) assist in search-and-rescue activities.

[b] IPC will protect peak spawning periods for smallmouth bass and crappie by limiting Brownlee Reservoir drafts to no more than 1 ft from the highest elevation reached during a 30-day period starting on May 21, and by maintaining an elevation of at least 2,069 ft-msl from the end of the 30-day period through July 4. This operational constraint is secondary to any conflicting operational requirement.

[c] A component of the 2005 Interim Agreement, Exhibit 2 to this AIR, provided that "IPC will use best efforts to hold Brownlee Reservoir at or near full elevation (approximately 2077 msl) through June 20th; and thereafter will draft Brownlee Reservoir to elevation 2059 (releasing up to 237 kaf) by August 7th." Pursuant to that Agreement, this flow augmentation operation was to continue through 2005 and thereafter under certain conditions. IPC has complied with that flow augmentation operational regime annually since 2006 and expects that operational regime to be a condition of the new HCC license.

[d] Flow below HCC within this period to be operationally stable at levels set annually between 8,500 cfs and 13,500 cfs as determined by flow forecasts. Minor deviations from the stable flow below HC Dam may be required to ensure Brownlee Reservoir does not fill prior to the 2nd Friday in December. Communication with NOAA Fisheries prior to deviating from minimum flow will be required to determine any potential effect to spawning fall Chinook salmon consistent with requirements identified in the Hells Canyon Complex Biological Opinion.

[e] The compliance point for ramp rate and flow measurements will be at the Johnson Bar Gage, located approximately 18 miles downstream of Hells Canyon Dam.

[f] A limit of 16,000 cfs will be in place during atypical conditions See *supra* note a for description of atypical conditions.

[g] A minimum reservoir elevation limit of 1,795 will be in place during atypical conditions. A maximum daily reservoir-level fluctuation will be 10 ft under atypical conditions. See *supra* note a for description of atypical conditions.

[h] A minimum reservoir elevation limit of 1,678 will be in place during atypical conditions. A maximum daily reservoir-level fluctuation will be 10 ft under atypical conditions. See *supra* note a for description of atypical conditions.

[I] At the conclusion of fall Chinook salmon stable flow program in early December (see *supra* note d), IPC biologists determine the flow required to protect the most critical shallow redd. This flow becomes the minimum flow during the fall Chinook salmon incubation and rearing period (typically near the middle to end of May). The conclusion of the incubation and rearing period is determined through weekly observations of fall Chinook salmon rearing areas during Entrapment Surveys (see *supra* note k) with agreement from NOAA Fisheries consistent with requirements identified in the Hells Canyon Biological Opinion.

[j] Article 43 of the current (1955) HCC license provides for a minimum flow of 5,000 cfs at Johnson Bar for navigation purposes. Since 1955, IPC and the U.S. Army Corps of Engineers have cooperated to achieve a balance between power and navigation flows. In 1988, the Corps and IPC agreed to an operating minimum flow at Hells Canyon Dam of 6500 cfs to support safe navigation, with flows less than that allowed under certain circumstances. Since 1988, IPC has voluntarily maintained a minimum flow of 6500 cfs except for short periods of time due to atypical conditions (see *supra* note a). FERC Staff recommended a minimum flow increase to 8500 cfs during the summer months with the recognition that "a very robust private and commercial outfitting industry has evolved, with advanced boat designs that allow for larger and heavier watercraft." (FEIS, pg. 607, 640). IPC does not concur with Staff's recommendation and maintains that flows of 6500 cfs support safe navigation.

[k] These flows also relate to navigation flows. FERC Staff concluded in the 2007 FEIS that while IPC did not propose 13,000 cfs at Lime Point for navigation purposes that "this value is consistent with the flow releases from Hells Canyon Dam assumed by [IPC] for modeling purposes. In the absence of an explicit proposal, we consider it part of [IPC's] proposed operation." In 2007, the U.S. Army Corps of Engineers recommended to FERC a minimum flow for safe navigation of 11,500 cfs at "the Snake River below McDuff Rapids at China Garden, Idaho gaging station 13317660." IPC concurs with the Corps' recommendation and anticipates that the new license will provide for a minimum flow of 11,500 cfs measured at McDuff Rapids at China Garden, Idaho gaging station 13317660 with a proviso that IPC would not be required to use reservoir storage to meet the 11,500 cfs minimum flow.

[l] Adaptive operations are described in the fall Chinook salmon Stranding and Entrapment Plan – Adaptive Operations will not deviate from other relevant operational constraints (e.g. – ramp rate).

4.5.1. Brownlee Reservoir Operations

Brownlee Reservoir is one of the three HCC developments and is IPC's only project with significant storage. It has 101 vertical feet of active storage capacity that equals approximately one million acre-feet of water. Brownlee Dam's powerhouse capacity is approximately 35,000 cubic feet per second (cfs).

Brownlee Reservoir is a multiple-use, year-round resource for the Northwest. Although its primary purpose is to provide a stable power source, Brownlee Reservoir is also used for flood risk management, fish and wildlife mitigation, and recreation.

For flood risk management, IPC operates the reservoir cooperatively with the U.S. Army Corps of Engineers (USACE) Northwestern Division. After flood risk management draft requirements have been met in early summer, the reservoir is refilled to meet peak summer electricity demands and provide suitable habitat for spawning bass (*Micropterus* spp.) and crappie (*Pomoxis* spp.). The full reservoir also offers optimal recreational opportunities through the Fourth of July holiday.

As part of the 2005 Interim Agreement, IPC agreed to provide up to 237,000 acre-feet of water from Brownlee Reservoir in June and July 2005 and 2006, provided such operation did not cost more than $2 million annually or jeopardize the reliability of the electric system. Although the portion of the 2005 Interim Agreement relating to annual flow augmentation releases has expired, in cooperation with the National Oceanic and Atmospheric Administration (NOAA) Fisheries, IPC has continued to provide these flow augmentation releases annually through 2017. FERC staff included a recommendation for the continuance of these flow augmentation releases from the HCC in the FEIS issued in August 2007 (FERC 2007). IPC expects to continue discussions with the federal resource agencies with regard to annual flow augmentation releases pending the relicensing of the HCC.

From early October to early December Brownlee Reservoir releases are managed to maintain operationally constant flows below HCD for SRFC spawning. Following the period of operationally constant flows, a minimum flow below HCD is established to ensure that the constructed redds will not be dewatered through the incubation and emergence period (mid to late May). These flow requirements are based on the *Fall Chinook Interim Recovery Plan and Study* (IPC 1991). IPC resumes load-following operations in mid-December to meet winter peak demands and continues to draft the reservoir through January and February to meet flood risk management elevation requirements, which begin in February and extend through April or May depending on hydrologic conditions.

4.5.1.1. Winter—December through February

Electricity demands are critical during the winter in IPC’s service area and throughout the Northwest. To meet peak winter demands, provide stable, reliable energy through the winter, reduce operating costs by minimizing the need for purchasing outside power, and maintain system reliability, Brownlee Reservoir should be operationally full in early December.

At the conclusion of the SRFC salmon stable flow program in early December, IPC biologists determine the flow required to protect the most critical shallow redd. This flow becomes the minimum HCD outflow during the SRFC salmon incubation and rearing period (typically near the middle to end of May) when load-following operations resume. Between December and February, IPC drafts Brownlee Reservoir to serve load and meet the first flood risk management target elevation at the end of February.

4.5.1.2. Spring—March through May

In accordance with its current FERC license and Section 7 of the Flood Control Act of 1944, Brownlee Reservoir is operated to help control flooding in the lower Columbia River and, if needed, to regulate flows in the lower Snake River. The current FERC license requires the reservoir to be no higher than an elevation of 2,034 ft above mean sea level (msl) by March 1 of each year to provide 500,000 acre-feet of storage space for flood risk management. By March 31, the reservoir is to provide up to an additional 500,000 acre-feet, if necessary, to help control flooding in the lower Columbia River, as determined by the USACE. Initially, the timing and amount of the March evacuation were determined each year on an ad-hoc basis.

In the mid-1980s, the USACE examined the Brownlee Reservoir flood-control operation with the purpose of relaxing the FERC requirements where feasible and formalizing the seasonal operating rules. In 1983 (later revised in 1987), a tabular procedure was introduced to determine the flood risk management draft, based on seasonal forecasts of water supply for the April–July period at Brownlee Reservoir and for the April–August period at The Dalles Reservoir. It became apparent during real-time operations that the 1987 procedure could be improved by providing a smoother transition between the stepped levels of water supply forecasts and the necessary flood risk management drafts. At times, small changes in the water supply forecast at either Brownlee Reservoir or The Dalles Reservoir caused a significant change in the amount of draft for flood risk management that was difficult to implement at Brownlee Reservoir. This problem was compounded when water supply forecasts varied through the season and caused the necessary flood risk management draft to bounce from one step to the next. For these reasons, IPC requested that the USACE reexamine the 1987 procedure to find a smoother flood risk management operation.

In 1998, the rule curve procedure was examined and improved by the USACE. This modified rule curve procedure delivered the same level of flood risk management protection, was easier to implement, and provided a smoother real-time reservoir operation than the previous procedure allowed. IPC implemented the 1998 modified rule curve procedure, developed by the USACE, for water year 2000 flood risk management requirements and has continued to use it since.

4.5.1.3. Summer—June through August

After IPC is released from flood risk management responsibilities, the company begins refilling Brownlee Reservoir. The refill target is 2,069 feet msl (approximately 8 feet below the full reservoir capacity of 2,077 feet msl) toward the end of May and full by the end of June. Meeting these targets ensures enough water is stored in Brownlee Reservoir to meet peak summer electricity demands, provide suitable spawning habitat for bass (*Micropterus* spp.) and crappie (*Pomoxis* spp.) and offer optimal recreational opportunities.

The relevant portions of the 2005 Interim Agreement state that IPC will use best efforts to hold Brownlee Reservoir at or near full elevation (approximately 2,077 ft msl) through June 20th and then draft Brownlee Reservoir to elevation 2,059 ft msl (releasing up to 237,000 acre-feet) by August 7th. The 2005 Interim Agreement stipulated that IPC would meet the draft requirement provided such operation does not cost more than $2 million annually or jeopardize the reliability of the electric system. Although the portion of the 2005 Interim Agreement relating to annual flow augmentation releases has expired, IPC has continued to provide these flow augmentation releases in cooperation with NOAA Fisheries annually through 2017.

4.5.1.4. Fall—September through November

Starting in September, Brownlee Reservoir is drafted or maintained below full pool to provide storage for inflows greater than Hells Canyon Dam outflows throughout the SRFC salmon spawning period. This drafting typically requires that Brownlee Dam outflows be increased during this period.

Beginning in mid-October and lasting through early December, IPC maintains an operationally constant flow, normally between 8,500 and 13,500 cfs below HCD. IPC establishes the spawning flows below the dam based on hydrologic conditions and forecasts. This operation ensures that the redds remain submerged during spawning. It also requires that inflows to Brownlee Reservoir in excess of the operationally constant flow below HCD be retained in Brownlee Reservoir, so Brownlee Reservoir refills during this period.

4.5.2. Oxbow Reservoir and Hells Canyon Reservoir Operations

Because Oxbow and Hells Canyon reservoirs have much smaller active storage capacities and slightly smaller powerhouse capacities, Brownlee Reservoir operations largely define the flow of water and, therefore, operations through Oxbow and Hells Canyon reservoirs.

When flows through the HCC are below powerhouse capacity, all three projects operate closely together to reregulate flows through the Oxbow and Hells Canyon projects so they remain within the 1-foot-per-hour ramp rate requirement (measured at Johnson Bar below HCD) and meet the daily peak load demands. However, when flows exceed the powerhouse capacity for any of the projects, water is released over the spillways at those projects.

IPC maintains minimum flow rates in the Snake River downstream of HCD as specified under Article 43 of the existing license. Neither the Brownlee Project nor the Oxbow Project has a minimum flow requirement below its powerhouse. However, because of the Oxbow Project’s unique configuration, a flow of 100 cfs is maintained through the bypassed reach of the Snake River below the dam (a segment called the Oxbow Bypass).

5. APPLICABLE WATER-QUALITY REGULATIONS

5.1. Beneficial Uses

As border water, the Snake River has designated uses established by both Oregon and Idaho. The ODEQ has designated fish and aquatic life, recreation, water supply, wildlife habitats, aesthetics, commercial navigation and transportation, and hydro power uses for the mainstem Snake River (Table 5.1-1). The IDEQ has designated similar uses (Table 5.1-2). In addition, the ODEQ has specified anadromous fish migration corridors, and salmon and steelhead (*Oncorhynchus mykiss*) spawning are designated uses downstream of HCD to the Washington border. Redband trout (*Oncorhynchus mykiss gairdnerii*) rearing is a designated use in the HCC upstream to the Idaho border.

Table 5.1-1
Oregon's designated uses (OAR 340-041 n.d.) and water-quality limiting pollutants (ODEQ 2014) for the mainstem Snake River

Snake River Segment	Designated Uses	Pollutants
Snake River: Washington border to HCD	Salmon and steelhead spawning Anadromous fish migration corridors Resident fish and aquatic life Water contact recreation Public/private domestic water supply Irrigation Livestock watering Industrial water supply Wildlife and hunting Fishing and boating Aesthetics Commercial navigation and transportation Hydro power	Temperature[1] Toxics (mercury)
Snake River: HCD to Idaho Border	Redband trout rearing Resident fish and aquatic life Water contact recreation Public/private domestic water supply Irrigation Livestock watering Industrial water supply Wildlife and hunting Fishing and boating Aesthetics Commercial navigation and transportation Hydro power	Temperature[1] Toxics (mercury) Chlorophyll *a*[2]

[1] A TMDL has been approved.

[2] Chlorophyll *a* was added in 2012 as a pollutant limiting water quality during the non-irrigation season.

Table 5.1-2
Idaho’s designated uses (*Idaho Administrative Procedures Act* [IDAPA] 58.01.02. n.d.) and water-quality limiting pollutants (IDEQ 2014) for segments of the Snake River

Snake River Segment	Designated Uses	Pollutants
Snake River: Salmon River inflow to HCD	Cold-water aquatic life Salmonid spawning Primary contact recreation Domestic water supply Agricultural water supply Industrial water supply Wildlife habitats Aesthetics	Temperature[1] TDG[1]
Snake River: HCD to Oxbow Dam (Hells Canyon Reservoir)	Cold-water aquatic life Primary contact recreation Domestic water supply Agricultural water supply Industrial water supply Wildlife habitats Aesthetics	Temperature[1] TDG[1] Mercury
Snake River: Oxbow Dam to Brownlee Dam (Oxbow Reservoir)	Cold-water aquatic life Primary contact recreation Domestic water supply Agricultural water supply Industrial water supply Wildlife habitats Aesthetics	Temperature[1] Total phosphorus (TP)[1] TDG[1] Sediment[1]
Snake River: Brownlee Dam to Scott Creek (Brownlee Reservoir)	Cold-water aquatic life Primary contact recreation Secondary contact recreation Domestic water supply Agricultural water supply Industrial water supply Wildlife habitats Aesthetics	Temperature[1] DO[1] TP[1] Sediment[1] Mercury
Snake River: Scott Creek to Weiser River	Cold-water aquatic life Primary contact recreation Domestic water supply Agricultural water supply Industrial water supply Wildlife habitats Aesthetics	Temperature[1] DO[1] TP[1] Sediment[1]

[1] A TMDL has been approved.

5.2. Applicable SR–HC TMDL Targets

The Snake River has been identified as water-quality limited under § 303(d) of the CWA. This designation indicates the appropriate agencies have identified the water quality in the Snake River as not meeting applicable water-quality standards (ODEQ 2014; IDEQ 2014). Tables 5.1-1 and 5.1-2 list the pollutants identified as limiting water quality in the HCC reach of the Snake River.

Because the Snake River is border water, the SR–HC TMDL addresses Oregon and Idaho water-quality standards. The SR–HC TMDL uses the more stringent standard from either state to identify appropriate water-quality targets (Table 5.2-1). The states have both numeric and narrative standards, so both quantitative and qualitative levels may apply. IPC was issued allocations in the SR–HC TMDL for temperature, DO, and TDG.

Table 5.2-1
Levels indicating water-quality limitations for the Snake River from near Weiser, Idaho, to the confluence with the Salmon River (IDEQ and ODEQ 2004)

Measures	Levels Indicating Water-Quality Limitations
Water temperature[1]	A 7-day average maximum (7DAM) temperature greater than 17.8°C for designated uses: fish and aquatic life, anadromous fish passage, and salmonid rearing. A MWMT greater than 13°C when and where salmonid spawning occurs, or greater than a 0.14°C increase from anthropogenic sources when the site potential is greater than the target temperature.
DO[2]	A single water-column measure less than 6.5 milligrams per liter (mg/L) for fish and aquatic life designated uses year round upstream of HCD and outside of the spawning period downstream of HCD. A single water-column measure less than 11 mg/L or less than 95% of saturation; with a single intergravel measure less than 8 mg/L, measured as a spatial median, when and where salmonid spawning occurs.
TDG	A single water-column measure greater than 110% of saturation for designated uses: fish and aquatic life, anadromous fish passage, salmonid rearing, and salmonid spawning (when and where it occurs).
Nutrients	A growing season TP concentration greater than 0.07 mg/L.
Nuisance algae	A mean growing season concentration greater than 14 micrograms per liter (µg/L) chlorophyll a (a surrogate for algal mass) and a nuisance threshold of 30 µg/L exceeded greater than 25%.
pH	A single water-column measure less than 7 and/or greater than 9 pH standard units (SU) for designated uses: fish and aquatic life, anadromous fish passage, salmonid rearing, and salmonid spawning (when and where it occurs).
Mercury	A single total mercury water-column measure greater than 0.012 µg/L and/or methylmercury in fish tissue greater than 0.35 milligrams per kilogram (mg/kg) for designated uses: fish and aquatic life, salmonid rearing, and salmonid spawning (when and where it occurs).
Bacteria	A single sample greater than 406 *Escherichia coli* (*E. coli*) organisms per 100 milliliters (ml) and a 30-day logarithmic mean greater than 126 E. coli organisms per 100 ml based on a minimum of 5 samples for the primary contact recreation designated use.
Sediment	A 14-day average total suspended sediment greater than 80 mg/L and a monthly average greater than 50 mg/L for designated uses: fish and aquatic life, salmonid rearing, and salmonid spawning (when and where it occurs).

Table 5.2-1 (continued)

Measures	Levels Indicating Water-Quality Limitations
Pesticides	Single water-column measure greater than 0.024 nanograms per liter (ng/L) dichlorodiphenyltrichloroethane (DDT), 0.83 ng/L dichlorodiphenyldichloroethane (DDD), 0.59 ng/L dichlorodiphenyldichloroethylene (DDE), and/or 0.07 ng/L dieldrin for designated uses: fish and aquatic life, salmonid rearing, and salmonid spawning (when and where it occurs).

[1] The ODEQ numeric criteria (OAR 340-041 n.d.) have changed since the approval of the SR–HC TMDL. Anadromous fish migration corridors and redband trout criteria are a 7DAM temperature of 20°C. The seasonal thermal pattern of the Snake River must reflect the natural seasonal thermal pattern (NSTP). All point sources and nonpoint sources are restricted to a cumulative increase no greater than 0.3°C above the applicable criteria.
Idaho approved site-specific numeric criteria (IDAPA 58.01.02.286. March 29, 2012) since the submission of the SR–HC TMDL to protect fall Chinook salmon spawning and incubation in the Snake River from HCD to the Salmon River. From October 23 through November 6, the weekly maximum temperature (WMT) must not exceed 14.5°C. From November 7 through April 15, the WMT must not exceed 13°C.
A 7-day average cannot be calculated until there are 7 consecutive days of record. The first day is October 29.
Both Oregon and Idaho have NCC. Natural thermal potential conditions supersede numeric criteria.

[2] Lower levels are allowed when conditions of barometric pressure, altitude, and temperature preclude attainment of the numeric criteria.

6. WATER-QUALITY STANDARDS EVALUATION

Since the HCC is located on border water, IPC assessed HCC water-quality data against the applicable standards in both Oregon and Idaho and load allocations for the HCC in the SR–HC TMDL (IDEQ and ODEQ 2004). In Section 7. Proposed PME Measures, IPC proposes a comprehensive Temperature Management Plan (TMP) that includes the development and implementation of a suite of robust upstream Snake River in river and tributary measures that provide temperature, water-quality, and habitat benefits to the Snake River above, within, and below the HCC (referred to herein as the Snake River Stewardship Program [SRSP]) in conjunction with operational measures that will be implemented over the term of the license as necessary to deal with changing future conditions. The complete temperature mitigation proposal provides reasonable assurance that SR–HC TMDL load allocations and applicable water-quality standards will be addressed.

6.1. Temperature

Solar radiation is the primary natural heat source responsible for the temperature of surface water. Other important natural sources of surface-water heating and cooling are atmospheric air temperature, evaporative cooling from wind, heat loss or conduction, temperature of inflow streams, and geothermal heating of sediments or tributary hot springs. Anthropogenic heat sources may include direct, point-source thermal discharges and indirect, nonpoint-source influences of flow alteration and habitat modification. The latter contribute to increased thermal loads by altering the hydrologic regime, geomorphic channel characteristics, and riparian vegetation, which influence the amount of natural solar radiation reaching the water. Any heat source, whether natural or anthropogenic, influences the thermal characteristics of water.

While the temperature of water is important and most standards are based on an absolute temperature, temporal or spatial changes, such as annual thermal stratification, are the most important physical events contributing to a lake or reservoir's thermal structure. It is this thermal structure that drives many of the chemical and biological processes and influences the biological communities present.

CWA § 303(d) requires states and tribes to identify and prioritize water bodies that do not meet water-quality standards and to develop a water quality improvement plan (i.e., a TMDL) that ensures the attainment of the water-quality standards. The EPA must approve the TMDLs before they go into effect. Oregon lists the Snake River in the SR–HC TMDL reach as limited by temperature during the summer (ODEQ 2013). EPA (2001) added temperature to Idaho's § 303(d) list in 1998 for the Snake River downstream of HCD. Idaho (IDEQ 2013) later added temperature as a pollutant limiting water quality in the Snake River upstream of, as well as throughout, the HCC. There are a number of EPA-approved temperature TMDLs in the Snake River watershed upstream of the HCC, as well as an EPA approved temperature TMDL for the Hells Canyon stretch of the Snake River (the SR–HC TMDL). The intended purpose of these temperature TMDLs is to provide a roadmap for bringing the respective water bodies into compliance with water-quality standards.

Temperature loading calculations performed by the IDEQ and ODEQ for the SR–HC TMDL demonstrated the dominant causes of elevated temperatures in the Snake River are natural non-anthropogenic heating and anthropogenic heat sources that have not been precisely quantified, such as upstream and tributary impoundments, water withdrawals, channel straightening and diking, and the removal of streamside vegetation (IDEQ and ODEQ 2004). The SR–HC TMDL stated it is difficult to determine the natural temperature conditions for such a highly regulated system or how altered current conditions differ from natural conditions (IDEQ and ODEQ 2004). As a result of these anthropogenic impacts and natural non-anthropogenic heating, the Snake River upstream of Brownlee Reservoir exceeds applicable temperature criteria during the critical months of June through September. In this context, the SR–HC TMDL (2004) determined these natural and non-quantifiable human influences preclude the attainment of the salmonid rearing and cold water criteria upstream of the HCC during these summer months[15]. The SR–HC TMDL did not assign the HCC a load allocation for exceedances of the aquatic life and salmonid rearing criteria below HCD. The presence of the HCC reduces downstream summer peak temperatures, as excessively warm water resulting from upstream conditions are held in Brownlee Reservoir. The HCC does not add heat to the river; in fact, water discharging from HCD in the summer is cooler than the high summer temperature of water entering Brownlee Reservoir. However, the HCC also delays fall cooling downstream for similar reasons.

The SR–HC TMDL observed that numeric salmonid spawning criteria in the fall are exceeded during the first few weeks of the spawning period for SRFC salmon in most years. It also noted limited data collected in the 1950s suggest criteria were also exceeded before the completion of the HCC dams in the 1950s[16]. The SR–HC TMDL determined that if water flowing into Brownlee Reservoir met the upstream temperature standards in the months (i.e., summertime

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[15] See the SR–HC TMDL, p. 465.

[16] "A general evaluation of pre-impoundment data shows that monthly averages above 13°C occurred at the beginning of the salmonid spawning period identified by this TMDL and extended for approximately 2 weeks." SR–HC TMDL, p. 384.

cold-water aquatic life standards) preceding the salmonid spawning period, outflow from the HCC would exceed the salmonid spawning criteria by only a "small margin." Therefore, the SR–HC TMDL concluded the HCC is responsible for the approximately 2-week exceedance of the salmonid spawning criteria. To address this, it presented an analysis to assess the influence of the HCC on water temperatures downstream and to develop a temperature load allocation for the project using inflow temperatures measured at Brownlee Reservoir as an estimate of site potential in the Snake River downstream of the HCC[17]. Site potential was defined as the temperature predicted to have occurred with direct sources of heat (predominantly natural atmospheric inputs) to the mainstem Snake River without the influence of the HCC but assuming the current altered hydrologic regime, climate, and tributary inputs (IDEQ and ODEQ 2004).

The SR–HC TMDL issued both load and waste load allocations to IPC. The HCC waste load allocations are for the 3 NPDES permits issued for the Brownlee, Oxbow, and Hells Canyon projects. The SR–HC TMDL set HCC's load allocation below HCD using the most stringent numeric criteria when the inflow temperature was less than criteria or set an allowable increase from anthropogenic sources when the inflow temperature was greater than numeric criteria. Oregon and Idaho have issued IPC a thermal load allocation for the outflow from HCD of no greater than a MWMT of 13 degrees Celsius (°C) when inflow temperature to Brownlee Reservoir is less than a MWMT of 13°C or no more than a 0.14°C increase in water temperature when inflow is greater than a MWMT of 13°C (IDEQ and ODEQ 2004)[18]. The load allocation applies from October 23 through April 15 for salmonid spawning and November 1 through March 30 for mountain whitefish spawning. The SR–HC TMDL provided that the actual excess thermal load relative to the issued load allocation is dependent on a temperature exceedance and a flow rate (i.e., cfs) and can be expressed in terms of energy (e.g., calories). The SR–HC TMDL further provided that "[s]pecific compliance parameters for meeting [HCC's] load allocation will be defined as part of the 401 Certification process[19]."

This application therefore addresses the HCC thermal load allocation to obtain certification pursuant to CWA § 401. In the following sections, IPC compares measured temperature data from an extensive historic dataset with the most stringent standards in both Oregon and Idaho. Consistent with the approach used to establish water-quality targets in the SR–HC TMDL (IDEQ and ODEQ 2004), where standards have been updated after the completion of the SR–HC TMDL, IPC presents a new analysis relative to the most stringent criteria. IPC also presents an analysis of the thermal load exceedances at the HCC outflow relative to the SR–HC TMDL load

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[17] On October 7, 2003, IPC filed a petition for judicial review in the Circuit Court for Baker County, Oregon, (Case No. 03-678) challenging those portions of the SR–HC TMDL that impose a temperature load allocation on the HCC. This petition is still pending; it has been extended annually by agreement between IPC and the State of Oregon and approval of the court. Nothing in this application is intended or should be interpreted as a waiver or relinquishment of the claims set forth, or that may be set forth, in that litigation. This notwithstanding, IPC proposes PME measures in this CWA § 401 application that address temperature effects of the HCC downstream of HCD.

[18] At the time the SR–HC TMDL was adopted, Oregon had a "no measurable increase" criterion, which was defined as 0.25°C. That criterion was replaced by a cumulative human use allowance of 0.3°C See OAR 340-41-28(12) (b).

[19] See SR–HC TMDL, p. 469.

allocation and establishes the HCC outflow cumulative thermal load to be offset by upstream restoration actions that reduce thermal loading to the river. Proposed measures to address this cumulative thermal load exceedance are presented in Section 7.1. Temperature Proposed Measures.

Since many of the numeric criteria are broadly developed and applied to large geographic areas to protect beneficial uses, the following sections also present information relative to key beneficial uses when appropriate (e.g., additional data available on the status of SRFC salmon, the primary salmonid spawning beneficial use below HCD). SRFC salmon redd counts and natural returning adults below HCD have been increasing under the existing thermal regime. In its January 27, 2011, comments on a previous 401 temperature proposal for the HCC, NOAA Fisheries indicated the current temperature conditions are not limiting SRFC salmon production, but rearing habitat for juveniles is limited below HCD and is the most significant concern for the recovery of SRFC salmon. Recently, NOAA Fisheries has further concluded that "while the temperatures are not always optimum, and while some Upper Hells Canyon reach spawners may be negatively affected, existing studies specific to Snake River fall Chinook salmon do not point to temperature as a significant limiting factor" (NOAA 2017; page 179).

6.1.1 Temperature Standards and SR–HC TMDL Targets

The application of temperature standards in Oregon and Idaho is similar. Both states have 5 types of temperature standards: 1) biologically based criteria that ensure thermally protective conditions; 2) natural conditions (as determined by the states) that supplement the biologically based criteria[20]; 3) air temperature exclusion criteria that allow for the exceedance of numeric and natural conditions; 4) human-use allowance or natural background conditions, which allows small increases in heat due to anthropogenic sources; and 5) site-specific criteria, requiring water-body-specific rulemaking based on the unique characteristics of the watershed.

The aquatic life beneficial-use classifications are for waters that are suitable, or intended to be made suitable for, the protection and maintenance of viable communities of aquatic organisms of significant aquatic species (IDEQ and ODEQ 2004). Resident and anadromous salmonids exist in the HCC and Snake River, and the applicable biologically based criteria are dependent on their distribution. Resident salmonids, particularly redband trout, are present upstream of HCD. Anadromous salmon and steelhead inhabit the Snake River downstream of HCD. Highly productive populations of cool- and warm-water aquatic species exist in the HCC reservoirs. These species predominantly include smallmouth bass (*Micropterus dolomieu*), black crappie (*Pomoxis nigromaculatus*), white crappie (*P. annularis*), and channel catfish (*Ictalurus punctatus*) (Richter and Chandler 2003). More detail on the resident fish community of the HCC

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[20] In *Northwest Environmental Advocates v. EPA et al., 855* F.Supp.2d 1199 (2012) (NWEA), Oregon's narrative NCC were invalidated by the court. Further litigation and settlement negotiations concerning Oregon's temperature water-quality standards are ongoing. In the interim, there are no substitute NCCs in place. As a result, IPC does not rely on the NCC for this application. This has direct implications for the application of the temperature load allocation given to the HCC, as explained in Section 7.1. Temperature Proposed Measures of this application.

reservoirs is available in Technical Report E.3.1-5 of the *New License Application: Hells Canyon Hydroelectric Complex*.

Idaho and Oregon have different standards that apply to the same reaches of the Snake River at the same time. The following sections outline these various criteria.

6.1.1.1. Cold-Water Aquatic Life

Idaho temperature criteria for the protection of cold-water aquatic life are a daily maximum temperature not to exceed 22°C, with a maximum daily average temperature of no greater than 19°C (IDAPA 58.01.02.250.02.b). These criteria apply to the Snake River both at the inflow to the HCC, through the HCC reservoirs, and downstream of the HCC.

6.1.1.2 Redband or Lahontan Cutthroat Trout

Oregon temperature criteria for the protection of streams identified as having Lahontan cutthroat trout (*Oncorhynchus clarkii henshawi*) or redband trout are a 7DAM temperature that may not exceed 20°C (OAR 340 041-0028(4)(e)). This criterion is applicable to the HCC reservoirs and Snake River upstream from RM 247.5 to RM 409.

6.1.1.3 Salmon and Steelhead Migration

In the SR–HC TMDL's evaluation of Oregon and Idaho water-quality standards, the then-existing Oregon numeric temperature criterion for salmonid rearing was identified as most stringent. That criterion provided for a 7DAM temperature of 17.8°C if and when the site potential is less than 17.8°C (IDEQ and ODEQ 2004). Therefore, the SR–HC TMDL applied this criterion for the inflows to the HCC reservoirs and the outflows from HCD from June to September[21]. Oregon has since revised its water-quality standards, including temperature standards. The EPA has approved these revisions. The revised standards follow EPA guidance, and the migration corridor use is designed "for waterbodies that are used almost exclusively for migrating salmon and trout during the period of summer maximum temperatures." (EPA 2003).

The revised Oregon migration corridor requirement for salmon and steelhead includes a numeric 20°C 7DAM criterion that applies to the river downstream of HCD (OAR 340-041-0028(4)(d)). It is the same as the numeric criteria to protect redband and Lahontan cutthroat trout in the Snake River upstream of HCD (OAR 340-041-0028(4)(e)). In addition to the numeric criterion, this provision establishes narrative requirements that the river has cold-water refugia that are sufficiently distributed to allow for salmon and steelhead migration without significant adverse effects from higher water temperatures elsewhere in the stream[22], and a seasonal thermal pattern in the Snake and Columbia rivers that reflects the NSTP.

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[21] There are 2 exceptions in the SR–HC TMDL: The numeric criterion does not apply when 1) the temperature in excess is naturally occurring or 2) the daily maximum air temperature exceeds the 90th percentile of the 7DAM air temperature calculated over 10 years.

[22] The SR–HC TMDL (IDEQ and ODEQ 2004) acknowledged there are sufficient cold-water refugia downstream of the HCC.

6.1.1.4 Salmonid Spawning

Oregon and Idaho have criteria to protect spawning salmonids in areas and during times the species are present. In the SR–HC TMDL's evaluation of Oregon and Idaho water-quality standards, the then-existing (i.e., at the time of the SR HC TMDL) numeric temperature criterion for salmonid spawning was identified as most stringent. That criterion provided for a MWMT temperature of 13°C if and when inflow temperature is less than 13°C (IDEQ and ODEQ 2004). The SR–HC TMDL stated that water quality standards for salmonid spawning would apply only to that portion of the Snake River below HCD (RM 247 to RM 188) from October 23 through April 15 for SRFC salmon and November 1 through March 30 for mountain whitefish (IDEQ and ODEQ 2004). Oregon has since revised its water-quality standards, including temperature standards. Oregon's current salmon and steelhead spawning temperature criterion is a 7DAM temperature not to exceed 13°C (OAR 340-041-0028(4)(a)). On March 29, 2012, Idaho approved a site specific numeric criteria for SRFC spawning and incubation in the Snake River downstream of HCD to the confluence with the Salmon River (RM 188 to RM 247.5) (IDAPA 58.01.02.286). The Idaho MWMT must not exceed 14.5°C from October 29 through November 6 and must not exceed 13°C from November 7 through April 15. Idaho submitted its site-specific temperature criteria for SRFC spawning to the EPA for approval on June 8, 2012. Because the EPA has failed to act on Idaho's adopted site-specific standard, this application addresses the current 13°C standard. As a result, the previous Idaho standard and Oregon's salmonid spawning criteria are the most stringent standards for the first 2 weeks of the spawning period. This criterion is applicable to the Snake River from RM 188 to RM 247.5 from October 23 through April 15 and from RM 169 to RM 188 from November 1 through May 15.

The IDEQ and ODEQ have interpreted the MWMT and the 7DAM temperature to be the mean of daily maximum temperatures measured over a consecutive 7-day period ending on the day of calculation. When used seasonally, as for spawning periods, the first applicable 7-day average occurs on the seventh day of the period. This interpretation is part of the IDEQ's site specific numeric criteria (IDAPA 58.01.02.286) and an ODEQ Internal Management Directive (ODEQ 2008), both of which follow the EPA's recommended guidance (EPA 2003).
The salmonid spawning temperature criterion below the HCC starts on October 23. Applying the criterion in accordance with IDEQ statutes, the ODEQ's interpretation, and the EPA's recommended guidance, the 7DAM is first calculated on October 29.

6.1.1.5 Human-Use Allowance Applied to Salmonid Spawning

The calculation described in the previous section does not, however, end the determination of the appropriate temperature standard to apply to this § 401 application. Oregon has revised its human-use allowance standard (OAR 340-041-0028(12)(b)) to include a cumulative increase from anthropogenic sources of no more than 0.3°C above the applicable criteria. This criterion was upheld by the federal district court for the district of Oregon[23]. While Idaho has no explicit human-use allowance, it does have a natural background conditions standard that allows an

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[23] See NWEA II, 855 F.Supp.2d at 1218 n.8 ("Plaintiff's challenge to the EPA's approval of the 'Human Use Allowance' is rejected. OAR 340–041–0028(12)(b). It is clear that the EPA evaluated the potential for cumulative impacts and its approval of the Human Use Allowance was in no way arbitrary or capricious.").

increase in temperature of up to 0.3°C when standards are exceeded because of natural thermal influences (IDAPA 58.01.02.2000.09.63). The SR–HC TMDL describes Idaho's natural conditions allowance of 0.3°C as a "no-measurable-increase" provision of Idaho and Oregon water quality standards. (See the SR–HC TMDL p. 394, Section 3.6.6.3; and p. 401, Section 3.6.8.1.). The SR–HC TMDL adopts the Oregon "no-measurable-increase" of 0.14°C as the more conservative standard. As noted above, Oregon's standard has been modified and approved by the EPA to a 0.3°C human-use allowance standard.

Idaho law provides a mechanism for either the waiver or raising of the applicable Idaho temperature standards to match those set by Oregon's human use allowance, which will avoid the necessity of determining which state standard is the most stringent.
IDAPA 58.01.02.070.07 provides:

> 07. Temperature Criteria. In the application of temperature criteria, the Director may, at his discretion waive or raise the temperature criteria as they pertain to a specific water body. Any such determination shall be made consistent with 40 CFR 131.11 and shall be based on a finding that the designated aquatic life use is not an existing use in such water body or would be fully supported at a higher temperature criteria. For any determination, the Director shall, prior to making a determination, provide for public notice and comment on the proposed determination. For any such proposed determination, the Director shall prepare and make available to the public a technical support document addressing the proposed modification. (4-5-00)

On November 18, 2015, IPC submitted to IDEQ Director Tippets a Request for Action by the Director under IDAPA 58.01.02.070. In that request, IPC asked the Director to exercise his discretion to waive or raise the salmonid spawning temperature standard by 0.3°C above the 13°C temperature standard for that portion of the Snake River below HCD. The request was made because the 13.3°C temperature regime fully supports the beneficial use of salmonid spawning for SRFC. The purpose of this request was to match Oregon's human use allowance of 0.3°C with a waiver of 0.3°C. This request requires a finding by the Director that the designated beneficial use is fully supported at the 13.3°C water temperatures under Idaho's Application of Standards rule. IDAPA 58.01.02.0070.07. Oregon's human use allowance has been found by the courts to fully protect the beneficial use of salmonid spawning, as noted above.

Moreover, the Idaho Board of Environmental Quality, on November 10, 2011, adopted a rule revising Idaho's Water Quality Standards to provide for a site-specific standard of 14.5°C during the first 2 weeks of the salmonid spawning period. (IDEQ Docket No. 58-0102-1102). That rule was subsequently approved by the Idaho Legislature during the 2012 Session and became final and effective on March 29, 2012; as noted above, the rule is still awaiting EPA approval. Laboratory and field studies support the rule and establish that water temperatures higher than 13°C, up to 16.5°C, are fully protective of SRFC spawning below HCD. NOAA Fisheries commented that the proposed 14.5°C site-specific standard was a protective spawning criteria. The information considered by IDEQ in that rulemaking shows that the site-specific standard of 14.5°C fully supports Chinook spawning, also supports the conclusion that a much lower temperature of 13.3°C will fully support SRFC spawning below HCD.

6.1.2. Conditions Relative to Temperature

The following discussion assesses current conditions relative to the applicable Oregon and Idaho standards as outlined in the previous section. In IPC's view, the site-specific standard adopted by the IDEQ represents the best science on the appropriate temperature standard to protect SRFC spawning. However, because the EPA has failed to take action on the Idaho 14.5°C MWMT standard[24] within the time period required by the CWA, IPC will use the former Idaho 13°C MWMT and the Oregon 13°C 7DAM site-specific temperature criteria for purposes of this application, and, consistent with the above, adjust those criteria to 13.3°C.

6.1.2.1 Inflow Temperature

Current Idaho temperature standards require that the daily maximum temperature not exceed 22°C, with a maximum daily average temperature of no greater than 19°C (IDAPA 58.01.02.250.02.b). The Oregon migration corridor requirement for redband and Lahontan cutthroat trout includes a numeric 20°C 7DAM criterion that applies to the river upstream of HCD (OAR 340-041-0028(4)(e)). This criterion replaced the 17.8°C/site potential criterion analyzed in the SR–HC TMDL (IDEQ and ODEQ 2004). The Snake River flowing into Brownlee Reservoir exceeds both Oregon and Idaho applicable criteria throughout the summer every year (IDEQ and ODEQ 2004). IPC has measured Snake River temperature inflow to Brownlee Reservoir (RM 345.6) either hourly or every 10 minutes from 1996 through 2017. Due to the influx of heat into the system upstream of Brownlee Reservoir, Idaho's 19°C daily average criterion and Oregon's 20°C 7DAM criterion were exceeded every year when summer temperatures were measured.

A summary of average daily inflow temperatures measured over the 1996 through 2017 period shows that the inflowing water to Brownlee Reservoir always exceeds the Idaho daily average temperature criterion and the Oregon 7-DAM for a substantial period in July and August of every year (Figure 6.1-1). Inflowing temperatures never fell below the Idaho 19°C daily average criterion from July 6 through August 26. Similarly, inflowing temperatures always exceeded the Oregon 20°C 7-DAM criterion from July 4 through September 1.

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[24] IPC will actively pursue formal adoption and approval of the 14.5°C site-specific standard in all appropriate forums. When adoption is complete, the 14.5°C site-specific standard will be the measure of the temperature obligation under this application.

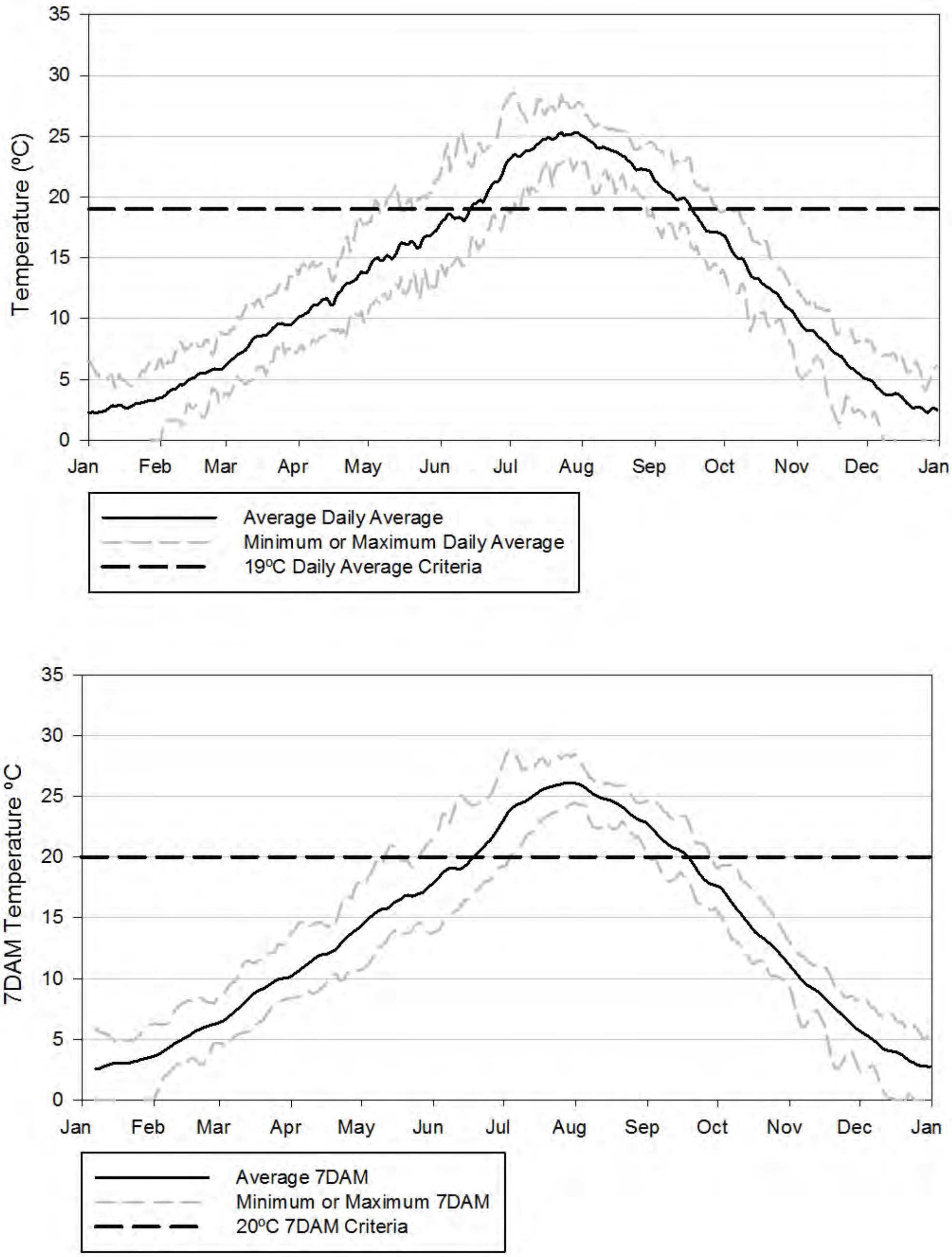

Figure 6.1-1
Average, minimum, and maximum daily values for the Snake River Brownlee Reservoir inflow temperature in °C for the 1996–2017 period of record calculated for the daily average temperature statistic, and the 7-DAM temperature statistic.

The SR–HC TMDL presented a temperature-loading analysis to investigate the sensitivity of mainstem Snake River temperature to various thermal influences, including 1) groundwater, 2) point sources, 3) tributaries and agricultural drains, and 4) natural atmospheric and non-quantifiable influences. The loading analysis evaluated mainstem warming from the Idaho and Oregon border (RM 409) to Brownlee Reservoir inflow (RM 335) and concluded that natural atmospheric and non-quantifiable influences were the primary factors affecting temperature. EPA (2003) identified the 4 largest anthropogenic sources of increased temperature in the Pacific Northwest as 1) the removal of streamside vegetation, 2) channel straightening or diking, 3) water withdrawals, and 4) dams and impoundments. The SR–HC TMDL acknowledged that all these anthropogenic influences were not specifically evaluated in the loading analysis and, by default, were included in the non-quantifiable category of influences (IDEQ and ODEQ 2004).

Water withdrawal and consumptive use, upstream dams and impoundments, and the removal of streamside vegetation, coupled with reduced hyporheic connectivity (Hanrahan et al. 2007), have transformed some reaches of the Snake River upstream of Brownlee Reservoir from a cold water river to a slow-moving, warm-water river supporting primarily non-game species of fish (Clark et al. 1998). Because these anthropogenic influences are significant thermal influences upstream of Brownlee Reservoir, they are presented below in greater detail to not only aid in understanding the effects these influences have on the temperature in the Hells Canyon reach of the Snake River but also in the eventual quantification of these influences.

The SR–HC TMDL recommends actions taken in relation to upstream TMDLs, currently developed to address the removal of riparian vegetation and to some extent channel morphology, be factored into temperature loading analyses for the SR–HC TMDL:

> Several upstream and tributary TMDLs have been completed, others are currently in process; still others will be initiated in the near future that may affect the water quality in the SR–HC TMDL reach. The current pollutant reductions identified by existing TMDLs have been incorporated in the loading analysis for the SR–HC TMDL to the extent possible. TMDLs currently in progress or scheduled for the near future will build on allocations developed by the SR–HC TMDL.
>
> All of these efforts will, collectively, be evaluated to determine future water quality benefits and long-term trends within the SR–HC TMDL reach. These assessments will be critical to the ongoing SR–HC TMDL process in order to monitor if identified reduction mechanisms are sufficient or if additional reductions may be necessary to meet water quality standards[25].

Anthropogenic sources of increased temperature occur on a broad watershed scale. Their cumulative effect influences Snake River temperatures above the HCC, inflow temperatures to Brownlee Reservoir, the HCC outflow fall thermal regime and, as a result, the capacity of the HCC to meet the numeric salmonid life-cycle criteria.

6.1.2.1.1. Water Withdrawl and Consumptive Use

Water resources of the Snake River Plain upstream of Brownlee Reservoir are heavily influenced by irrigation and other uses. Consumptive water use on the Snake River Plain substantially depletes flow and results in increased water temperature. The storage and diversion of water changes the timing and magnitude of the seasonal flow regime. The SR–HC TMDL reported

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[25] See SR–HC TMDL, p. 92.

estimates that between 14.5 and 16.5 million acre-feet per year are diverted from surface water for irrigation supply. Goodell (1988) estimated, in 1980, approximately 12.6 million acre feet of water were diverted by gravity or pumped from rivers and streams for the irrigation of approximately 2 million acres of land on the Snake River Plain (i.e., upstream from Weiser, Idaho). Goodell's (1988) estimates included approximately 3.2 million acre-feet diverted from the Boise, Payette, Owyhee, Weiser, and Malheur watersheds combined. Of this, approximately 1.7 million acre-feet were diverted from the Boise River system (Table 6.1-1). Responding to diminished surface-water supplies, groundwater pumping has become an increasingly important water source, especially in the upper Snake River Basin (i.e., upstream from King Hill, Idaho). Clark et al. (1998) reported estimates that from 1980 to 1990 in the upper Snake River Basin, surface-water diversions may have decreased by approximately 10%, while groundwater pumping increased nearly 35%. This phenomenon of reduced surface-water diversions is also observed closer to the SR–HC TMDL reach of the Snake River. For the Boise River watershed, more recent diversion estimates are approximately 1.4 and 1.3 million acre-feet diverted in 1996 and 2000, respectively (Urban 2004). This is approximately 21% less water diverted than in 1980 (Goodell 1988).

Table 6.1-1
Summary of water diversions throughout the Snake River watershed in 1980 from Goodell (1988)

River Reach	Length of Reach (miles)	Total Diversions (acre-feet)
Snake River		
Snake River at Milner and upstream	214.9	6,936,160
Snake River at King Hill and upstream to Milner	92.1	101,340
Snake River at Weiser and upstream to King Hill	206.6	626,500
Major Tributaries		
Snake River tributaries upstream of Owyhee River	353.1	1,726,590
Owyhee River	27.3	539,580
Boise River	63.6	1,713,120
Malheur River	19.8	52,100
Payette River	38.4	812,110
Weiser River	14.9	90,640
Total	**1,030.7**	**12,598,140**

Goodell (1988) also estimated that overall consumptive use, including crops irrigated by surface water, groundwater, public supply, rural, industrial, and aquaculture, equaled approximately 5.1 million acre-feet. The consumptive use specific to the water evapotranspired by crops irrigated with diverted surface water was approximately 3.5 million acre-feet, approximately 30% of the 12.6 million acre-feet diverted. More recently, the SR–HC TMDL (IDEQ and ODEQ 2004) reported an overall consumptive use from surface-water diversions upstream of Brownlee Reservoir between 6 and 8 million acre-feet per year. Urban (2004) reported crop consumptive use near 45% of the diverted volume from the Boise River system. The remainder of the diverted volume evaporates from canal or soil surfaces, is evapotranspired by canal vegetation, remains in the soil, infiltrates to groundwater, or returns to streams.

The overall effect of consumptive use upstream of Brownlee Reservoir is the depletion of streamflow, which reduces the Snake River's buffering capacity to atmospheric warming, increases residence time in the reservoir, and results in warmer water temperatures during summer months. This, combined with the sequential pattern of water withdrawal, use, and the return of water warmed on fields and through canal systems, results in an increasing effect on temperatures during spring and summer periods.

To estimate the effect of upstream diversion and consumptive use on Snake River flow into Brownlee Reservoir, IPC used a USACE estimate of unregulated flow upstream of the HCC. The USACE estimate accounted for storage and diversions (R. Delaney, USACE, pers. comm.). Essentially, the current computed local gage flow below storage facilities was adjusted based on operations or changes in storage. This was termed the adjusted local gage flow. From the adjusted local gage flow, diversion flows obtained from the Idaho Department of Water Resources (IDWR) were added. This iterative computation was carried throughout the Snake River watershed and resulted in an estimate of unregulated flow for the Snake River at Weiser, Idaho. The USACE unregulated flow estimate was calculated based on the daily average flow and, thus, incorporated seasonal variability in flow. Estimates of unregulated Snake River flow at Weiser were also available from the IDWR Snake River Planning Model (SRPM). The SRPM estimates were available on a monthly basis and compare well with the USACE estimates (Figure 6.1-2).

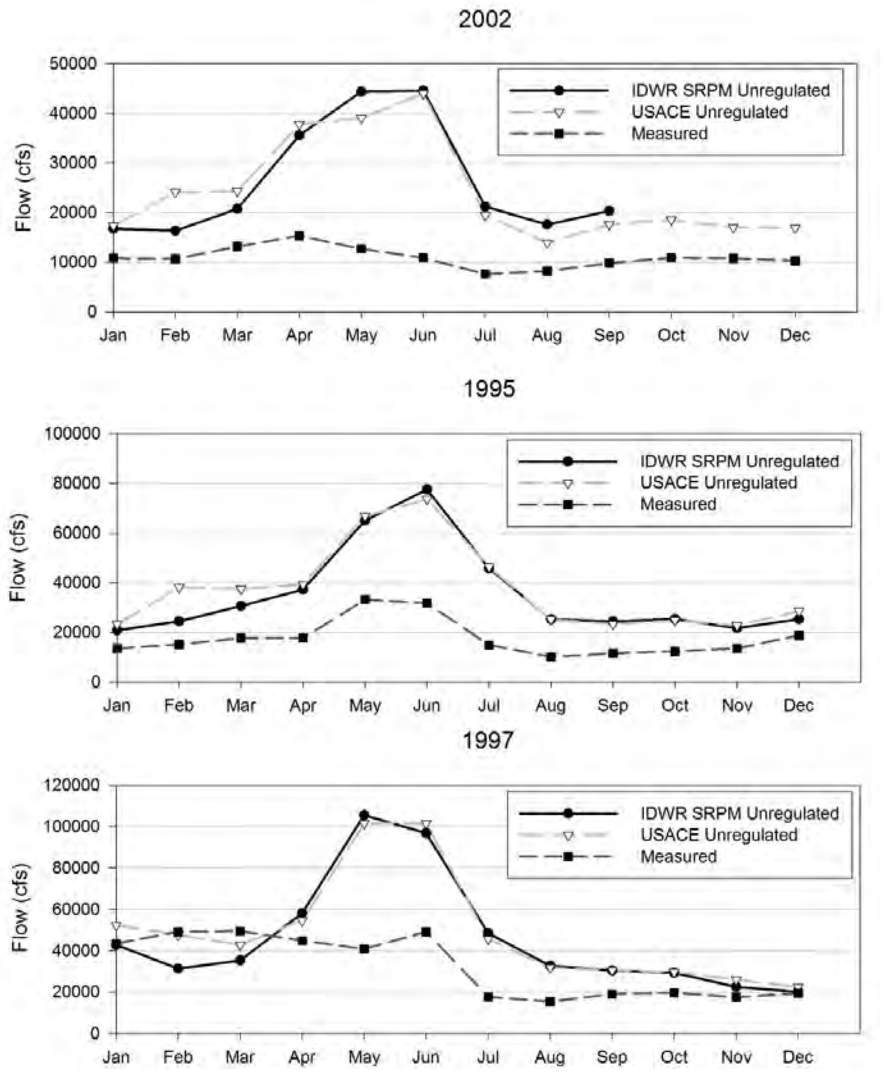


Figure 6.1-2
Comparison of IDWR SRPM and USACE monthly average unregulated Snake River flow estimates at Weiser, Idaho, for low (2002), medium (1995), and high (1997) water years. Monthly average measured flow at Weiser, Idaho (USGS gage 13269000), is also shown for comparison.

The USACE unregulated flow estimates show that the total annual Snake River volume entering Brownlee Reservoir may be lowered by 33 to 53% by current upstream water management and use (Table 6.1-2). The reduction in flow is largest during the spring runoff period and into July (Figure 6.1-3). During July, when Snake River temperatures typically peak, unregulated flow estimates were approximately 50% higher than measured flow.

Table 6.1-2
Comparison of measured (USGS gage 13269000, Snake River at Weiser) and unregulated (USACE unregulated Snake River flow at Weiser) Snake River volume at Weiser, Idaho (millions of acre feet), during the calendar year for low (2002), medium (1995), and high (1997) water years

Year	Measured Inflow Volume (acre-feet)	Unregulated Inflow Volume (acre-feet)	Difference (acre-feet)	Percent Difference
2002	7.9	17.1	9.1	53%
1995	12.7	26.8	14.1	53%
1997	23.2	34.7	11.5	33%

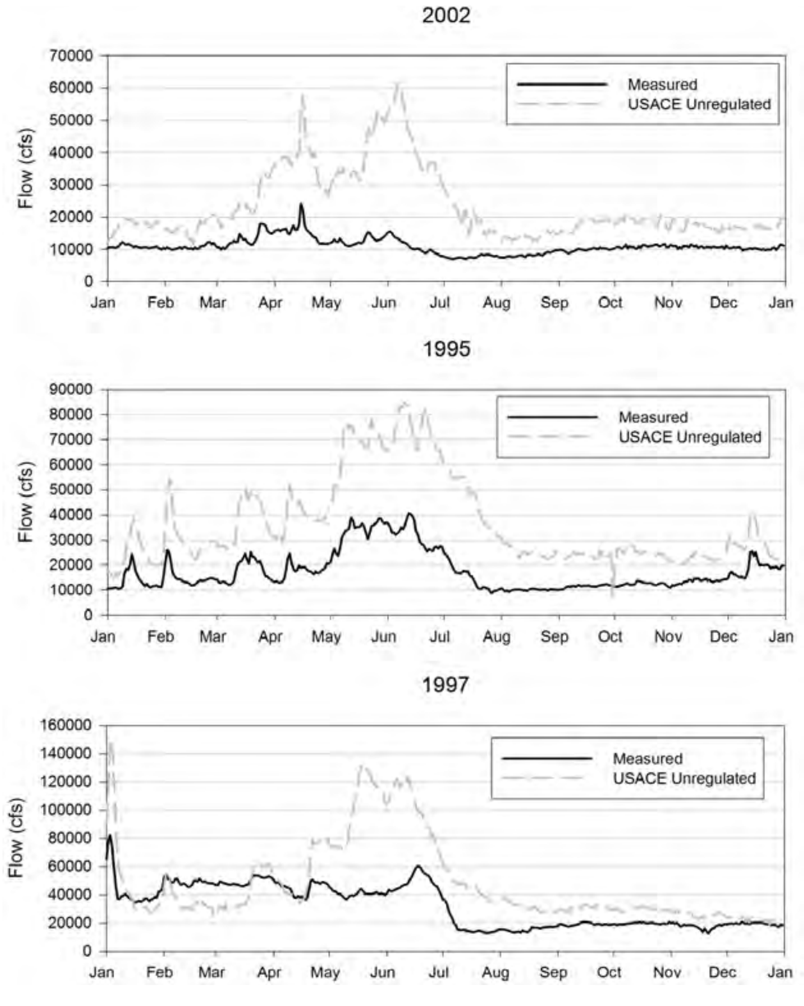


Figure 6.1-3
Daily average USACE unregulated and measured (USGS gage 13269000) Snake River flow at Weiser, Idaho, for low (2002), medium (1995), and high (1997) water years.

6.1.2.1.2 Dams and Impoundments

Water withdrawal and the use of Snake River water is facilitated by a complex network of reservoirs, diversions, canals, and pumping stations. Dams and impoundments contribute to changes in the thermal regime by slowing water velocity and increasing residence times. The IDWR lists a total of 572 dams on the Snake River and its tributaries upstream of HCD with a total storage capacity of approximately 11.8 million acre-feet (Table 6.1-3). The largest of these on the mainstem Snake River include the USBR American Falls Reservoir (1.7 million acre feet) and Palisades Reservoir (1.4 million acre-feet). The largest reservoirs on the tributaries include 2 additional USBR reservoirs: Owyhee Reservoir on the Owyhee River (1.1 million acre feet) and Cascade Reservoir on the Payette River (0.7 million acre-feet). The Boise River projects store an additional 1.1 million acre-feet. These include Anderson Ranch Reservoir (0.5 million acre-feet) and Arrowrock Reservoir (0.3 million acre-feet), both USBR projects, and the USACE project, Lucky Peak Reservoir, which stores 0.3 million acre-feet.

Table 6.1-3
Volume of water impounded and the percentage (%) impounded by owner in the entire Snake River watershed upstream of HCD and the SR–HC watershed (RM 247.6 409)

Impoundment Owner	**Snake River Impounded Volume**		**SR–HC Watershed Impounded Volume**		**Upstream Impounded Volume**	
	acre-feet	**%**	**acre-feet**	**%**	**acre-feet**	**%**
USBR	7,345,402	62	2,987,956	51	4,357,446	73
IPC	1,989,950	17	1,698,200	29	291,750	5
Other	1,361,852	11	902,991	15	458,861	8
USACE	307,000	3	307,000	5	0	0
U.S. Bureau of Indian Affairs	397,000	3	5,500	0	391,500	7
Big Wood Canal Company	191,500	2	0	0	191,500	3
Salmon River Canal Co. Ltd.	230,665	2	0	0	230,665	4
Total	**11,823,369**	**100**	**5,901,647**	**100**	**5,921,722**	**100**

IPC-owned dams account for nearly 2 million acre-feet, or 17% of the total storage capacity upstream of HCD (Table 6.1-3). In the portion of the Snake River watershed upstream of HCD that’s included in the SR–HC TMDL (i.e., RM 409 to RM 247.6), the IDWR lists 380 dams on the Snake River and tributaries, with a total storage capacity of nearly 6 million acre-feet, of which IPC-owned dams account for approximately 29% based on total storage. On the Snake River and tributaries upstream of RM 409, there are 192 dams, with IPC-owned dams accounting for 5%.

6.1.2.1.3. Removal of Riparian Vegetation and Channel Modification

The removal of riparian vegetation increases direct solar radiation to the surface of a stream, thereby increasing heat loading to the stream and ultimately water temperature. As described earlier in Section 6.1. Temperature, there are many important natural sources of water heating and cooling, with solar radiation being the primary natural heat source responsible for the temperature of water (Brown 1970). Boyd and Casper (2003) and Shumar and de Varona (2009) consider shade and stream morphology factors that affect or control the amount of solar radiation intersecting a water surface. Shade is provided by surrounding vegetation and other physical features, such as hillsides, canyon walls, terraces, and high banks. Stream morphology affects how closely riparian vegetation grows. Additionally, these factors are the most likely to have been influenced by anthropogenic activities and activities that can be most readily addressed in the confines of a TMDL.

Wyoming has not currently developed any temperature TMDLs for Snake River hydrologic unit codes (HUC) (WDEQ 2012), and the EPA has approved only 1 in Oregon for the Upper Malheur (ODEQ 2012). Idaho has 27 EPA-approved temperature TMDLs for Snake River HUCs (IDEQ 2012). The temperature TMDLs approved by the EPA in Idaho have generally followed 2 methodologies: either a reduction in water temperature to meet numeric criteria or a heat load allocation based on potential natural vegetation (PNV).

Most recently, Oregon and Idaho have assigned heat load allocations to temperature-limiting streams through a similar process. The ODEQ has applied the Heat Source model module Shade-a-lator, and the IDEQ has applied a method to determine reduced solar radiation from PNV. Both describe the riparian plant community that provides system potential shade—a mature, site-potential, vegetated landscape. System potential shade is then used as a surrogate representing natural background temperatures. IPC believes that, while the ODEQ’s Shade-a-lator module is more data intensive than the IDEQ’s PNV methodology, the basic principles governing the effect of direct solar radiation to the stream surface are similar.

The EPA has approved heat load allocations calculated using the Heat Source model module Shade-a-lator and the PNV methodology on nearly 2,850 miles of rivers and streams in Oregon and Idaho.

Additionally, the IDEQ has prepared other temperature TMDLs using the PNV methodology but has not yet submitted them to the EPA for approval. More temperature TMDLs in Oregon and Idaho are likely as many more miles of rivers and streams are listed as limited by temperature (IDEQ 2010; ODEQ 2010).

6.1.2.1.4 Hyporheic/Groundwater Modification

Hyporheic flow along a river channel produces a moderating effect on water temperature (Poole and Berman 2001; Lancaster et al. 2005). Reduced hyporheic exchange can reduce the capacity for water temperature buffering. Hyporheic exchange occurs when surface water enters the riverbed and flows subsurface before returning to the main channel. An exchange of water between the water column and hyporheic zone is potentially one of the more important thermal buffering processes (Poole and Berman 2001). The beneficial effects of hyporheic exchange have been found to be significant in smaller streams, but relatively high exchange rates also occur in larger, unconstrained channels where gravel deposits can be reworked.

Hanrahan et al. (2007) studied hyporheic exchange characteristics in historic (i.e., Swan Falls area) and contemporary (i.e., below HCD) SRFC spawning areas. Measurements of hydrologic interactions between the river and the riverbed showed less movement of water through the riverbed in the Swan Falls area. In addition, the accumulation of silt and fine sand over the spawning gravels was significantly higher in the Swan Falls area and was correlated with reduced movement of water through the riverbed.

The Snake River below HCD does not have these hyporheic flow issues because the HCC assists in removing a large portion of the sediment and silts that would otherwise accumulate downstream. Therefore, the HCC provides a substantial benefit to downstream spawning gravels by capturing silt and sediment that would otherwise cover existing SRFC salmon spawning gravels similar to the Marsing reach. In fact, SRFC salmon spawning might not be possible below HCD without the sediment and silt accumulation that occurs in the HCC.

6.1.2.2 Reservoir Temperature

Impounding a riverine system changes the system's hydrodynamics and thermal structure. Brownlee Reservoir exhibits 3 identifiable zones with different temperature characteristics: 1) the riverine zone, 2) transition zone, and 3) lacustrine zone. These 3 zones are common in large reservoirs (Thornton et al. 1990). The riverine zone develops in the upstream reaches of a reservoir and is characterized by a temperature similar to that of the upstream river (i.e., a slower, broader river). The transition zone, as the name implies, is the reach of the reservoir between the riverine and lacustrine zones. The lacustrine zone (the zone farthest downstream) is characterized by lake-like hydrodynamics. Similar to lakes, the lacustrine zone exhibits thermal stratification with the classic strata: epilimnion, metalimnion, and hypolimnion that develop in early spring and persist through late fall (Figure 6.1-5). The vertical location of the metalimnion is relatively deep in Brownlee compared to natural lakes and is strongly influenced controlled by the physical configuration of the power intake channel from which the penstocks draw water, with the top of the metalimnion forming at the centerline elevation of the penstocks.

Acknowledging and understanding the complex hydrodynamics within Brownlee Reservoir is important in understanding the thermal effects of inflowing water on outflow temperatures. Specifically, the quantity and temperature of water entering the reservoir in the spring and summer affects outflow temperatures through the summer and fall. Even after the water has been physically evacuated from the reservoir, it has played a role in the ongoing thermal structure of the reservoir, which in turn affects outflow temperatures.

The thermal structure of Brownlee Reservoir is dependent on the water-year type (i.e., high, low, or average flow conditions). The most notable pattern that occurs is in higher water years when the USACE mandates that Brownlee Reservoir be drafted significantly for flood control. Significant drafting of Brownlee Reservoir for flood control results in a relatively warm hypolimnion because the cold winter water that would otherwise remain in the hypolimnion is mixed with inflow waters until a later date in the spring (Figure 6.1-4). More information relative to the thermal structure of Brownlee Reservoir and patterns among water years can be found in Technical Report E.3.2-2 of the *New License Application: Hells Canyon Hydroelectric Complex.*

Because of the temperature structure and hydrodynamics in Brownlee Reservoir and the location of the outlet structures, the temperature regime of water leaving Brownlee Reservoir is notably different than the inflowing temperature regime. Current conditions relative to criteria in Oxbow and Hells Canyon reservoirs are therefore driven by Brownlee outflow temperature (see Section 6.1.2.3. Outflow Temperature).

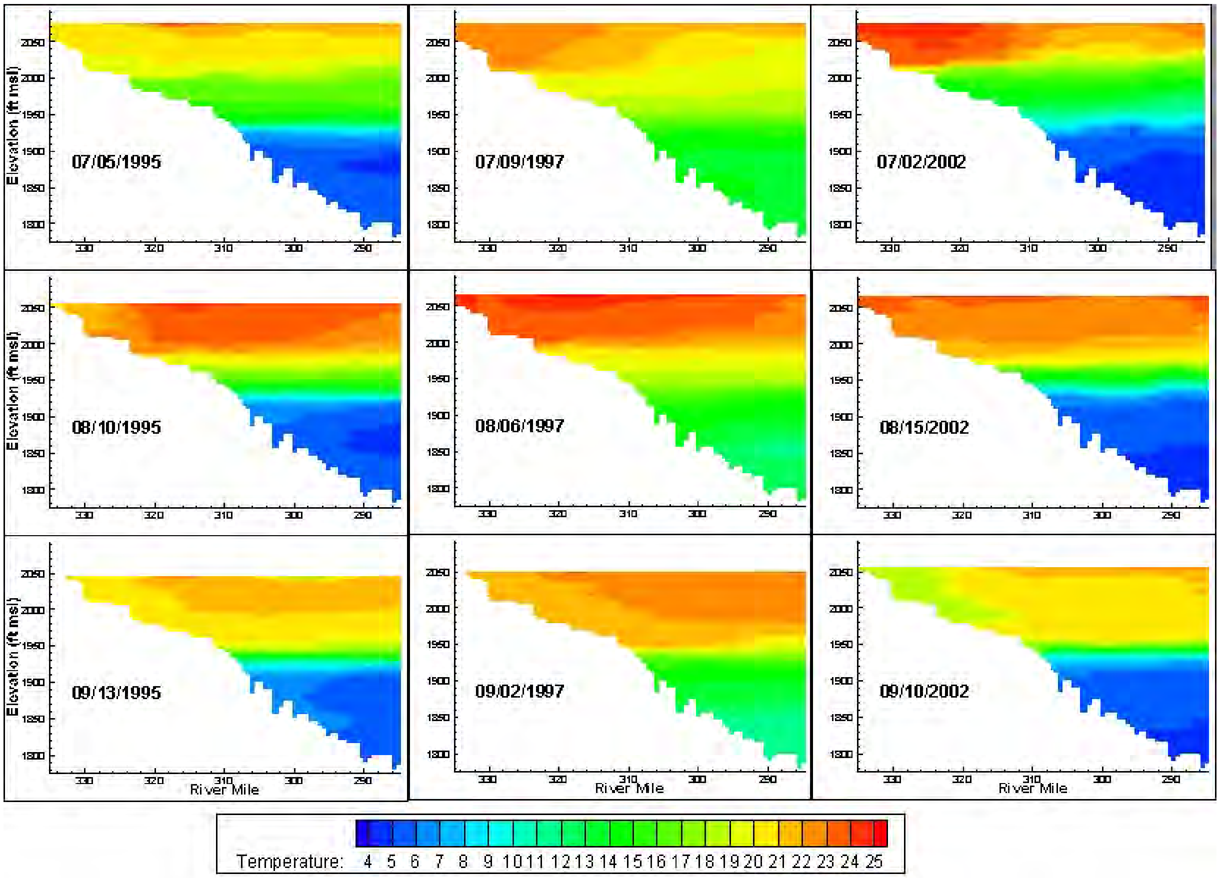
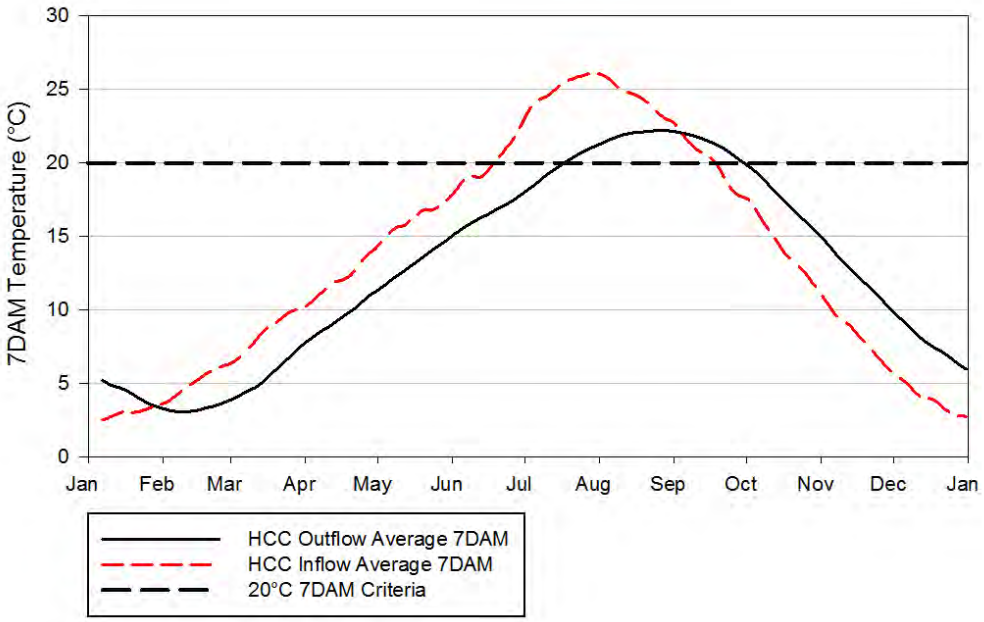


Figure 6.1-4
Measured Brownlee Reservoir temperature in °C, by river mileage and reservoir depth, for July, August, and September in an average (1995), high (1997), and low (2002) water year

6.1.2.3. Outflow Temperature

Idaho's EPA-approved temperature standards include a numeric 13°C MWMT salmonid spawning criterion (former IDAPA 58.01.02.286). Similarly, Oregon's temperature standards include a numeric 13°C 7DAM salmonid spawning criterion that applies to the river downstream of HCD (OAR 340-041-0028(4)(a), Table 121B). Idaho temperature criteria for the protection of cold-water aquatic life are a daily maximum temperature not to exceed 22°C, with a maximum daily average temperature of no greater than 19°C (IDAPA 58.01.02.250.02.b). The Oregon migration corridor requirement for salmon and steelhead includes a numeric 20°C 7DAM criterion that applies to the river downstream of HCD (OAR 340-041-0028(4)(d)). In addition to the numeric component, this OAR provision establishes narrative requirements that the river has cold-water refugia that are sufficiently distributed to allow for salmon and steelhead migration without significant adverse effects from higher water temperatures elsewhere in the stream, and a seasonal thermal pattern in the Snake and Columbia rivers that reflects the NSTP. With respect to the effect of the HCC on outflow temperatures, the SR–HC TMDL noted that "if upstream conditions were cooler, the water exiting the HCC would also be cooler." Therefore, the SR–HC TMDL concluded the HCC is not contributing to temperature exceedances specific to the cold-water aquatic life and the salmon and steelhead migration designated use (IDEQ and ODEQ 2004). Accordingly, the SR–HC TMDL did not assign HCC a load allocation for exceedances of the aquatic life and salmon and steelhead migration criteria below HCD. Conversely, the SR–HC TMDL did issue a thermal load allocation to IPC for the outflow from HCD during the beginning of the salmonid spawning period.

Summer water temperatures are elevated throughout the Snake River; however, the duration and magnitude of exceedance were generally less in waters below the HCC than in inflow waters. Myers et al. (2003) attributed this summer cooling to the volume of cool water retained in Brownlee Reservoir. Data collected through 2017 shows that outflow temperatures in water being released from HCD has slightly less duration of substandard temperatures than inflowing water, but notably less magnitude of exceedance. (Figure 6.1-5). The improved temperature conditions in the outflow from HCD relative to the inflowing water to Brownlee Reservoir is attributable to the Brownlee Reservoir’s depth and thermal stratification. Cool water is retained in Brownlee Reservoir through the summer because of the reservoir’s depth and the strong summer thermal stratification of the water column. A portion of this cool water is delivered downstream through the summer because Brownlee Dam’s intakes are located relatively deep in the water column (approximately 40 m below full pool elevation).



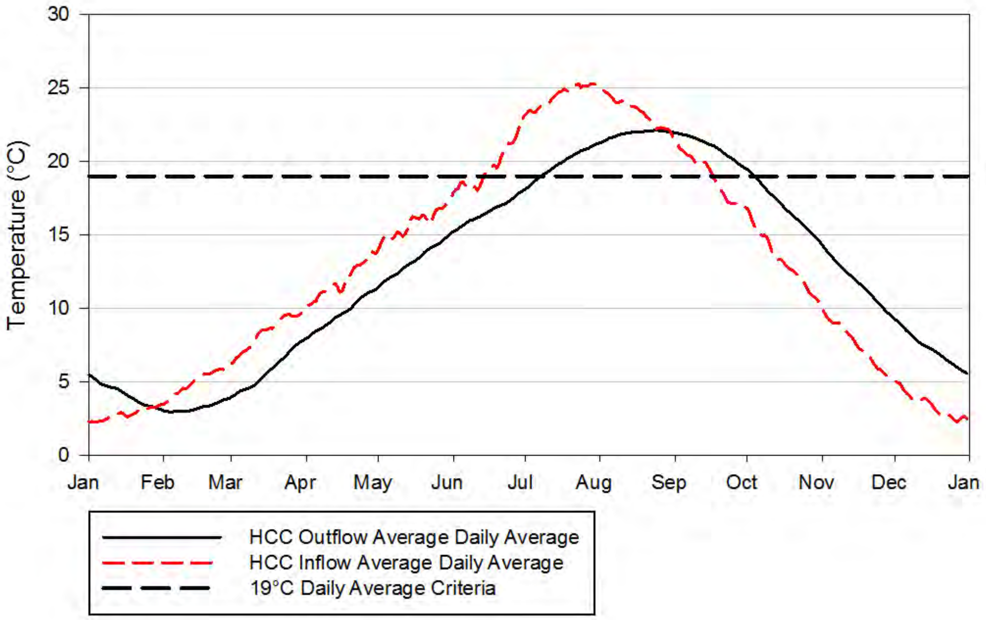


Figure 6.1-5
Summary temperature conditions of inflowing water to Brownlee Reservoir (period of record, 1996 2017) and outflowing water from HCD (period of record, 1991–2017) compared with Idaho's daily average 19°C criterion and Oregon's 7DAM criterion.

The data indicate that the magnitude of flows in a year affect the relative amount of cooling caused by the HCC. In high-water years, like the late 1990s, and more recently in 2011 and

2017, when the USACE mandates the drafting of Brownlee Reservoir for flood control in the spring, relatively little summer cooling is evident (Figure 6.1-6). This is likely due to the fact that much of the accessible cool water (i.e., water above the intake elevation) has been drafted. There is an obvious trend to the summer cooling effect of the HCC in medium and low water years. In the low-water year 2002, there were as many as 40% fewer days the criterion was exceeded at the HCC outflow compared to the inflow and nearly a 7°C reduction in the maximum temperatures measured. More detail on the HCC's effect on water temperature is available in Technical Report E.3.2-2 of the *New License Application: Hells Canyon Hydroelectric Complex*.

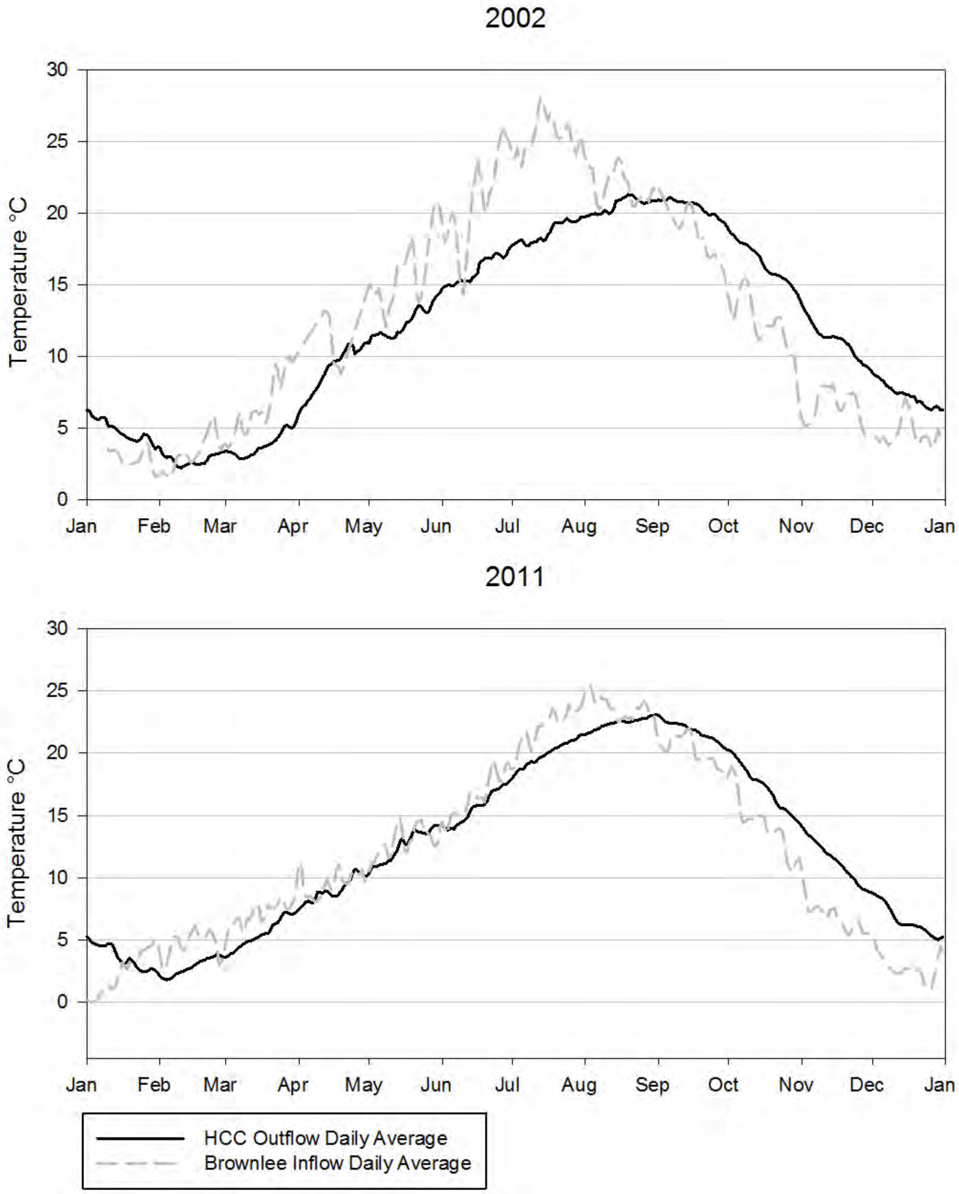


Figure 6.1-6
HCD outflow and Brownlee Reservoir inflow daily average temperature in a low (2002) and high (2011) water year.

This summer cooling effect of the HCC on Snake River temperatures has important benefits to aquatic life and salmonid rearing. Chandler et al. (2003) and Richter and Chandler (2003) found that fish communities downstream of Brownlee Dam favored cold-water indicator species more than those in Brownlee Reservoir and the Snake River upstream. The SR–HC TMDL corroborated this finding, stating that while aquatic life and salmonid-rearing use is impaired upstream in the Snake River, the use is supported in "other segments [of the HCC and Snake River downstream] due to the availability of coldwater refugia" (IDEQ and ODEQ 2004). This is a particularly important finding not only because OAR 340-041-0028(4)(d) requires "sufficiently distributed coldwater refugia[,]" but also in relation to biological criteria (biocriteria) (OAR 340-041-0011). Specifically, the availability of the cold-water refugia downstream of the HCC is of sufficient quantity and quality to support aquatic species and resident biological communities that are not supported in the Snake River upstream of the HCC (see Section 6.1.2.3.1.1. Cold Water Refugia). The Snake River downstream of the HCC exhibits more natural river processes that provide high connectivity to hyporheic environments. This connectivity creates areas of downwelling and upwelling through alluvial deposits in the riverbed.

6.1.2.3.1. Salmon and Steelhead Migration and Cold-Water Aquatic Life

In Oregon, the beneficial-use designation downstream of HCD is salmon and steelhead migration corridors (OAR 340-041-0028(4)(d)). The Idaho cold-water aquatic life 19°C daily average criterion applies at the HCC outflow, as well as the inflow (IDAPA 58.01.02.250.02.b). Neither the water flowing into the HCC, nor the water flowing out of the HCC, is compliant with the 22°C, 20°C, or 19°C criteria at all times (Figure 6.1 5). However, water leaving the HCC is closer to compliance in both frequency and magnitude. Specifically comparing the Oregon 20°C 7DAM criterion, inflowing water is noncompliant an average of 92 days per year (period of record 1991–2017), while outflows are noncompliant 74 days (period of record 1996–2017). Further, on average, inflows 7-DAM values peak 5.3°C over the 20°C criterion on July 29, while outflows peak on average 2.2°C over 20°C on August 27. (Figure 6.1-5)

Water temperature data from the inflows and outflows of the HCC demonstrate the HCC is not causing, nor contributing to, a violation of the 20°C Oregon criterion or the 19°C Idaho water quality criterion. In fact, they show the HCC is having a net positive effect relative to these criteria. This conclusion is consistent with the assessment in the SR–HC TMDL. The SR–HC TMDL concludes the HCC does not add heat to the river, warm summer temperatures in Hells Canyon are caused by "natural" or "non-anthropogenic" influences, and anthropogenic activities not currently quantified or regulated upstream of the HCC.

The SR–HC TMDL supported this conclusion with an analysis of the measured temperature dataset available at that time and the results of IPC temperature modeling (SR–HC TMDL at 381; 402–04). The model scenario used temperature data collected in 1995. The temperature model showed that if inflows met the numeric temperature criteria, the outflow at HCD would also meet the numeric temperature criteria for cold-water aquatic life and salmonid migration. The SR–HC TMDL specifically concluded "if upstream conditions were cooler, the water exiting the HCC would also be cooler. Therefore, it is concluded the HCC is not contributing to temperature exceedances specific to the cold-water aquatic life/salmonid migration designated use." For this reason, the SR–HC TMDL does not assign a temperature load allocation to the HCC with regard to the time period and conditions outside the salmonid spawning period.

In sum, the SR–HC TMDL concluded the HCC is not responsible for elevated Hells Canyon temperatures in the summer months and, therefore, continued operations of the HCC following relicensing will not cause or contribute to a violation of either the 19°C Idaho or the 20°C Oregon numeric criteria.

6.1.2.3.1.1. Cold-Water Refugia

The first of the 2 Oregon narrative criteria related to migration requires "coldwater refugia that are sufficiently distributed so as to allow salmon and steelhead migration without significant adverse effects from higher water temperatures elsewhere in the water body" (OAR 340-041-0028(4)(d)). The purpose of the refugia criterion is to ensure there are pockets of cooler water available to migrating fish during the time of peak summer temperatures in excess of 20°C. See EPA Temperature Guidance at 29.

The SR–HC TMDL concludes that, both within and downstream of the HCC, the "designated beneficial uses are being supported through availability of cold-water refugia" (TMDL at 422). This conclusion is founded on a population study of fish above, in, and below the HCC that documented fluvial populations of rainbow trout in the HCC and fluvial populations of rainbow trout and bull trout downstream of the HCC. Fluvial trout are not found upstream of the HCC. (Chandler et. al 2003). The study further showed that the rainbow trout populations in the HCC and rainbow trout and bull trout downstream were using cold-water refugia provided by the tributaries during summer months by either migrating upstream into the tributaries or associating with the cold-water plume of the tributaries during the summer months. Fluvial populations of rainbow trout and bull trout move out of the tributaries into the reservoirs or the river below HCD to over-winter.

The finding in the SR–HC TMDL is consistent with recent studies that demonstrate river temperatures are often more complex than previously thought (Fullerton et al. 2015) and that cold-water refuges are present at multiple spatial scales created by a variety of controls, such as geomorphology, tributary influence, and groundwater exchange points (Ebersole et al. 2015; Fullerton et al. 2015). Between HCD and the Clearwater River confluence, there are 132 perennial streams distributed throughout the length of the Snake River corridor (see Exhibit 6.1 1) that may provide some thermal refugia not only from the surface flow and plumes of these streams, but also through hyporheic and groundwater upwelling through the alluvial fans associated with the streams. Ebersole et al. (2015) conservatively defined cold water patches as discrete areas of relatively cold water that were ≥3°C colder than the ambient stream temperature. While not a complete data set of all perennial streams, monthly average temperature data of surface flows collected by Idaho Power in 2003 and 2004 at many of the perennial streams in Hells Canyon shows that during the critical summer months of July through September, the majority of the perennial streams measured would provide refugia (Exhibit 6.1 1).

The State of Oregon defines "Cold-water Refugia" (CWR) as "those portions of a water body where or times during the diel temperature cycle when the water temperature is at least 2 degrees Celsius colder than the daily maximum temperature of the adjacent well-mixed flow of the water body" (OAR 340-041-0002(10). A more refined comparison of two small subsets of perennial streams to the Snake River using daily maximum temperatures further demonstrates the extent of refugia that would be provided daily (Exhibit 6.1-1). One set of streams included Getta Creek

(RM 205), Wolf Creek (RM 202), Deep Creek (RM 199), Divide Creek (RM 193) and were compared to the Snake River at RM 202. The other set included Deep Creek (RM 247), Granite Creek (RM 239), Sheep Creek (RM 229), Bernard Creek (RM 235), Three Creeks (RM 238), Kirkwood Creek (RM 220) and Temperance Creek (RM 223) and were compared to the Snake River at RM 247. The Imnaha River (a moderately large tributary relative to most of the perennial streams) was also included in the comparison relative to the Snake River at RM 202. Generally, the first set of perennial streams have headwaters that originate in relatively low elevations compared to the second set of perennial streams that except for Temperance Creek, originate in the higher elevation headwaters associated with the Seven-Devil Mountains in Idaho.

The comparison demonstrated that all the tributaries in the low elevation headwater data set compared to the Snake River provided CWR during at least some portion of the day, except for a few days in the middle of July, where all diel metrics exceeded the -2 °C CWR definition. Generally, by mid-August, the daily average temperatures started to drop below the -2 °C CWR definition which suggests that the majority of the diel cycle was providing thermal refugia. Finally, by around the first of September, all of the tributaries provided CWR during the entire diel cycle

The higher elevation headwater tributaries demonstrate a much colder pattern relative to the Snake River. All of the tributaries with the exception of Temperance Creek and Kirkwood Creek provide significant CWR during all portions of the diel cycle. Temperance Creek and to a lesser extent Kirkwood Creek show patterns similar to those in the proximity of RM 202. There are multiple drainages on the Idaho side of the Snake River between RM 247 and RM 220 that are associated with this high elevation run-off (see Exhibit 6.1-1).

These two data sets provide further support to the finding in the SR–HC TMDL and, overall, perennial tributaries in the Hells Canyon reach of the Snake River provide some level of thermal refugia based on surface water temperature. These measurements do not include the potential additional benefit of subsurface flow upwelling into the Snake River at these stream mouths. Ebersole et al. (2015) also found that many tributaries with dry channels also provided significant cold-water patches in mainstem rivers through hyporheic and groundwater upwelling during the time of year with the warmest water temperatures. There are 813 drainages in the Hells Canyon corridor that are classified as intermittent streams. The extent that these perennial and intermittent streams provide thermal refugia has not been measured but may be significant relative to thermal refugia. Based on these studies, and consistent with the SR–HC TMDL, the refugia criterion is currently attained within the downstream reach of Hells Canyon affected by the HCC and will not change as a result of relicensing and continued HCC operations.

The SR–HC TMDL does, however, conclude there is a lack of cold-water refugia upstream of the HCC due to the degradation of the upstream watershed (see TMDL at 422). While the HCC does not impact the availability of upstream cold-water refugia and therefore requires no mitigation under this § 401 application, Section 7.1. Temperature Proposed Measures of this application describes the mechanism for how IPC's proposed SRSP will aid in addressing the lack of upstream refugia habitat identified in the SR–HC TMDL, while also offsetting IPC's cumulative thermal load exceedance during the salmonid spawning period. In addition to decreasing the amount of thermal load that enters the upstream tributaries, the riparian revegetation and in-stream projects proposed as part of the SRSP will also create extensive new habitat designed to promote cold-water refugia.

6.1.2.3.1.2. Natural Seasonal Thermal Pattern

The second narrative criterion associated with the migration corridor use is a requirement that "the seasonal thermal pattern in Columbia and Snake Rivers must reflect the natural seasonal thermal pattern" (OAR 340-041-0028(4)(d)). This criterion is not further defined in rule or Internal Management Directive, and has not yet been applied in other contexts. Therefore, in this section, IPC presents its understanding of the intent behind the criterion and its application to the HCC.

Like the refugia criterion, the NSTP criterion is intended to minimize the exposure of migrating fish to peak 20°C or greater temperatures. In its Temperature Guidance document, the EPA explained the relationship among the 3 components of the migration corridor standard as follows:

> To protect this use, EPA recommends a 20°C maximum 7DADM numeric criterion plus a narrative provision that would require the protection, and where feasible, the restoration of the natural thermal regime. EPA believes that a 20°C criterion would protect migrating juveniles and adults from lethal temperatures and would prevent migration blockage conditions. However, EPA is concerned that rivers with significant hydrologic alterations (e.g., rivers with dams and reservoirs, water withdrawals, and/or significant river channelization) may experience a loss of temperature diversity in the river, such that maximum temperatures occur for an extended period of time and there are little cold-water refugia available for fish to escape maximum temperatures. In this case, even if the river meets a 20°C criterion for maximum temperatures, the duration of exposure to 20°C temperatures may cause adverse effects in the form of increased disease and decreased swimming performance in adults, and increased disease, impaired smoltification, reduced growth, and increased predation for late emigrating juveniles (e.g., fall Chinook in the Columbia and Snake Rivers). Therefore, in order to protect this use with a 20°C criterion, it may be necessary for a State or Tribe to supplement the numeric criterion with a narrative provision to protect and, where feasible, restore the natural thermal regime for rivers with significant hydrologic alterations. (EPA Temperature Guidance at 29)

In 2011, the ODEQ confirmed that the intent of the Oregon NSTP standard reflects the EPA's intent to protect the migration corridor use. Specifically, the ODEQ stated the following:

> Review of DEQ rulemaking files indicates that the intent of the NSTP language was to protect migrating fish from temperatures routinely exceeding the 20°C criterion. Attainment of NSTP would allow the migrating fish to experience varying temperatures, not constant warm temperature. (Memorandum from ODEQ Water Quality Division to IPC, June 30, 2011)

That the protection of the migration corridor use is the singular focus of the NSTP criterion is consistent with the rulemaking history of the migration corridor standard. During the rulemaking, the ODEQ specifically rejected a recommendation from its Technical Advisory Committee (TAC) to apply the NSTP to the salmon and steelhead spawning use rather than the migration corridor use. The TAC recommended the ODEQ not adopt a numeric spawning standard and instead adopt a narrative standard requiring “regulated rivers” to “take all feasible steps to mimic the natural thermal regime” ODEQ temperature TAC meeting notes (July 1, 2003). The ODEQ instead adopted a numeric standard of 13°C for the spawning use and a narrative NSTP for the migration use. This is evident in that the NSTP language is present only in subsection (4)(d) for migration corridors, but not present in the other subsections addressing other salmonid uses, including salmonid spawning. Therefore, consistent with the ODEQ’s action during the rulemaking and the applicable regulations, NSTP is associated only with the migration corridor use and is intended to minimize the duration of peak temperatures in excess of 20°C downstream of the HCC.

The presence of the HCC reservoirs has resulted in a subtle temporal shift of seasonal temperatures relative to inflowing water and what occurred prior to construction of the HCC (Figure 6.1-7). While quantitative values can be assigned to this shift, because the NSTP standard was intentionally established as a narrative standard, quantification is not appropriate. The intent of the NSTP standard, consistent with the EPA temperature guidance, was to protect migrating fish from temperatures above 20°C if the thermal regime of the system had been altered, resulting in the extended duration of temperatures over 20°C. Figure 6.1-7 shows the HCC is not creating conditions whereby migrating fish are being exposed to substantially extended periods of temperatures in excess of 20°C, and when temperatures are above 20°C, the outflow is typically cooler than the inflow.

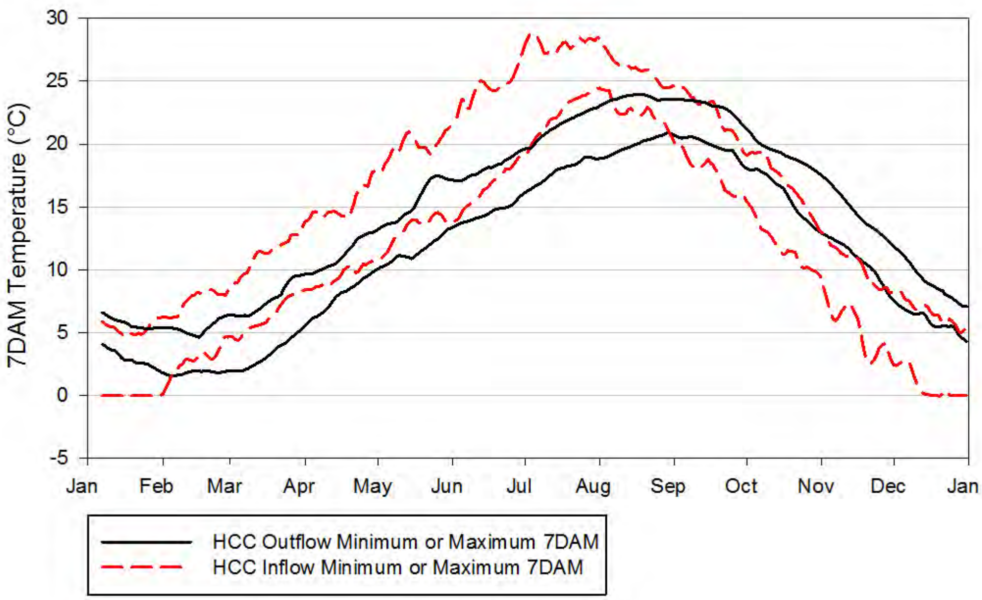


Figure 6.1-7
Minimum and maximum 7DAM temperature for water flowing into Brownlee Reservoir (Inflow Minimum or Maximum) and water flowing out of HCD (Outflow Minimum or Maximum). The period of record for outflow is 1991 to 2017, and the period of record for Inflow is 1996 to 2017.

The EPA temperature guidance indicates it may be necessary to supplement the numeric criterion with a narrative provision like NSTP to address the concern "that rivers with significant hydrologic alterations (e.g., rivers with dams and reservoirs, water withdrawals, and/or significant river channelization) may experience a loss of temperature diversity in the river, such that maximum temperatures occur for an extended period of time and there is little cold water refugia available for fish to escape maximum temperatures." The HCC does not cause a condition where "maximum temperatures occur for an extended period of time." In fact, the average period when temperatures of water flowing into Brownlee Reservoir exceeds the 7-DAM criterion of 20°C is 92 days while the period when outflows from HCD exceed the 20°C 7-DAM is 74 days. The HCC not only causes a reduction in maximum temperatures, but also reduces the time period when conditions exceed the numeric criterion.

Therefore, the HCC does not create the type of condition the NSTP criterion was meant to address, and, in fact, enhances conditions. Continued operation of the HCC will be in compliance with the NSTP criterion. Moreover, as noted above, there are adequate cold-water refugia below the HCC for migrating fish to escape maximum summer temperatures. Further, IPC's proposed SRSP provides additional reasonable assurance that the NSTP criterion will be met below HCD (See Section 7.1. Temperature Proposed Measures).

6.1.2.3.2. Salmonid Spawning

The SR–HC TMDL used Idaho's criterion, which at the time was a MWMT of 13°C. Similarly, Oregon's salmon and steelhead spawning temperature criterion is a 7DAM temperature not to exceed 13°C (OAR 340-041-0028(4)(a)). Under current regulations, the numeric spawning criteria can be increased by up to 0.3°C to account for anthropogenic influences (see Section 6.1.1.4. Salmonid Spawning)[26]. The SR–HC TMDL presented and discussed HCC outflow temperature exceedances of the numeric salmonid spawning criterion based on the data set available at that time. The SR–HC TMDL also recognized that the actual thermal load exceedance for the HCC on any one day is dependent on both the temperature of the outflow and the flow on that day. Accordingly, the SR–HC TMDL documented a methodology to calculate an excess thermal load per day. IPC applied this methodology to a current dataset consisting of 27 years of measured data (1991–2017, Exhibit 6.1-2) to calculate the excess thermal load on each day, for each year, when the HCC outflow temperature was above the salmonid spawning criteria (13.3°C). The daily excess thermal loads were then summed to calculate a cumulative thermal load exceedance for each year (Exhibit 6.1-3).

6.1.2.3.2.1. Calculation Methodology and Results

For each year in the 27-year period, thermal load exceedances above the numeric 7DAM spawning criteria (13.3°C) were calculated for the period when the HCC outflow temperature was above the salmonid spawning criteria. Beginning October 29 of each year in the 27-year period—which is the first applicable day during that period for which 7DAM can be calculated (see Section 6.1.1.4. Salmonid Spawning)—measured HCC outflow temperature data was

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[26] When the SR–HC TMDL as approved, Oregon included an allowable anthropogenic increase of up to 0.14°C. SR–HC TMDL, p. 468. The TMDL incorporated the Oregon standard because it was more stringent than the Idaho standard at the time, which included an allowable anthropogenic increase of up to 0.3°C. Oregon standards now include allowable anthropogenic increases up to 0.3°C.

compared to the numeric 7DAM salmonid spawning criterion (i.e., 13.3°C). The temperature criterion was exceeded in the Snake River downstream of HCD in all but 1 year (Table 6.1-4). The elevated temperatures that exceed the criterion occurred during the first few weeks of the SRFC spawning period (Exhibit 6.1-2 and 6.1-3). For each day of each year in the 27-year period where the 7DAM temperature measurement exceeded the salmonid spawning criterion, measured flow data from the HCD outflow was also used. The actual measured temperature exceedance on each day over the duration for each year was combined with the average HCC outflow volumes on that day to calculate a daily thermal load exceedance using the following equation from the SR–HC TMDL:

$$Thermal\ Load\ (\frac{bkcal}{day}) = \left(Q\frac{cf}{sec} * \Delta T(^{\circ}\mathrm{C}) * \frac{28.324kg}{cf} * \frac{86400sec}{day} * \frac{1kcal}{\frac{kg}{1}{^{\circ}\mathrm{C}}} \right) / 1{,}000{,}000{,}000$$

Where:

- Q = Daily average HCC outflow in cfs
- ΔT = The magnitude of exceedance above the 13.3°C criterion based on the 7DAM temperature

The daily thermal load exceedances for each year, which are documented in Table 3 of Exhibit 6.1-3, were then summed to calculate a cumulative thermal load exceedance for each year’s salmonid spawning period (see the Cumulative Thermal Load Exceedance column in Table 6.1-4 and Exhibit 6.1-3. The cumulative approach incorporates the thermal exceedances observed each day that the outflow temperature exceeds the daily salmonid spawning criterion. By summing all observed daily thermal exceedances into a cumulative thermal load exceedance, this approach accounts for the entirety of the excess pollutant load (magnitude) observed during the spawning period (duration). Thermal load exceedances varied from 0.0 to 1256.4 over the 27 years of data, (Table 6.1 4, Figure 6.1 8). This range of cumulative thermal load exceedances represents the variable flow, climatic, and meteorological conditions that have been observed during the salmonid spawning period over the last 27 years. The cumulative thermal load exceedances followed the same general pattern as temperature exceedances with the highest observed exceedances in low water years IPCs proposal to address the cumulative thermal load exceedances of the salmonid spawning criterion is developed and presented in Section 7.1 Temperature Proposed Measures.

Table 6.1-4
HCC outflow 7DAM temperature, exceedance of the 7DAM salmonid spawning criterion of 13.3°C on October 29, and the cumulative thermal load exceedance over the duration of time when the HCC outflow temperature was greater than 13.3°C (1991-2017). Also shown for reference is the annual average Snake River flow in cfs measured at Weiser, Idaho, and water-year category.

Year	7DAM Temperature (°C)	Criteria Exceedance (°C)	Duration (days after 10/29)	Cumulative Thermal Load Exceedance (bkcal)	Annual Average Flow (cfs)	Water-Year Category
1991	16.4	3.1	12	453.2	10,400	Low
1992	15.8	2.5	16	551.0	8,400	Low
1993	15.7	2.4	10	366.5	16,500	Medium
1994	15.5	2.2	12	353.0	10,800	Low
1995	14.6	1.3	7	114.8	17,500	Medium
1996	14.8	1.5	8	150.2	24,600	High
1997	13.3	0.0	0	0.0	32,000	High
1998	14.0	0.7	6	58.7	23,000	High
1999	14.5	1.2	8	181.4	22,900	High
2000	15.0	1.7	9	192.9	15,100	Medium
2001	15.8	2.5	14	422.2	9,800	Low
2002	15.3	2.0	8	210.3	11,000	Low
2003	16.8	3.5	13	547.7	11,700	Low
2004	16.3	3.0	15	500.4	10,900	Low
2005	15.7	2.4	15	456.0	11,100	Low
2006	15.3	2.0	8	184.9	21,500	Medium–high
2007	14.5	1.2	9	116.3	11,000	Low
2008	14.9	1.6	10	175.1	12,700	Low
2009	14.6	1.3	6	95.2	14,400	Medium–low
2010	16.8	3.5	20	809.9	13,300	Medium–low
2011	15.4	2.1	11	428.0	24,900	High
2012	15.8	2.5	16	438.1	15,800	Medium
2013	15.3	2.0	11	277.4	9,700	Low
2014	17.2	3.9	21	1,044.9	11,200	Low
2015	17.9	4.6	23	1,256.4	10,200	Low
2016	16.0	2.7	24	686.5	12,200	Low
2017	14.4	1.1	8	105.9	25,600	High

Note: 1993 AND 2001 temperature data was not collected at the penstock monitor, so data collected within 20 miles downstream of HCD was used to fill the data gaps so a representative cumulative thermal load exceedance could be calculated for those years.

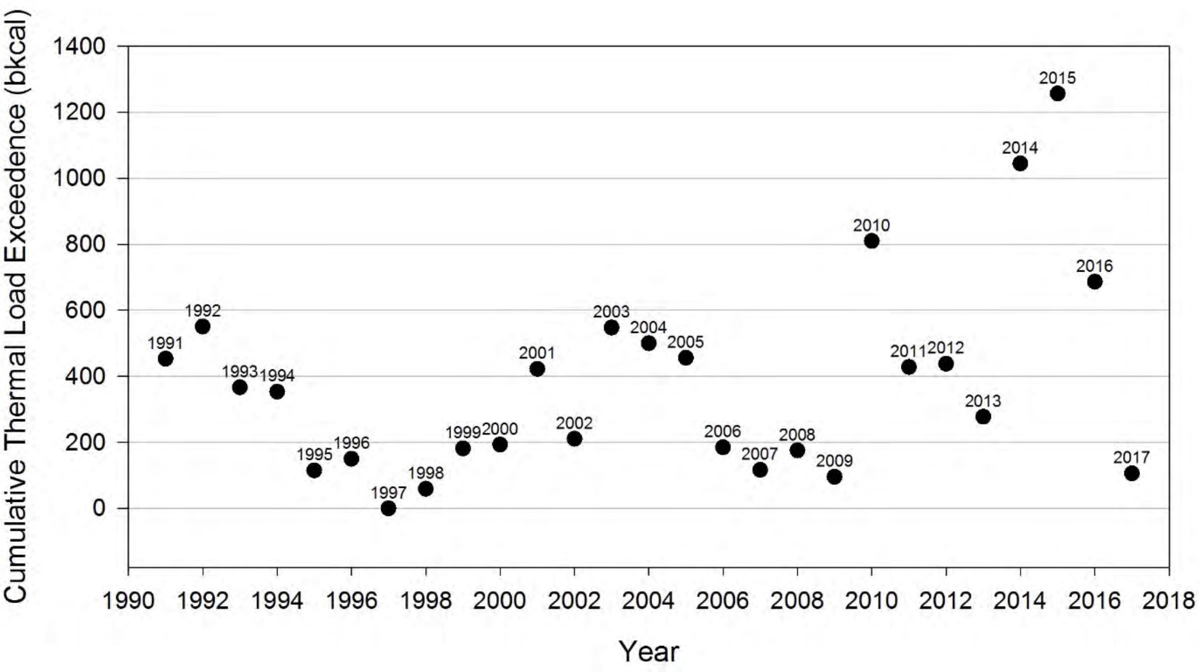

Figure 6.1-8
Cumulative thermal load exceedance in bkcal for each year, chronologically, during the 1991 through 2017 period.

6.1.3. Snake River Fall Chinook Life History and Status

The previous section compared and discussed current HCC outflow conditions with a narrow focus on the applicable criteria. However, a narrow comparison of current conditions with criteria is only 1 step in the analysis; it is also important to consider the criteria are designed with the specific intent of beneficial use protection and support, in this case SRFC salmon spawning. Substantial information exists relative to the history, changes, and current status of SRFC salmon. A summary of this information is presented below and suggests that while there are documented criteria exceedances during the first 2 weeks of the SRFC salmon spawning period, the beneficial use of salmonid spawning is being supported downstream.

The present-day Snake River spawning and incubation habitat from what is now Brownlee Reservoir through Hells Canyon to near the confluence of the Grande Ronde River (RM 169) was neither extensively used by, nor particularly conducive to, SRFC salmon for spawning and incubation before the construction of the HCC. Spawning of SRFC salmon occurred from about the confluence of the Grande Ronde River downstream to the confluence of the Snake and Columbia rivers. However, the more significant population of SRFC salmon was located primarily from the confluence of the Boise River (RM 392) up to Shoshone Falls (RM 615). Following the construction of Swan Falls Dam (RM 458) in 1901, SRFC salmon spawned primarily in the Marsing reach of the Snake River, which extends between Swan Falls Dam and the town of Marsing, Idaho (RM 424). The Snake River in Hells Canyon was primarily used as a migration corridor to and from these upstream reaches of the Snake River. From the onset of development in southern Idaho, altered hydrographs and high sediment and nutrient loads in the Snake River in the area upstream of Brownlee Reservoir have contributed to the significant degradation of these historic spawning habitats. Since, and unrelated to, the construction of Brownlee Reservoir, this upstream spawning habitat has become too degraded to support SRFC salmon spawning because the intergravel environment has become anoxic and infiltrated with fine sediments (Groves and Chandler 2005).

Following the construction of Brownlee Reservoir, efforts were made to pass SRFC salmon to spawning habitats in the Marsing reach. Passage was not successful for juvenile SRFC salmon, and passage efforts ceased in 1964. HCD was completed in 1968 and became the upstream terminus for migration. Spawning habitats in the lower Snake River were lost with the construction of the federal Lower Snake River dams, beginning in 1962 with the completion of Ice Harbor Dam and going through 1975 with the completion of Lower Granite Dam.
This construction further limited spawning in the Snake River to the approximately 100 miles of free-flowing river between HCD and Lower Granite Reservoir. Today, spawning is distributed throughout the entire 100-mile reach. In contrast to past upstream habitats, today spawning habitats below HCD are relatively clean of fine sediments, and the intergravel environment is well oxygenated with high connectivity to the water column. Fine sediments from southern Idaho and eastern Oregon land uses are primarily captured in the HCC reservoirs. SRFC salmon continue to increase in numbers as various measures and hatchery supplementation programs have been implemented to enhance this population. In 2013 and 2014, near record numbers of SRFC salmon redds—approaching 3,000 in both years—were observed in the Hells Canyon reach. Adult returns above Lower Granite Dam in 2013 exceeded 50,000, of which approximately 21,000 were naturally produced adults. In summary, the habitat in the Hells Canyon reach has changed from primarily a migration corridor for SRFC salmon with limited spawning to habitats that now support extensive spawning and incubation for SRFC salmon. This, in part, is the result of a changed thermal regime of the Hells Canyon habitat caused by the construction of the HCC, which resulted in warmer fall and winter temperatures relative to the pre-HCC thermal regime. The thermal environment below the HCC now supports incubation and emergence timing similar to the historic habitats upstream of the HCC, whereas historically the HCC was a colder incubation environment that would have delayed emergence timing.
This thermal regime change is significant to the status of SRFC salmon. NOAA Fisheries concurs, “the current water temperature regime downstream from HCD is more beneficial to SRFC than the natural regime, primarily due to warmer fall and winter water temperatures that accelerate fry emergence.”

6.1.3.1. Snake River Thermal Regimes

SRFC salmon have a varied history of different thermal regimes. Adults migrate in late summer and early fall when summer maximum temperatures are at or near their peak. They spawn during a declining thermal pattern in the fall. These thermal regimes vary among years and spawning locations, influenced by differences in water year and air temperatures. Despite this variability, adult migration and spawn timing has changed very little over the period of record. This suggests significant plasticity in their ability to adapt and function in variable thermal regimes and a reliance on more stable cues for these events, such as a photoperiod.

The core population of SRFC salmon historically occupied the mainstem Snake River primarily upstream of Swan Falls Dam. They were closely associated with the warmer winter thermal regime of the Middle Snake River, which was significantly influenced by the discharge of the Eastern Snake Plain Aquifer (ESPA). The thermal pattern of the Snake River is unique from other rivers because of the high volume of groundwater stored in the ESPA that enters the Snake River between approximately RM 553 and RM 620. In total, approximately 5,000 cfs of groundwater enters the Snake River in the form of springs that flow from basalt cliffs, primarily on the north side of the river. Development rates of incubating embryos increase with water temperature, and emergence timing is dependent on when spawning occurs and the accumulated thermal units (ATU) through incubation. SRFC salmon reach emergence around 1,000 ATUs. The warmer incubation temperatures influenced by the ESPA allowed for early emergence from spawning areas, where fish would rear for a brief period before migrating to the ocean. This typical life history for fall Chinook salmon is referred to as an ocean type or Age-0 life history, where fish migrate to the ocean in their first year of life. This life history is dependent on early emergence to allow sufficient growth to migrate before summer water temperatures become unsuitable. This is compared to an Age-1 type life history for some Chinook salmon, where fish will rear during the first year in freshwater and migrate to the ocean as a 1-year old fish. The thermal regime for Age-1 life histories must be cool enough to support summer rearing, which was not likely in the arid desert environment of the mainstem Snake River. Today, fall Chinook salmon that spawn in the Clearwater River emerge relatively late and typically display an Age-1 life history, because releases of cold water from Dworshak Reservoir have created cooler conditions in the lower Clearwater and Snake rivers.

The influence of the ESPA diminishes downstream, especially when larger tributaries, such as the Boise and Payette rivers, enter the Snake River. Prior to the construction of the HCC, the Snake River in Hells Canyon was relatively cold, and fish would have emerged late relative to those upstream in the Swan Falls reach and would have had to rear and migrate during warm summer temperatures. This thermal regime was very similar to the Salmon River, which historically has not supported significant SRFC salmon spawning. When Brownlee Reservoir and Dam were constructed and blocked migration, it also created a thermal shift with warmer fall temperatures. The reservoir also moderated winter temperatures to be warmer than what historically occurred below Brownlee Dam. This new thermal regime created conditions for emergence timing comparable to below Swan Falls Dam and continues today to support the Age 0 life history.

To illustrate this effect, the mean of the daily average water temperatures was plotted from several locations in the Snake River (Figure 6.1-9). These data sets include the Snake River at Bliss Dam (RM 560) and Swan Falls Dam (RM 458) and the Snake River before it enters into Brownlee Reservoir (RM 345) for the time period 1996 to 2006 (IPC, unpubl. data.). The Bliss Dam is located downstream of the majority of spring flow. A fourth data set includes the Snake River at RM 273 (pre-Oxbow Dam site) and includes mean daily average temperatures from 1954 to 1957, prior to the effect of the HCC (FWS 1957, 1958). For comparative purposes, a fifth data set includes the mean daily average temperature of the Salmon River measured at RM 1 for the time period 1996 to 2006. These data sets demonstrate that the thermal regime in the pre-HCC time period was colder during winter months than the upstream locations, had comparable maximum (though slightly cooler) summer temperatures at the inflow and Swan Falls locations, and summer was substantially warmer than the Bliss Dam location (Figure 6.1-

10). With the exception of the spring months during spring run-off, the thermal regime of the pre-HCC time period was very similar to that of the Salmon River today (Figure 6.1-10) that enters the Snake River at RM 188. Construction of Brownlee Dam (1958) modified the thermal regime in the Hells Canyon reach of the Snake River, causing 1) delayed fall cooling, 2) increased winter base temperatures, 3) delayed spring warming, and 4) cooler summer temperatures relative to inflow conditions. This modification of the thermal regime is represented by using the mean daily average temperature of the Snake River measured below HCD for the time period 1996 to 2006 (Figure 6.1-10).

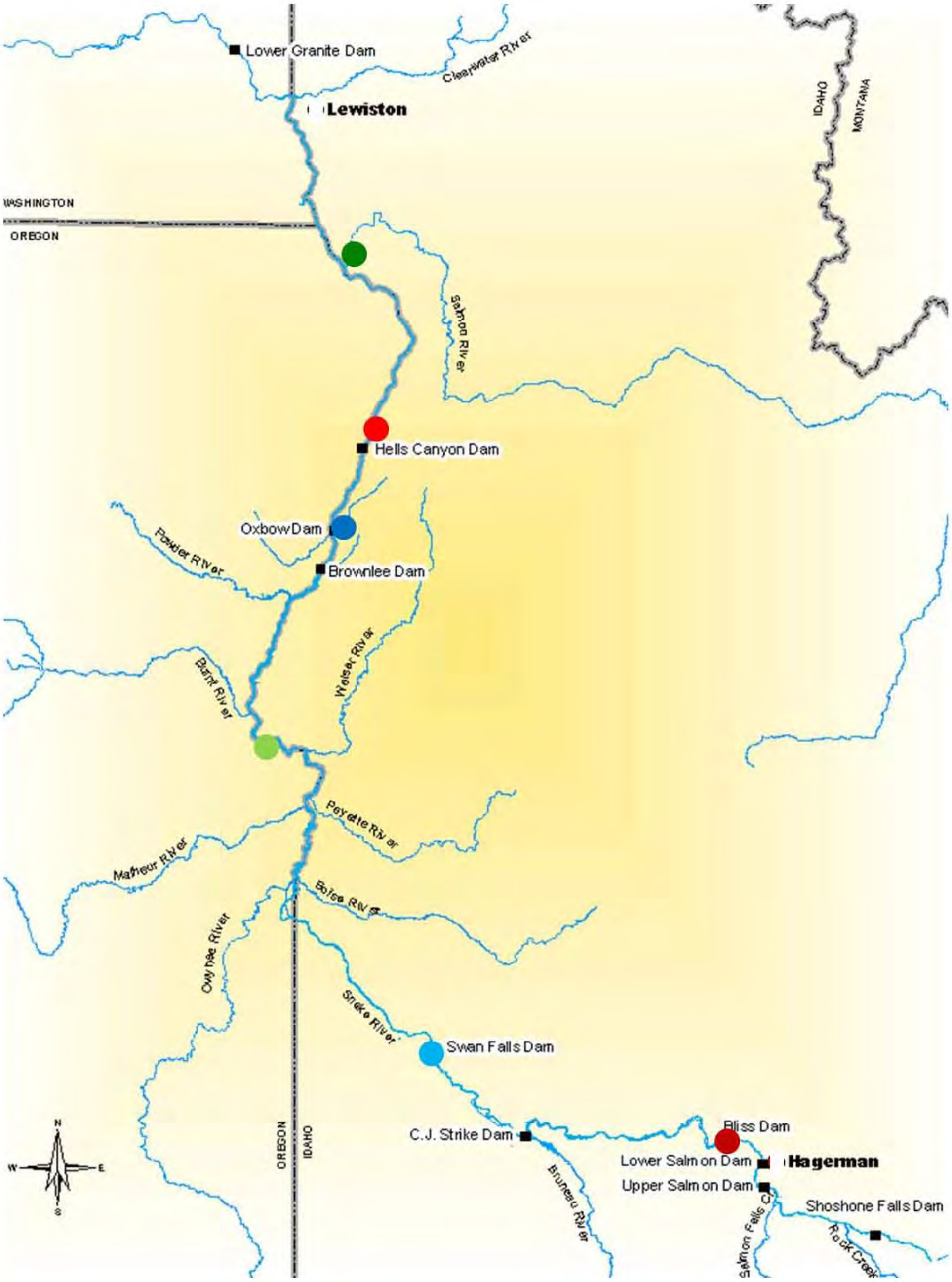

Figure 6.1-9
Locations along the Snake River where temperature data sets used for comparisons of thermal regimes were collected. They include Bliss Dam (dark red circle; RM 560), Swan Falls Dam (light-blue circle; RM 458), the inflow into Brownlee Reservoir (light-green circle; RM 345), near present-day Oxbow Dam (dark-blue circle; RM 273), and below HCD (light-red circle; RM 247). Another data set used for comparison was collected in the Salmon River at RM 1.

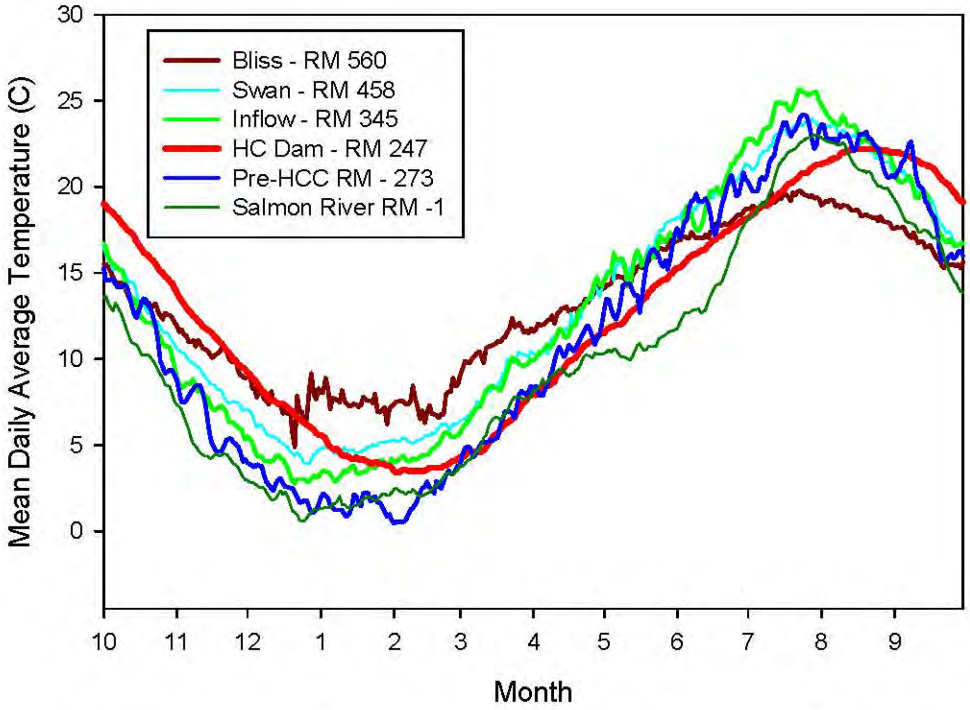

Figure 6.1-10
Mean daily average water temperature in °C that represents thermal patterns of the Snake River for the time period 1996–2006 at Bliss Dam (RM 560), Swan Falls Dam (RM 458), a location above the inflow to Brownlee Reservoir (RM 345), HCD (RM 247), and the Salmon River (RM 1) and for the time period 1954–1957 for the pre-HCC location at RM 273.

6.1.3.2 SRFC Salmon Spawning, Incubation, and Emergence Periods

Because SRFC salmon spawn during a declining fall thermal regime in all environments, earlier spawners initiate spawning in temperatures warmer than later spawners. In the Snake River, under the current thermal regime, spawning can initiate in water temperatures exceeding 16°C. Similar observations of spawning occur in other fall Chinook salmon populations, including the Hanford reach of the Columbia River. Thermal characteristics are different in all of the major spawning areas, such as the upper and lower Snake River (above or below the Salmon River), various sections of the Clearwater (above or below the North Fork), and the Grande Ronde and Imnaha rivers. Geist et al. (2006) compared incubation success of SRFC salmon under different initial spawning temperatures and a declining thermal regime to a winter base temperature comparable to what is observed in the Snake River. Geist et al. (2006) did not find significant differences in survival among initial incubation environments at temperatures between 16.5°C and 13°C.

The spawning period for SRFC salmon observed today and historically in reaches upstream of the HCC do not differ greatly, despite the different thermal regimes. Surveys were not conducted at the same level of detail as those in Hells Canyon over the last 20 years, so definitive historic start and end dates for comparison are difficult to determine. Today, some of the earliest spawning observed in the Snake River is during the second week of October. The peak spawning period (the median distribution of redd observations for the years 1993–2009) is November 4. The latest spawning observations are generally near the second week in December.

Evermann (1896) reported observations of ripe and spent fall Chinook salmon in a fishery at Millet Island in 1894. The fishery began on October 1 and extended through October 31. Their first observed spent female in the fishery was on October 10, which comports well with present-day observations. Ripe fish were still being captured at the close of the fishery, suggesting spawning continued after November 1. An observation reported by Evermann from an interview with a seine fisherman near Glenns Ferry (RM 539) reported observing carcasses through the first half of November. Similarly, below Swan Falls Dam, Zimmer (1950) reported 3 redds observed in the first week of October 1947, with a peak number of redds counted on the November 6 flight, and spawning was generally completed by the end of the first week in December. These observations comport very well with what is observed today in the Snake River and what is observed in other populations, such as the Hanford reach of the Columbia River. With this information, for purposes of comparing emergence timing among historic and present-day reaches of river, the application of the present-day spawning distribution to the various thermal regimes to estimate differences in emergence timing among those locations is reasonable.

Emergence timing reflects the different thermal patterns of the Snake River and demonstrates a negative linear relationship with river mile (Figure 6.1-11). The linear relationship further suggests cooling of the Snake River progressed at a predictable rate with distance from the large inflow of the ESPA. Emergence timing in the primary historic spawning area as represented by the Bliss Dam temperature regime would have been early, with a median emergence date of March 1. Median emergence dates became later as spawning progressed downstream such that below Swan Falls Dam the median emergence date would be more than 1 month later on April 7. In reaches further downstream, including the inflow to Brownlee Reservoir and the pre-HCC Oxbow Dam site—sites that did not support significant spawning—the median emergence dates are estimated to have been April 25 and May 11, respectively. Today, with the influence of the HCC (principally, Brownlee Reservoir), the shift in the thermal regime has shifted the median emergence date to April 17, close to what was observed below Swan Falls Dam (Figure 6.1-11), which supported significant SRFC salmon spawning prior to the construction of the HCC.

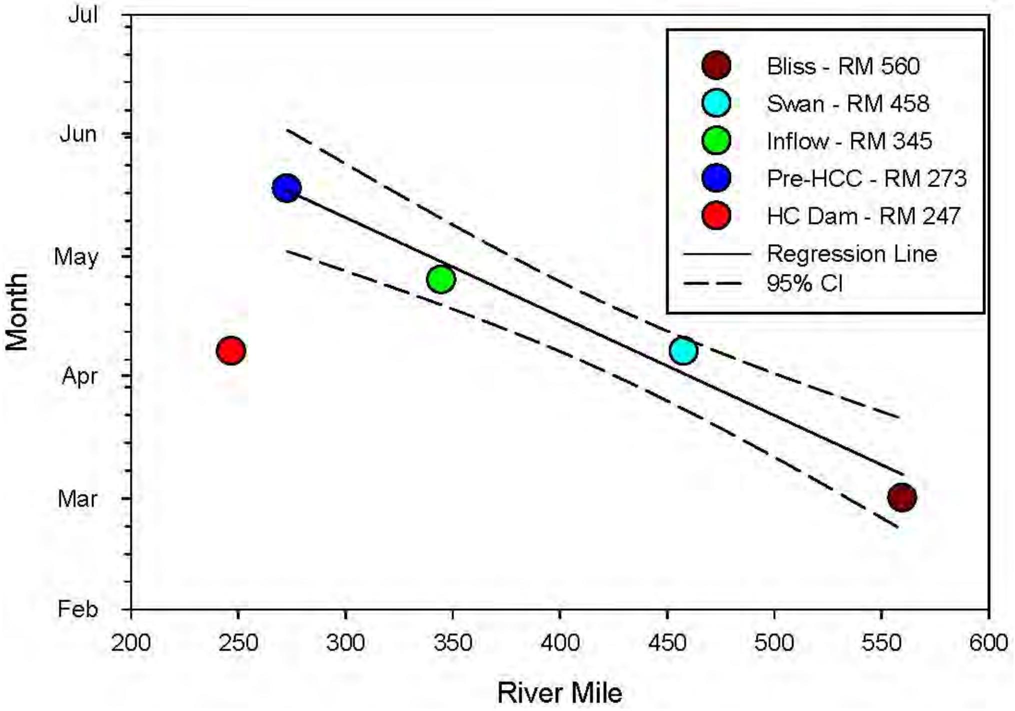

Figure 6.1-11
Estimated median emergence timing compared to different thermal regimes and time periods at locations in the Snake River. All thermal data sets used in the estimation, except the pre-HCC data, are from the time period 1996–2006. The pre-HCC time period estimation is based on thermal data from the time period 1954–1957.

The thermal shift created by Brownlee Reservoir also allows for slower warming during the spring months and moderates summer maximum temperatures. Cooler spring temperatures likely also benefit SRFC salmon juveniles by creating a habitat less thermally suitable for predators of juvenile Chinook salmon, especially smallmouth bass. Smallmouth bass are non-native predators that forage more actively as water temperatures increase. Despite the cooler temperatures in the spring, SRFC salmon juveniles continue to display exceptional growth during their brief rearing period.

6.1.3.3. Fall Chinook Juvenile Outmigration

Today, early emergence has significant implications for SRFC salmon relative to outmigration survival. The sub-yearling SRFC salmon that begin moving downstream the first week of July (after flows begin to decline and downstream reservoirs warm) survive at rates of only 5 to 20%, whereas those that initiate movement earlier (in late May) survive at rates of 65 to 90% (Connor et al. 2003; Smith et al. 2003). Based on the estimated emergence timing using the pre-HCC thermal regime, outmigration would be significantly delayed and likely not initiated until later June or July when outmigration survival would be significantly reduced.

In the pre-HCC environment (before 1958, when Brownlee Reservoir was completed), there were no lower Snake River reservoirs or dams encountered by juvenile outmigrants, and it is possible that survival was much different relative to the outmigration timing observed today. However, as indicated by the pre-HCC thermal regime and even the Salmon River, water temperatures in July were relatively warm during this period and may have influenced the survival of late outmigrants. The pre-HCC thermal regime maximum summer temperatures were warmer than those observed today that are moderated as a result of the influence of the HCC. These pre-HCC lower river reaches may not have supported significant spawning because of poor over-summer survival associated with late emergence timing as observed today (Connor et al. 2003; Smith et al. 2003) with later outmigrants. This would be consistent with the likely reason that fall Chinook salmon spawning is not supported in the Salmon River—because there is no cool over-summer rearing habitat available.

6.1.3.4. Adult Migration

Adult SRFC salmon migrate from the ocean to spawning areas during late summer and early fall months. Anthropogenic changes have increased summer temperatures in the historic upstream habitats. Brownlee Reservoir generally moderates the peak summer temperatures in the outflow to Hells Canyon to be cooler than the inflow. This thermal benefit continues through early September, when the thermal shift starts to result in warmer temperatures than the inflow. Water temperatures are generally below 20°C when this thermal shift starts to be apparent.

The start of the SRFC salmon migration period for counting purposes in the Columbia River system has been identified as August 1 for observations at Bonneville Dam and August 18 for observations at Lower Granite Dam (Data Access in Real Time [DART] Adult Passage Reporting; cbr.washington.edu/dart/adult.html). Water temperatures throughout the lower Columbia River and Snake River, as well as the lower end of major tributaries, commonly exceed 20°C during this time. Concern relative to thermal regimes on adults relates primarily to adult migration periods, the potential of pre-spawn mortality, and potential effects to gamete viability. A temperature data set from 1954 to 1957 for the Central Ferry location (approximate location of present-day Lower Granite Dam) was used for comparative purposes to reflect conditions in the Lower Snake River before the construction of the HCC or any of the lower Snake River dams (Figure 6.1-12).

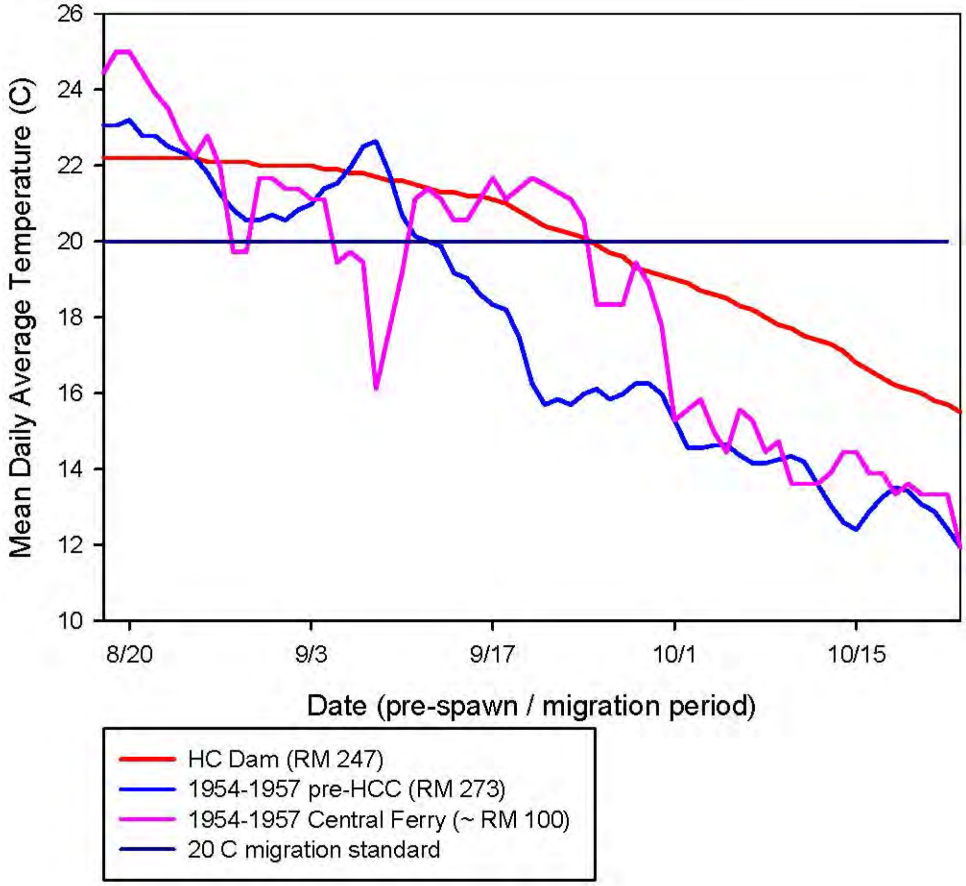

Figure 6.1-12
Mean daily average water temperatures that represent thermal patterns of the Snake River for the time period 1996–2006 at HCD (RM 247) and for the time period 1954–1957 for the pre-HCC location at RM 273 and RM 100 during August through mid-October.

In a pre-HCC thermal regime and in the lower Snake River (Central Ferry [approx. RM 100]), adult SRFC salmon would have experienced a similar period of exposure to temperatures elevated above 20°C between mid-August and mid-September as they do under the thermal regime present today below the HCC. However, early-arriving adults would experience a lower maximum temperature today than during the pre-HCC condition. Temperatures in all the thermal regimes examined, including present-day thermal regimes, would have dropped below the 20°C migration corridor standard by mid- to late-September.

There is no information as to how a pre-HCC thermal regime, Central Ferry thermal regime, or even the lower Columbia River thermal regime would have related to pre-spawn mortality or gamete viability. However, under the present-day HCC thermal regime, no evidence exists that pre-spawn mortality is different from that which occurs in other reaches (e.g., the Hanford reach). This is based on fish-to-redd ratios observed over the last 2 decades (Groves et al. 2007). Also, the operations of Dworshak Reservoir on the Clearwater River release cold water in the summer that substantially cools portions of Lower Granite Reservoir, creating thermal refugia in Lower Granite Reservoir and in the lower Clearwater River during the early pre-spawn environment. Therefore, thermal conditions prevalent in the Snake River today are cooler for pre-spawning adults than conditions prior to the construction of the HCC. In addition, the presence of natural thermal refugia throughout the adult migration may play a significant role in the migration and pre-spawn environments. Once fish migrate up the Snake River past the influence of the cold-water releases from Dworshak Reservoir, they enter a free-flowing environment. Unlike much of the impounded sections in the lower Columbia and Snake rivers, this free-flowing reach maintains much of the natural river processes that create thermal refugia. As discussed previously, this environment has a high connectivity to hyporheic habitats throughout its length to Hells Canyon. Locations of upwelling waters from the hyporheic environment likely provide thermal refuge, especially in areas associated with large gravel deposits and the many fluvial fans associated with the many perennial streams that enter the Snake River. These influences are difficult to measure or quantify but are likely significant in providing thermal refuge. In addition, there are several significant cold-water inflows to Hells Canyon, especially in the upper portion of this reach where high-elevation drainages from the Seven Devils Mountains enter the Snake River.

6.2. DO

Physical, chemical, and biological processes control the oxygen content of water. The solubility of DO decreases as water temperature increases, so changes in seasonal water temperatures substantially change the saturation level for DO. Reaeration, another physical process, tends to add DO to the water column when DO levels are low and release DO to the atmosphere when levels are above saturation. DO concentrations can also be affected by several biological processes related to elevated nutrient, organic matter, or algal levels. Nutrients promote algal growth that, in turn, generates oxygen during photosynthesis and consumes oxygen during respiration. Aerobic decomposition of dead algae, organic sediments, and other organic matter further depletes oxygen. Municipal, industrial, and agricultural wastes can also create a biochemical oxygen demand (BOD) as these wastes oxidize.

In the SR–HC TMDL, the IDEQ and ODEQ reported excessive TP concentrations in the Snake River upstream of the HCC (RM 409 to RM 335) and routinely observed nuisance algal growths in this reach and the upper end (riverine zone) of Brownlee Reservoir (IDEQ and ODEQ 2004). These findings corroborated those reported by Webb (1964) and Worth (1994). The IDEQ and ODEQ concluded from the data analysis that most phosphorus promoting the nuisance growths originated from sources upstream of the HCC (IDEQ and ODEQ 2004). Myers et al. (1998) and Hoelscher and Myers (2003) reported similar findings. The SR–HC TMDL linked nutrients and chlorophyll a with low DO levels downstream and set targets for both TP and algae for the attainment of DO criteria and the protection of beneficial uses (IDEQ and ODEQ 2004). They predicted that upstream reductions in TP loading, based on SR–HC TMDL allocations, would improve water quality in the Snake River and DO levels in Brownlee Reservoir. Specifically, low DO levels within the HCC are attributable to in-reservoir processing of inflow organic matter. The organic matter is a source of energy for the heterotrophic bacteria. Oxygen is consumed from the water when the heterotrophic bacteria decay the organic matter (Maier et al. 2000). An analysis has shown that upstream water-quality conditions influence water quality within and below the HCC, including oxygen demand and DO concentrations (Harrison et al. 1999; Myers et al. 2003). Substantial improvements to DO conditions in Brownlee Reservoir and downstream are anticipated following the attainment of the upstream TP and algae targets. To address the remaining DO deficit relative to the aquatic life criterion in the HCC, a DO load allocation of 1,125 tons of DO per year was established in the SR–HC TMDL for Brownlee Reservoir (IDEQ and ODEQ 2004). The SR-HC TMDL set the appropriate DO load allocation for IPC relative to degraded conditions in Brownlee Reservoir. Further, it identified the HCC 401 certification process as the mechanism for IPC to implement the load allocation.

The SR–HC TMDL did not evaluate nor establish any load allocations for DO below HCD. Beneficial uses below HCD include aquatic life and spawning (tables 5.1-1 and 5.1-2). Because downstream salmonid spawning uses have more stringent targets than those for which the upstream SR–HC TMDL targets were developed, the upstream allocations may not be adequate for downstream beneficial-use support. However, in the absence of a TMDL and resulting allocations, IPC has no defined DO load allocation to implement to ensure the continued operation of the HCC would not cause or contribute to an exceedance of downstream DO standards. In the sections that follow, IPC assessed the DO deficit downstream of Brownlee Reservoir under current conditions to quantify the effects of Oxbow and Hells Canyon reservoirs on current DO conditions within and downstream of the reservoirs. The analysis is conservative in that it assumes no improvements in upstream DO conditions that are expected to occur in the future with the upstream SR–HC TMDL implementation.

In addition to the analysis of current data, IPC has conducted modeling to estimate the DO conditions downstream of Brownlee Dam under full implementation of the SR-HC TMDL. While the analysis of measured data defines the effects of Oxbow and Hells Canyon reservoirs on current DO conditions, the modeling analysis illustrates that downstream DO standards should be met with implementation of the SR-HC TMDL. Some components of the SR-HC TMDL may have a protracted implementation schedule; however, IPC is proposing to mitigate the effects of the HCC upon issuance of the FERC license.

6.2.1. DO Standards

The application of DO standards applies to specified river reaches and times depending on the species present and life cycle needs. Oregon and Idaho both have standards specific to aquatic life and salmonid rearing and spawning (IDAPA 58.01.02.; OAR 340 041). Salmonid spawning standards further differentiate between water column and intergravel environments. The intergravel environments are essential, as eggs are deposited within gravels for development.

6.2.1.1 Brownlee, Oxbow, and Hells Canyon Reservoirs

The IDEQ and ODEQ determined that 6.5 mg/L for water column dissolved oxygen was the appropriate and most stringent standard for the HCC reservoirs (IDEQ and ODEQ 2004). This was based on the resident fish community dominance of smallmouth bass, black crappie, and white crappie. The SR–HC TMDL target for the HCC is Oregon’s criterion of no less than 6.5 mg/L is applicable to waters dominated by cool-water species such as smallmouth bass, and crappie (OAR 340 041 0016(3)). When the ODEQ determines, at its discretion, that adequate data exist, the DO may be no less than 6.5 mg/L as a 30-day average minimum, 5 mg/L as a 7-day minimum mean, and 4 mg/L as a daily minimum (Table 6.2-1). Idaho’s current DO criterion is no less than 6.0 mg/L, with allowances for specific strata in lakes and reservoirs to exhibit levels less than 6.0 mg/L (IDAPA 58.01.02.).

Table 6.2-1
State of Oregon DO criteria in mg/L for the protection of cool-water aquatic life (OAR 340 041. n.d.)

Criteria	Aquatic Life (Cool-water)
Absolute minimum criteria[1]	6.5
Multiple criteria[2]	
Daily minimum	4.0
7-day minimum mean	5.0
30-day mean minimum	6.5

1 Applicable criterion when data are limited
2 Applicable criterion when adequate data exist at ODEQ discretion

6.2.1.2. Snake River Downstream of HCD

Salmonid spawning and migration corridor are designated uses of the Snake River downstream of the HCC. Salmonid spawning criteria apply to that portion of the Snake River below HCD (RM 247 to 188) from October 23 through April 15 for SRFC and November 1 through March 30 for mountain whitefish. Because the Snake River downstream of HCD is designated as a migration corridor, during periods outside of the salmonid spawning time period, the 6.5 mg/L dissolved oxygen Oregon standard applies and is a more stringent criterion than Idaho’s 6.0 mg/L general criterion.

Oregon and Idaho have salmonid-spawning standards for water column and intergravel environments. Oregon’s water-column DO criteria are no less than 11 mg/L; however, if the minimum intergravel DO, measured as a spatial median, is 8 mg/L or greater, the water-column DO criterion can be a minimum of 9 mg/L (OAR 340-041-0016(1)(a)). Where conditions of barometric pressure, altitude, and temperature preclude the attainment of the 11-mg/L or 9-mg/L criteria, the DO may be no less than 95% of saturation (OAR 340-041-0016(1)(b)). The spatial median intergravel DO criterion is no less than 8 mg/L (OAR 340-041-0016(1)(c)). Idaho’s general water-column criterion is no less than 6 mg/L or 90% of saturation (IDAPA 58.01.02.250.f.i.2.a.). The intergravel criteria are no less than 5 mg/L as an absolute minimum and no less than 6 mg/L as a 7-day average mean (IDAPA 58.01.02.250.f.i.1.). The Oregon standards are more stringent and are used in the following analysis.

Intergravel DO concentrations are important to support salmonid spawning. While water-column DO is often relied on as an indicator of suitable salmonid-spawning habitat, concentrations of intergravel DO directly affect egg survival in salmonid redds (Alderice et al. 1958; Cobel 1961; Maret et al. 1993). The Oregon salmonid-spawning standards for water-column levels are designed to attain intergravel levels of 8 mg/L. Therefore, the water-column criterion of 11 mg/L assumes a differential (i.e., water-column DO minus intergravel DO) of 3 mg/L. There is a sufficient amount of water-column and intergravel DO data for the Snake River below the HCC to determine a water-column DO level that would result in meeting the intergravel criterion of 8 mg/L based on measured differentials. This type of evaluation is consistent with the approach used for the Oregon standard that allows water-column levels of 9 mg/L, provided intergravel levels are no less than 8 mg/L.

Water-column and intergravel DO measurements have been collected by IPC biologists as part of a study to evaluate the incubation survival of SRFC above and below the HCC (Hanrahan et al. 2007; Groves and Chandler 2005; Hanrahan et al. 2005; P. Groves, IPC, unpubl. data). As part of this study, DO measurements in the water column, artificial redds, and ambient hyporheic zone were collected approximately every 2 weeks throughout the 2003/2004 and 2004/2005 spawning periods. In 2003/2004, 8 sites were sampled below HCD (5 above the confluence of the Salmon River and 3 below). In 2004/2005, 6 sites were sampled (4 above the confluence of the Salmon River and 2 below). Sample sites were located at observed spawning areas below HCD (Figure 6.2-1). At each site, a cluster of 3 artificial redds was constructed. Artificial redd locations at each site were chosen at random. The locations exhibited the habitat use criteria described for SRFC within the Snake River (Groves and Chandler 1999). Artificial redds were constructed in shallow water (approximately 0.6-meters [m] deep), where water velocities averaged 0.7 meters per second (m/s), to facilitate construction and ensure personnel safety.

Artificial redds were constructed using a shovel to lift and toss substrate downstream. This activity mimics the action of a salmon digging (Chapman 1988) and helps winnow fines from the gravels (based on methods described by Burton et al. 1990; McHenry et al. 1994; and Clayton et al. 1996). A characteristic depression (approximately 1 meter [m] in diameter) and “tailspill” is constructed using this technique. An intergravel sampling tube or an intergravel sampling tube and egg basket were placed within each artificial redd. The egg basket was buried approximately 20 centimeters (cm) deep (measured from the top surface of the basket to the surface of the substrate). Therefore, the eggs were approximately 20 to 35 cm below the gravel’s surface within a hyporheic stratum. This depth is similar to that of a SRFC egg pocket 18 to 43 cm below the substrate surface (Chapman et al. 1986; Chapman 1988).

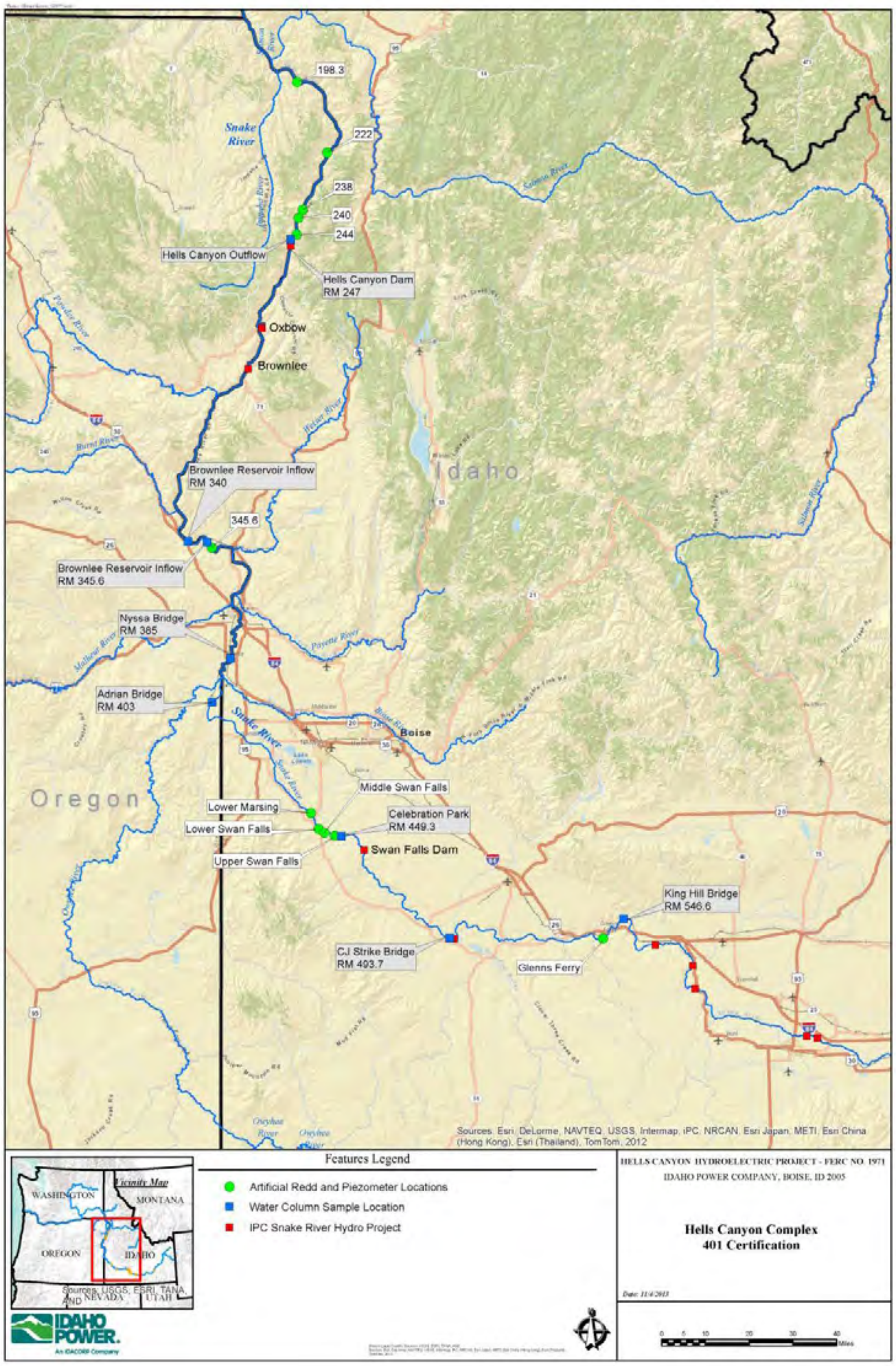

Figure 6.2-1
Map showing locations of artificial redds and water-column sampling sites on the Snake River from the Salmon River confluence upstream to King Hill

Periodic intergravel water samples representative of conditions surrounding the developing embryos were collected through an intergravel sampling tube. Intergravel DO was measured using a peristaltic pump and a flow cell on a Hydrolab® Minisonde Multiprobe maintained and calibrated per the manufacturer’s specifications. IPC evaluated DO concentrations and egg survival in 3 types of artificial redds over 2 spawning periods. The following were the 3 types of artificial redds:

1. **Empty redds** are artificial redds that contained only an intergravel sampling tube. Empty redds were constructed during the last 2 weeks of October (early spawning period).

2. **Green-egg redds** are artificial redds and egg baskets that contained “green” eggs. Green egg redds were constructed during the first week of November (peak spawning period).

3. **Eyed-egg redds** are artificial redds and egg baskets that contained “eyed” eggs. Eyed egg redds were constructed during the first week of December (end of the spawning period).

Intergravel DO concentrations measured in artificial redds below the HCC were generally very similar to water-column measurements made at the same time (figures 6.2-2, 6.2-3, and 6.2-4). With respect to permeability and transport capability, the substrate quality within the Hells Canyon reach of the Snake River was relatively high when compared to other regional samples and literature values (Arntzen et al. 2001). Therefore, when intergravel DO was low below the HCC, it was a result of low water-column DO levels. This illustrates the correlation between the intergravel and water-column DO below the HCC related to high permeability and other water-quality characteristics. A relatively small difference is consistently seen between water-column and intergravel DO; as water-column DO increases below the HCC, intergravel DO also increases. As discussed in following sections, this correlation does not always exist. In some locations, such as upstream of Brownlee Reservoir, plugging of the artificial redd interstices and biological processes in the gravels over the life of a redd strongly controls intergravel DO levels (Groves and Chandler 2005). In these situations, water-column DO can be high and increasing while intergravel DO in an artificial redd can be low and decreasing.

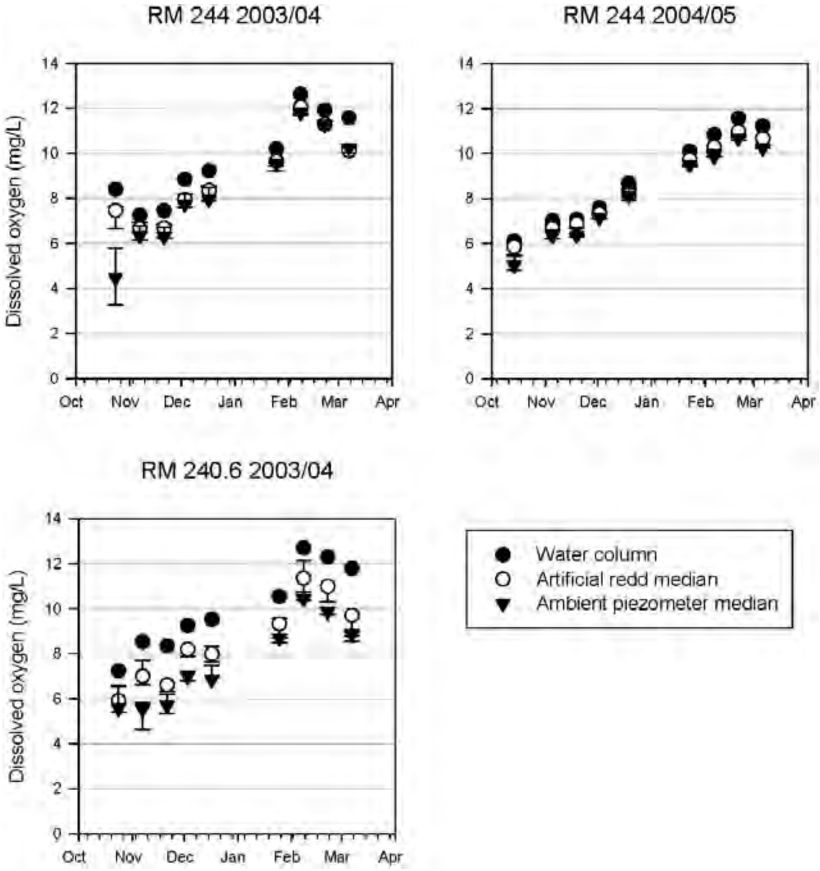

Figure 6.2-2
Intergravel DO in mg/L at sites downstream of HCD with no eggs in the 2003/2004 and 2004/2005 periods. Symbols show the median of 3 artificial redds or ambient piezometers, while error bars show the minimum and maximum values.

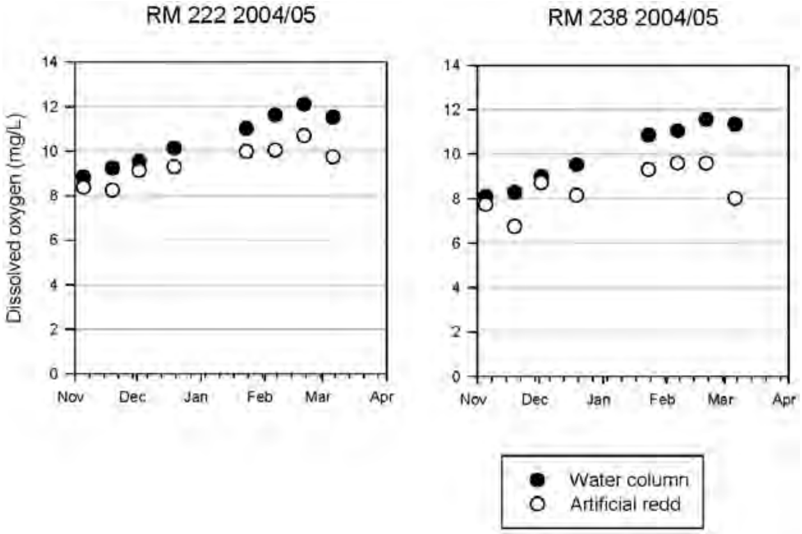

Figure 6.2-3
Intergravel DO in mg/L concentrations at sites downstream of HCD with green eggs in the 2004/2005 period

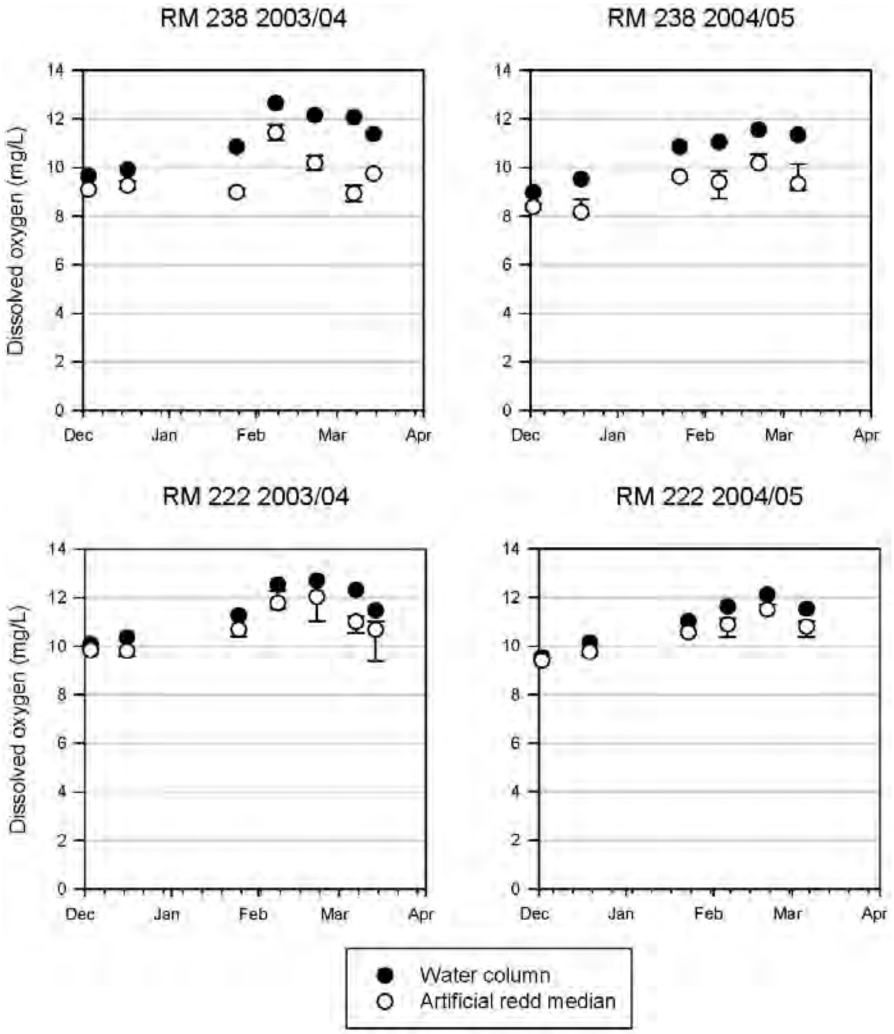

Figure 6.2-4
Intergravel DO in mg/L at sites downstream of HCD with eyed eggs in the 2003/2004 and 2004/2005 periods. Symbols show the median of 3 artificial redds, while error bars show the minimum and maximum values.

Intergravel and water-column DO measurements collected below the HCC were used to calculate a water-column DO level that would support the 8 mg/L Oregon intergravel criteria. A DO differential was calculated for each sample event by subtracting the intergravel DO (from each artificial redd) from the water-column DO (measured at the same time at each site).

The summarized differentials from the artificial redds above the Salmon River confluence were generally less than 3 mg/L, with 90% of all the differentials less than 2 mg/L 8 weeks following redd construction (Table 6.2-2). Not all artificial redds were constructed on the same date; therefore, differentials are summarized by sample timing following construction (i.e., the first date is immediately after construction, and the second date is 2 weeks later). Sampling occurred approximately every 2 weeks. The differentials generally increased over time due to processes affecting intergravel DO levels after redd construction, such as the plugging of gravels by organic and inorganic materials.

Table 6.2-2
Summarized DO differentials in mg/L between intergravel DO measured in artificially constructed redds and DO in the water column for sites on the Snake River below HCD and above the Salmon River confluence. The time period between subsequent dates is approximately 2 weeks.

Upper Hells Canyon	First Date	Second Date	Third Date	Fourth Date	Fifth Date	Sixth Date	Seventh Date	Eighth Date	Ninth Date
Minimum	0.0	0.1	0.2	0.2	0.3	0.3	0.5	0.5	0.5
10th percentile	0.2	0.2	0.2	0.3	0.5	0.5	0.5	0.6	0.5
25th percentile	0.4	0.4	0.5	0.7	0.7	0.8	0.6	0.7	0.9
Median	0.5	0.7	0.8	0.9	1.0	1.3	1.2	1.3	1.5
75th percentile	0.6	0.8	1.3	1.3	1.5	1.8	1.6	1.8	2.1
90th percentile	1.3	1.5	1.7	1.6	1.7	2.3	2.0	2.1	2.3
Maximum	1.8	2.0	2.0	2.9	2.3	3.5	2.1	3.3	3.0
N	30.0	30.0	30.0	30.0	30.0	30.0	21.0	15.0	9.0

Note: Summary includes 2003/2004 and 2004/2005 datasets for below the HCC and above the confluence with the Salmon River.

Oregon's standards reference a spatial-median intergravel DO level. To compare the differentials summarized in Table 6.2-2 to the Oregon standard, the median differential of each site (i.e., a cluster of 3 artificial redds) was calculated. This median value, when added to the intergravel DO criterion of 8 mg/L, represents a water-column DO target that would result in meeting the spatial-median intergravel criterion at that site. The maximum median differentials were below 2 mg/L and changed through the period (Table 6.2-3). The 90th percentile of these median differentials was selected as a level appropriate to apply in determining a water-column criterion. The first 5 sample dates were used, and the value on the fifth date carried through the remainder of the salmonid spawning period. The first 5 sample dates represent 10 weeks into the spawning period (October 23–January 1), after which measured data below the HCC show criteria are met (see Section 6.2.2.1.5. Outflow DO). The resulting water-column criteria ranged from 9.1 mg/L on October 23 to 9.6 mg/L through the end of the period (Table 6.2-4). These water-column criteria were applied to the Snake River below HCD from October 23 through April 15 in all following analyses relative to the HCC outflow DO.

Table 6.2-3
Summarized site median DO differentials in mg/L between intergravel DO measured in artificially constructed redds and DO in the water column for sites on the Snake River below HCD and above the Salmon River confluence. The time between subsequent dates is approximately 2 weeks.

Upper Hells Canyon	First Date	Second Date	Third Date	Fourth Date	Fifth Date
Minimum	0.2	0.2	0.2	0.3	0.5
10th percentile	0.2	0.3	0.2	0.6	0.6
25th percentile	0.3	0.4	0.4	0.8	0.7
Median	0.5	0.6	0.9	0.9	0.9
75th percentile	0.6	0.8	1.2	1.1	1.5

Upper Hells Canyon	First Date	Second Date	Third Date	Fourth Date	Fifth Date
90th percentile	1.1	1.5	1.7	1.5	1.6
Maximum	1.7	1.5	1.7	1.5	1.7
N	9.0	9.0	9.0	9.0	9.0

Note: Summary includes 2003/2004 and 2004/2005 datasets for below HCD and above the confluence with the Salmon River.

Table 6.2-4
Water-column DO criteria in mg/L calculated from the 90th percentile of the summarized site median DO differentials. Dates are 2-week increments during the salmonid spawning period when criteria apply.

	First Date (10/23)	Second Date (11/7)	Third Date (11/22)	Fourth Date (12/7)	Fifth Date (12/21–4/15)
Water-column DO criteria (mg/L)	9.1	9.5	9.7	9.5	9.6

6.2.2. Conditions Relative to DO

The following discussion assesses DO conditions relative to either the 6.5 mg/L criterion, or the water column criteria necessary to maintain 8.0 mg/L intergravel conditions during salmonid spawning (Table 6.2-4). A description of upstream conditions is included because of the relevance of upstream (inflowing) water quality to conditions within the HCC.

6.2.2.1. Current Conditions

6.2.2.1.1. Water-Column Conditions Upstream of the HCC

The SR-HC TMDL identified the segment of the Snake River including the inflows into Brownlee Reservoir as water quality limited (see Section 5.1). While IPC data for nutrients and algae conditions in the upstream river indicate conditions may have improved since approval and implementation of the SR-HC TMDL, fully assessing the current conditions relative to those described in the SR-HC TMDL is beyond the scope of this 401 application.

Elevated primary productivity in the Snake River reach upstream of Brownlee Reservoir was the primary focus of the SR–HC TMDL, and a reduction in primary productivity was sought through the development of the TP target (IDEQ and ODEQ 2004). Elevated primary productivity has noticeable impacts to DO conditions flowing into Brownlee Reservoir, DO conditions in Brownlee Reservoir and the HCC due to the settling and decay of large loads of algae and suspended organic material, and intergravel DO conditions upstream of the HCC. IPC studied water quality and intergravel conditions in the Snake River upstream of the HCC relative to the support of salmonid spawning. Water-column data collected from March 2002 through April 2003 at 7 sites along the Snake River from King Hill (RM 546), Idaho, to below HCD (Harrison 2005) provides a broad perspective of water-quality parameters related to particulate material and longitudinal changes through the Snake River (Table 6.2-5, Figure 6.2-5).

Table 6.2-5
Selected parameters collected in 2002 and 2003 as part of a Snake River organic matter study

Parameter	Units	Sample Size	Description
Chlorophyll a	µg/L	22–24	Indicator of algal biomass.
Total organic carbon (TOC)	mg/L	22–24	Total carbon concentration per liter of sample.
Dissolved organic carbon (DOC)	mg/L	22–24	Total carbon concentration per liter of filtered (0.45 micrometers [µm]) sample.
Particulate organic carbon (POC)			
(POC = TOC – DOC)	mg/L	22–24	TOC minus DOC. The amount of carbon per liter that is retained on the 0.45-µm filter.
TSS	mg/L	22–24	Dry weight of material retained on a filter.
Volatile suspended solids (VSS)	mg/L	22–24	Weight of TSS material that will combust at 550°C.
5-day and 30-day BOD (BOD5, BOD30)	mg/L	13–16	Oxygen consumed per liter in 5 or 30 days.
5-day and 30-day dissolved BOD (dissolved biochemical oxygen demand [DBOD]5, DBOD30)	mg/L	13–16	Oxygen consumed per liter of filtered sample in 5 or 30 days.
5-day and 30-day particulate BOD (particulate biochemical oxygen demand [PBOD]5, PBOD30)			
(equals BOD – DBOD)	mg/L	13–16	BOD minus dissolved BOD. The amount of oxygen consumed in 5 or 30 days that is attributable to the material retained on the 0.45-µm filter.
Chemical oxygen demand (COD)	mg/L	22–24	Oxygen consumed per liter following the complete oxidation of the sample with a strong oxidizing agent.
Bacteria (heterotropic plate counts)	#/100 ml	13–16	Number of colony-forming units (CFU) per 100 ml of sample.
Bacteria secondary production (BSP)	µg carbon/L/hour (hr)	13–16	Rate of carbon incorporation due to bacterial secondary production.
TP	mg/L	22–24	TP per liter sample.
Orthophosphate (OP)	mg/L	22–24	Dissolved OP per liter sample.
Particulate phosphorus (PP)	mg/L	22–24	TP – OP; the amount of phosphorus retained on the filter

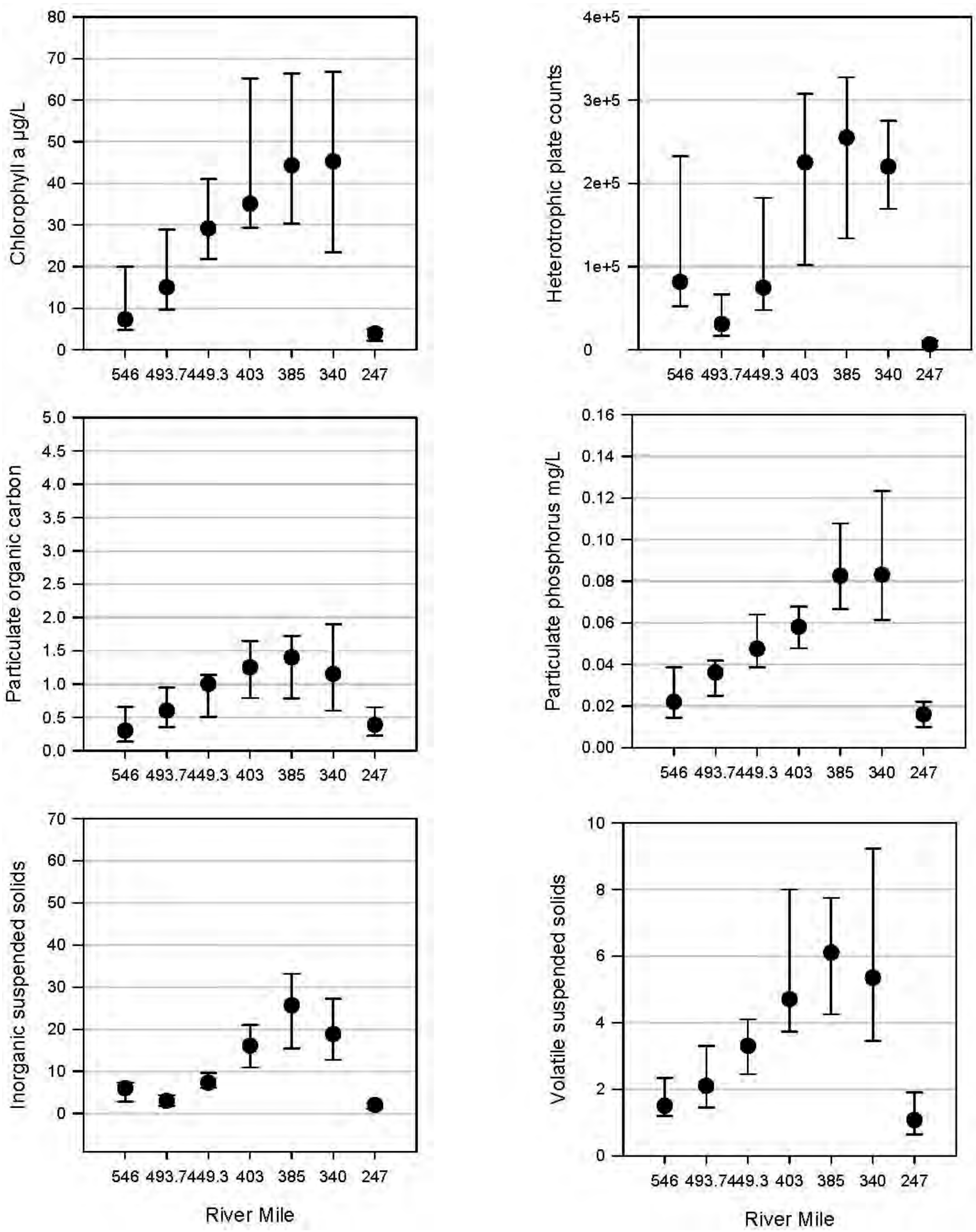

Figure 6.2-5
Water-column concentrations of particulate material at 7 sites in the Snake River. Dots showing medians and error bars are the 75th and 25th percentiles of data collected from March 2002 through April 2003.

Algal levels change considerably from King Hill to below the HCC. Figure 6.2-5 shows algal levels, as indicated by chlorophyll a, were approximately 10 µg/L near King Hill (RM 546) and increased to approximately 45 µg/L at Brownlee Reservoir inflow (RM 340).

These increases were followed by substantial decreases to less than 10 µg/L in the HCC outflow

(RM 247). Levels of particulate organic material (including algae) and inorganic sediment also increased from King Hill to the Brownlee Reservoir inflow. Similar trends were also reported in the Snake River by the IDEQ (Worth 1994). Substantial decreases again occurred through the HCC (Figure 6.2-5). These changes through the HCC are indicative of the settling of particulate material in Brownlee Reservoir. The organic material that settles in Brownlee Reservoir decays, and this process consumes oxygen, contributing to the current low DO levels in Brownlee Reservoir (see Section 6.2.2.1.4. Reservoir DO).

These water-column data showed relatively low levels of particulate organic matter and inorganic sediment released from the HCC compared to levels upstream. As discussed below, these differences are directly related to DO conditions in Brownlee Reservoir and differences in intergravel conditions upstream and downstream of the HCC.

6.2.2.1.2. Intergravel Conditions Upstream of the HCC

Intergravel DO conditions upstream of the HCC were in sharp contrast to conditions measured downstream of the HCC. Water-column DO concentrations and intergravel DO concentrations measured in artificial redds below the HCC (see Section 6.2.1.2. Snake River Downstream of HCD) were both below criteria at the initiation of the SRFC spawning period and increased as the period progressed and the embryos developed (figures 6.2-2, 6.2-3, and 6.2-4). Counter to this, at sites sampled by IPC in 2003/2004 and 2004/2005 above the HCC (Figure 6.2-1), intergravel DO concentrations measured in artificial redds were generally below criteria, even though water-column DO levels often met criteria (figures 6.2-6, 6.2-7, and 6.2-8). Similar data collected during the 1999/2000 and 2000/2001 periods by Groves and Chandler (2005) at these same sites (and others) showed that intergravel DO in artificial redds dropped below 8 mg/L at sites above the HCC (near 2 mg/L at some sites). DO levels in the undisturbed ambient gravels (i.e., adjacent gravels not disturbed by the construction of artificial redds) above the HCC were generally less than 2 mg/L through the whole period (Figure 6.2-6).

Unlike locations below the HCC, most locations above the HCC had higher intergravel DO in the beginning, shortly after artificial redd construction, and concentrations declined thereafter. Median intergravel DO levels dropped below 8 mg/L in artificial redds constructed near the Brownlee Reservoir inflow (RM 345) and near the city of Glenns Ferry, Idaho (Figure 6.2-6). Median intergravel DO levels also declined following artificial redd construction in the Swan Falls reach[27]; however, initial concentrations were less than 8 mg/L (figures 6.2-7 and 6.2-8).

Differences in ambient gravel characteristics do not explain the differences in intergravel DO. Using freeze core and hydraulic slug test techniques, Hanrahan et al. (2005) examined ambient gravel characteristics at 2 historic spawning locations in the Swan Falls reach and showed that hydraulic conductivity in gravel at the Swan Falls sites was comparable to rates measured in spawning gravel in the Hells Canyon reach of the Snake River and the Hanford reach of the Columbia River. Using a temperature-modeling approach showed that velocities in the artificial redds in the Hells Canyon reach reduced from initial levels immediately after construction but remained relatively high through the spawning period (Hanrahan et al. 2007). Similar analysis

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[27] The sites in this reach are the same sites sampled in 1999/2000 and 2000/2001 and reported in Groves and Chandler (2005).

above the HCC showed the construction of an artificial redd dramatically increased intergravel velocities from velocities in ambient gravels. However, following artificial redd construction, intergravel velocities rapidly decreased.

In addition to intergravel DO measurements from the artificial redds, fertilized fall Chinook eggs were incubated in egg baskets in some of the artificial redds constructed in the Swan Falls reach. The baskets were retrieved just prior to calculated emergence based on degree days and survival (among other variables) recorded. Overall survival in the Swan Falls reach was very poor in both periods (Table 6.2-6). The middle site in the Swan Falls reach showed the highest survival, although no survival was seen for green eggs at this site (Table 6.2-6).

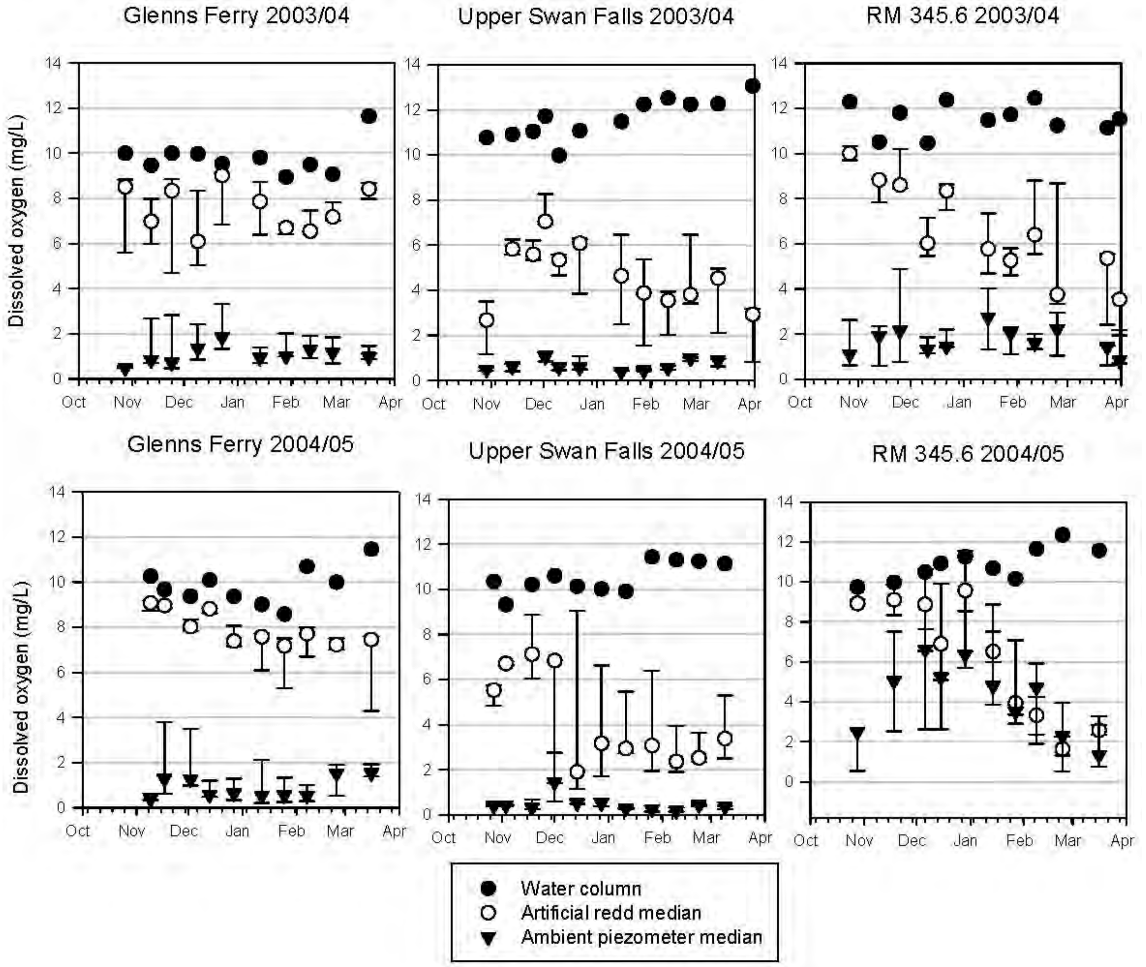


Figure 6.2-6
Intergravel DO in mg/L at sites upstream of Brownlee Reservoir with no eggs in the 2003/2004 and 2004/2005 periods. Symbols show the median of 3 artificial redds or ambient piezometers, while error bars show the minimum and maximum values.

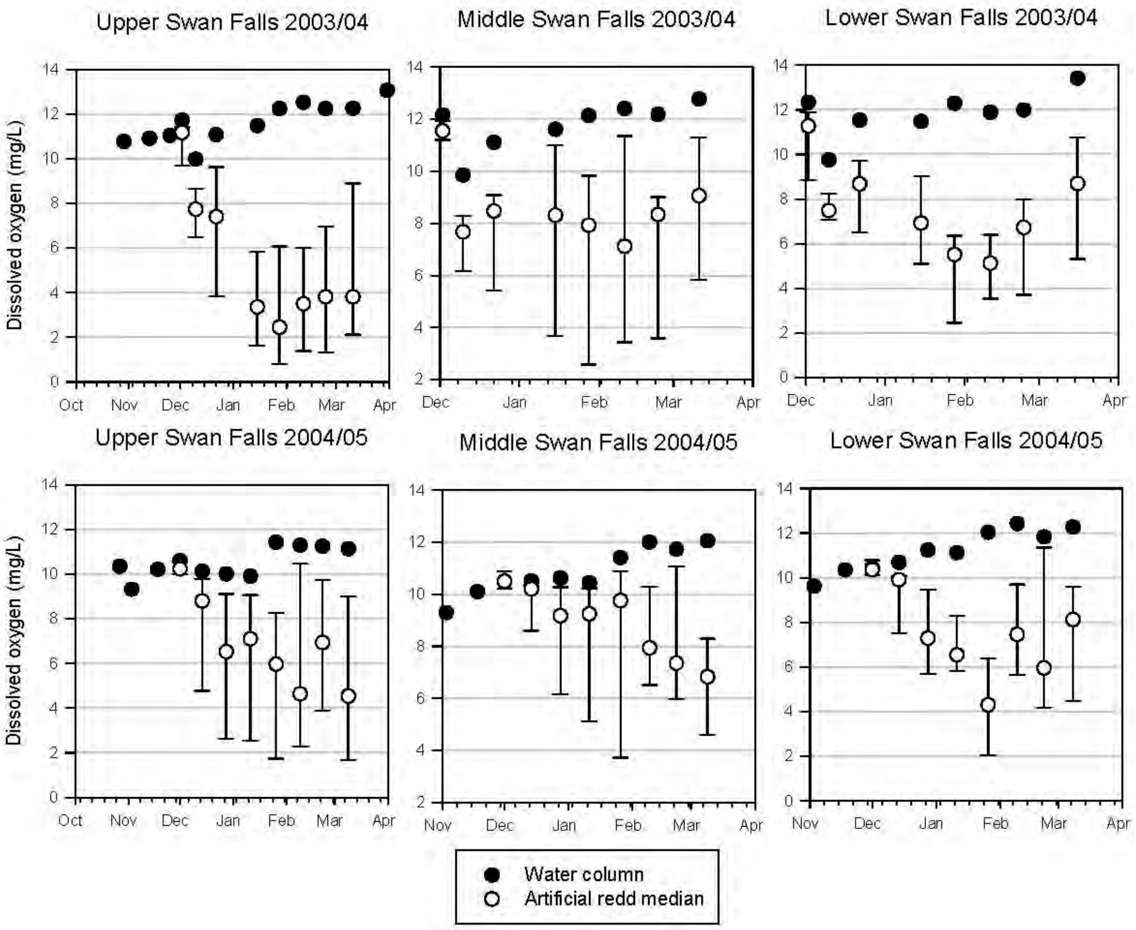


Figure 6.2-7
Intergravel DO in mg/L at sites upstream of Brownlee Reservoir with eyed eggs in the 2003/2004 and 2004/2005 periods. Symbols show the median of 9 (2003/2004) or 7 (2004/2005) artificial redds, while error bars show the minimum and maximum values.

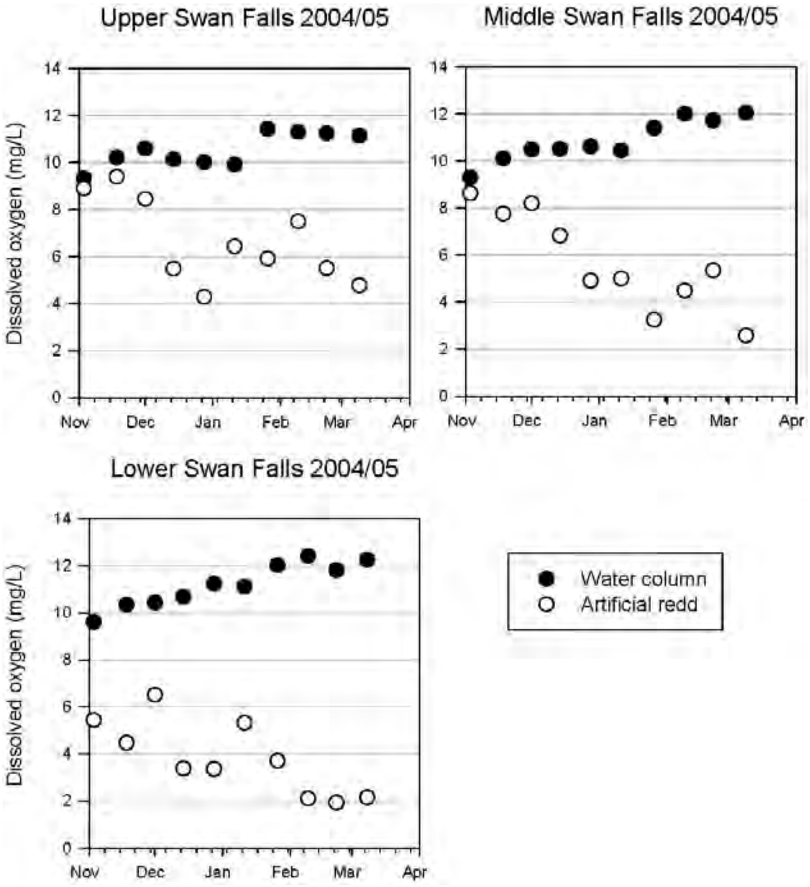


Figure 6.2-8
Intergravel DO in mg/L at sites upstream of Brownlee Reservoir with green eggs in the 2004/2005 period

Table 6.2-6
Survival of SRFC eggs placed in artificial redds above and below the HCC for the 2003/2004 and 2004/2005 periods

Study Year and Location	Average Survival for Eyed Eggs	Average Survival for Green Eggs	No. of Egg Baskets	Total No. of Eyed Eggs	Total No. of Green Eggs
2003/2004					
Swan Falls overall	0.23	–	27	2,700	–
Upper Swan Falls	0.00	–	9	900	–
Middle Swan Falls	0.68	–	9	900	–
Lower Swan Falls	0.00	–	9	900	–
Downstream of HCC overall	0.83	–	18	1,800	–
2004/2005					
Swan Falls overall	0.17	0.00	28 eyed, 4 green	2,800	600
Upper Swan Falls	0.12	0.00	7 eyed, 1 green	700	150
Middle Swan Falls	0.42	0.00	7 eyed, 1 green	700	150

Study Year and Location	Average Survival for Eyed Eggs	Average Survival for Green Eggs	No. of Egg Baskets	Total No. of Eyed Eggs	Total No. of Green Eggs
Lower Swan Falls	0.00	0.00	7 eyed, 1 green	700	150
Lower Swan Falls	0.02	0.00	7 eyed, 1 green	700	150
Downstream of HCC overall	0.79	0.55	18 eyed, 6 green	1,800	900

6.2.2.1.3. Interconnection between Water-Column and Intergravel Conditions

Oregon's salmonid-spawning water-column DO criteria require levels designed to ensure intergravel DO levels of 8 mg/L are attained. Water-column and intergravel DO data collected below the HCC show a strong correlation between water-column DO and intergravel DO suggesting that maintaining water-column levels at sufficient levels assists in maintaining intergravel DO criteria. However, Snake River data collected above the HCC show that high water-column DO levels (e.g., at or above saturation) do not always result in intergravel DO levels that meet the criterion. The following are factors that affect intergravel DO concentrations:

- Exchange rate between surface and subsurface waters
- Residence time of water in the subsurface
- Processing of nutrients (including organic matter, nitrogen, and phosphorus) in the hyporheic zone

Two dominant factors controlling nutrient processing in the hyporheic zone are 1) surface to subsurface water-exchange rate and 2) residence time of water within gravels (Findlay 1995; Mulholland and DeAngelis 2000). Physical plugging of gravels by inorganic and organic (detrital) matter is one of the many processes that reduces water exchange rates and leads to increased residence times. Physical plugging occurs as water-column particulate matter infiltrates gravel either through settling or from surrounding surface-water velocities. During high-water events, these materials can also become mixed with gravels as streambeds are eroded and redeposited. It is likely that low intergravel DO levels are related to the reduction in intergravel velocities in artificial redds due to physical plugging of gravels (Hanrahan et al. 2007). Water-column sampling showed that higher levels of particulate matter occurred upstream of the HCC (Figure 6.2-5) and is likely a reason intergravel DO levels decreased after the initial artificial redd construction.

Plugging can also be caused by the production of either periphyton on the substrate surface or biofilm within the gravels (Battin and Sengschmitt 1999). Biofilms are primarily layers formed by bacteria on substrate surfaces. Bacteria secrete extracellular polysaccharides (glycocalyx) that form a visible slime layer and provide a matrix for building the "biofilm community" (Marshall 1997). Periphyton, which forms in the polysaccharide matrix produced by bacteria, is generally considered to be autotrophic algae (Welch and Lindell 1996). However, heterotrophic bacteria and fungi can dominate if there is a source of dissolved organic matter or if light is restricted. Extensive areas of periphyton, which can include protozoa and insects, have been observed by IPC biologists in the Snake River above the HCC. Additionally, the formation of heterotrophic biofilm within gravels is likely, considering the relatively high organic-matter levels and heterotrophic bacteria levels observed in the Snake River above the HCC (Harrison 2005).

The other dominant factor is the level of organic matter in hyporheic zone water, which is influenced by organic-matter levels in the water column. The decay of DOC and POC consumes DO in the gravels (Findlay et al. 1993). While plugging can reduce water-exchange rates and the flux of DO and organic matter entering the gravels, lower velocities within the gravels increase the residence time, allowing more time for organic-matter processing and related DO depletion (Kaplan and Newbold 2000).

Low intergravel DO levels above the HCC can be related to the rapid recycling of the more labile dissolved organic matter (Romani et al. 2004) produced in this eutrophic reach of the Snake River (IDEQ and ODEQ 2004; Harrison 2005). Downwelling water-column water with elevated levels of dissolved organic matter will deplete intergravel DO through increased bacterial activity (Kaplan and Newbold 2000). The depletion of DO was also evidenced by the occurrence of anoxic or anaerobic conditions in the gravel (Figure 6.2-6).

Additionally, relatively high nutrient levels support algal, periphyton, and macrophytic production of extracellular dissolved organic matter that stimulates the respiration of polysaccharide-producing bacteria in the sediments (Bell and Sakshaug 1980; Kaplan and Newbold 2000). The secondary production in the sediments can increase organic-matter levels within gravels. And, while most organic matter is produced in the warmer periods, materials produced during the growing season are susceptible to sloughing during the colder winter periods (Park and Clough 2004), then settle and are resuspended as river velocities fluctuate.

Dissolved organic matter that infiltrates a redd can greatly affect DO dynamics in the redd (Soulsby et al. 2001a, b). Also, when vertical movement of water through the redd is slowed due to plugging, the hydrodynamics change, allowing for more ambient hyporheic water to influence the redd (Soulsby et al. 2001a). This process is detrimental in reaches where ambient hyporheic water is anoxic or very low in DO (e.g., upstream of the HCC). POC produced or buried in sediments (including biofilms) can cause anaerobic layers that contribute oxygen-demanding material to nearby sediments (Kaplan and Newbold 2000). Data showed generally increasing levels of POC in the water column above the HCC (Figure 6.2-5) that can mix with gravels under higher water conditions. The decay of organic matter in the gravels was indicated by anoxic conditions prevalent upstream of the HCC (Figures 6.2-6, 6.2-7, and 6.2-8).

Data collected above and below the HCC demonstrated organic matter assimilation was higher in a reservoir reach compared to a river reach. The data showed the HCC improved intergravel DO downstream of the HCC even though water-column levels were depressed. This was caused by the higher level of settling in the HCC reservoirs than in a river. Lower suspended solids and POC levels downstream of reservoirs (Figure 6.2-5) reduced inorganic and organic plugging and organic matter decay in gravels. Data collected above and below the HCC demonstrated this difference and the positive effects on intergravel DO.

6.2.2.1.4. Reservoir DO

The aquatic-life criterion established in the SR–HC TMDL as the DO target for the HCC and applied throughout the HCC is Oregon's criterion of no less than 6.5 mg/L (IDEQ and ODEQ 2004). The minimum DO target of 6.5 mg/L applies unless adequate data are available, in which case multiple targets could apply (Table 6.2-1). Currently, DO levels in the HCC do not always meet the 6.5 mg/L criterion. DO in Brownlee Reservoir can become severely degraded, especially during July (Figure 6.2-9), and has occasionally caused fish mortality (Myers et al. 2003). In particular, low DO conditions in the transition zone of Brownlee Reservoir have potentially limited the survival of the white sturgeon (*Acipenser transmontanus*) population in the river from Brownlee Dam upstream to Swan Falls Dam (Jager et al. 2003).

Like temperature, DO is related to hydrologic conditions. Low DO is typically more widespread and longer in duration during low water years. During low water conditions, anoxia can develop as early as April near the bottom of the reservoir in the transition zone. Anoxia typically continues to build through the season, gradually depleting oxygen from the transition zone, metalimnion, and hypolimnion. The metalimnion, hypolimnion, and a significant volume of the transition zone are typically anoxic by the end of July (Figure 6.2-9). As inflows begin to cool in September, anoxic waters are gradually mixed out of the transition zone and upper levels of the metalimnion into the epilimnion near the dam. The lowest DO levels in the epilimnion near the dam and in Brownlee outflow are typically seen through September.

In higher water years, anoxic conditions first develop downstream of the transition zone and in the hypolimnion (Figure 6.2-9). This is due to a combination of warmer hypolimnion water (and faster oxygen depletion rates) in high water years resulting from a larger Brownlee spring drawdown for flood control and high inflow. While anoxic conditions are not as widespread as in low water years, the conditions in the hypolimnion can be more extreme with increased production and the accumulation of anoxic products, such as sulfide and ammonia.

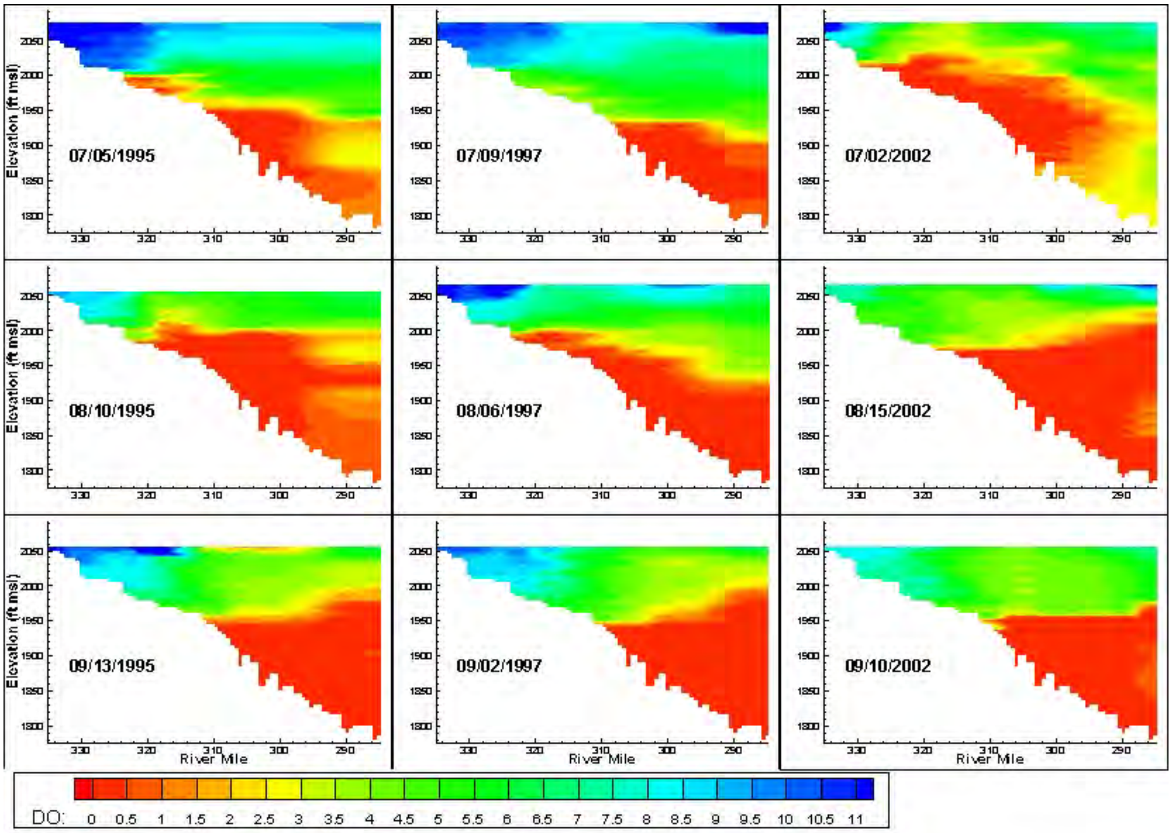


Figure 6.2-9
Measured Brownlee Reservoir DO in mg/L in July, August, and September in an average (1995), high (1997), and low (2002) water year

Brownlee Reservoir receives waters from the inflowing Snake River that were identified in the SR–HC TMDL as having excess TP concentrations and routinely observed nuisance algal growths (IDEQ and ODEQ 2004). The IDEQ and ODEQ linked these conditions to low DO in the Snake River and Brownlee Reservoir. This is best illustrated in the frequency with which the DO criterion is exceeded in the riverine and transition zones of Brownlee Reservoir. Therefore, the current degraded DO current conditions are a result of the degraded upstream Snake River, and how the excessive nutrients and organic matter flowing into Brownlee Reservoir are processed within the reservoir.

TP concentrations measured at the inflow to Brownlee Reservoir have been declining. We used the seasonal Mann-Kendall Test for trend (SMK) and Theil-Sen's slope estimator to test for trends using both the raw data and residuals from a locally weighted scatterplot smooth (LOESS) curve between discharge and concentration (Hirsch et al. 1982, Hirsch et al. 1991, Helsel and Hirsch 2002). The LOESS step in this analysis is intended to factor out variability in the concentration data that is statistically related to discharge. We used a span of 0.5 and a degree of 1 as settings for the LOESS curve after confirming these settings resulted in a reasonably straight line at zero when plotting the residuals against the fitted values for all parameters. The SMK test was conducted on both the raw data and the residuals from the loess between discharge and concentration (residuals) for the May-September time period. This time period relates to the growing season or critical time frame as evaluated in the SR HC TMDL. The SMK test and Theil-Sen's slope estimation were conducted using the 'rkt' package (Marchetto 2013) in the R statistical language (R version 3.4.0, The R Foundation for Statistical Computing 2017). Month was used as the seasonal blocking variable in the SMK test meaning that seasonality is accounted for by comparing only within month trends. This is done by comparing data for each month over the years separately and then comparing all the monthly results for the overall trend result. Since all the data was used for the analysis an initial step in the 'rkt' package is to determine a median value for each month and this value is then compared through the years. All the data was included only to determine the most accurate median value as one value per year per month is a requirement of the SMK test (Hirsh et al. 1982). The trend tests show significant ($p<0.001$) decreasing trends in TP during the May-September period (Figure 6.1-10). The decreasing trend was significant ($p<0.001$) both using the raw data and the residuals with a slope on the residuals showing a 1.3% decrease in TP per year.

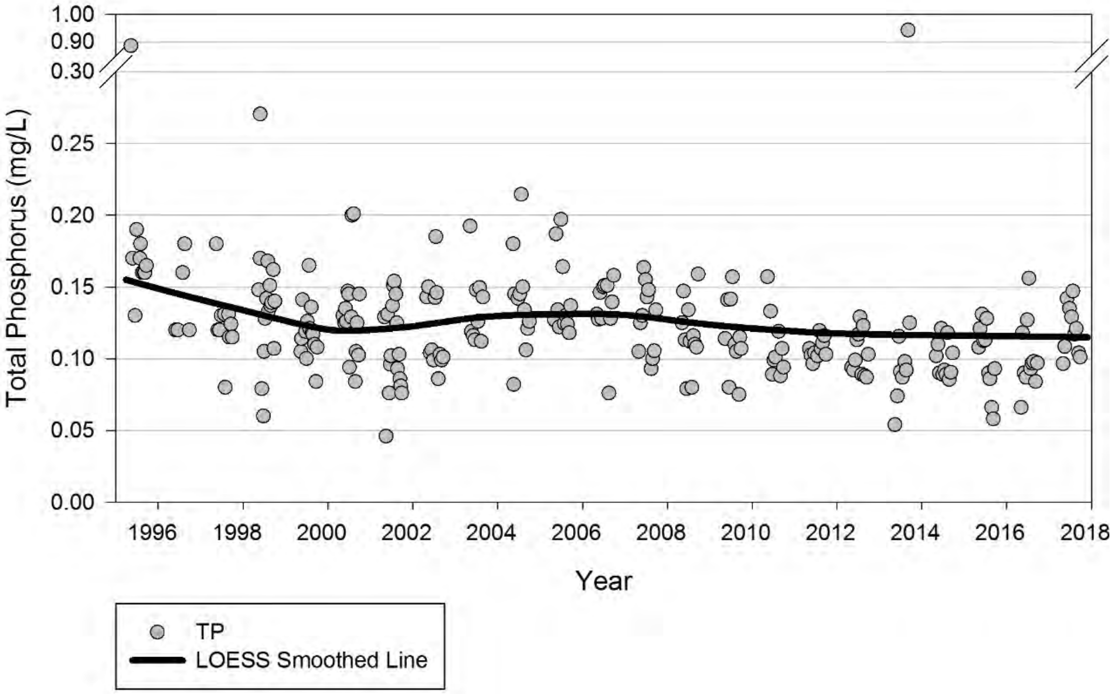


Figure 6.2-10
Measured Brownlee Reservoir inflow total phosphorus (TP) during the May-September period from 1995 to 2017.

6.2.2.1.5. *Outflow DO*

As current conditions in Brownlee Reservoir suggest, outflow DO from Brownlee is typically below applicable criteria beginning in July and going into December (Figure 6.2-11). DO levels can vary considerably throughout the day in the Brownlee outflow (e.g., 2 to 4 mg/L). In contrast to the daily inflow DO pattern, daily changes in Brownlee outflow DO are related primarily to flow through the units at Brownlee Powerhouse. Since, during most of the year, Brownlee Reservoir is stratified with variable oxygen levels through the water column a lower flow rate through the powerhouse typically releases slightly deeper water with lower DO levels, while higher flow rates include more surface waters with higher DO levels.

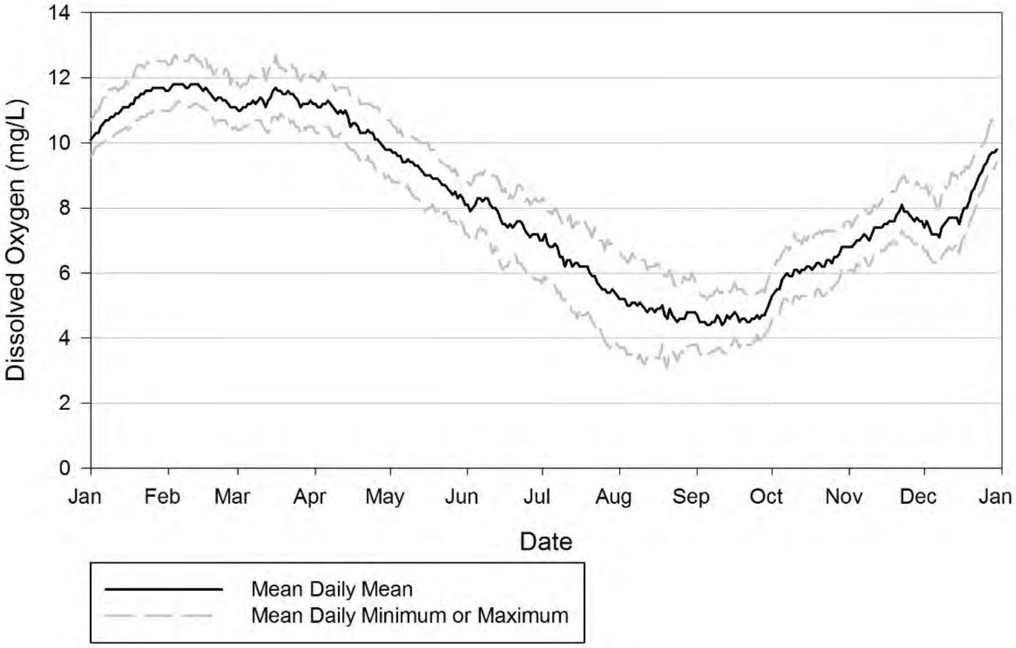


Figure 6.2-11
Brownlee Reservoir outflow mean daily mean, mean daily minimum, and mean daily maximum DO in mg/L summarized from measurements made approximately every 10 minutes over the 2004 through 2017 period.

As water travels from Brownlee outflow, processes (i.e., mixing, reaeration, algal production, demand) combined with different in reservoir thermal structure, DO structure and powerhouse operations for Oxbow and Hells Canyon cause a gradual decrease in the daily variability in outflow DO levels. As water flows out of Hells Canyon Powerhouse the daily variability is reduced to around 0.5 mg/L (Figure 6.2-12). Many of the above processes may cause increases or decreases in DO levels within the reservoirs and at the outflows. While there may be times when slight increases or decreases are seen when comparing Brownlee and Hells Canyon outflow DO, on an overall average basis the combined effect of Oxbow and Hells Canyon Reservoirs on outflow DO from Hells Canyon is slightly positive (Figure 6.2-13). Comparing daily average DO at Brownlee and Hells Canyon showed an average increase of 0.4 mg/L during the low DO period of July 1 through December 31 (Table 6.2-7).

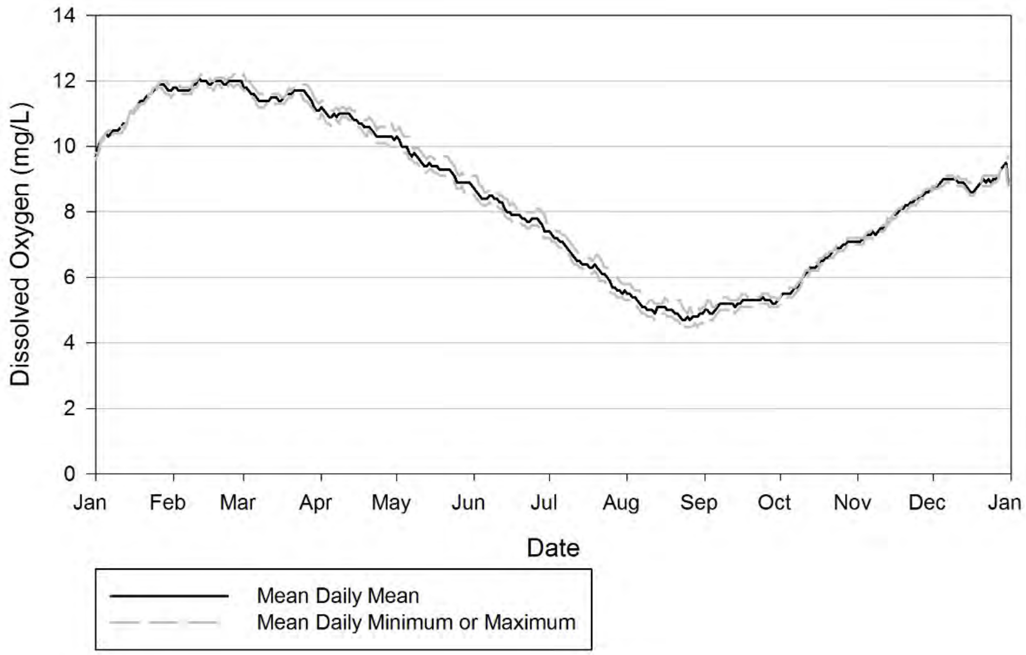


Figure 6.2-12
Hells Canyon outflow mean daily mean, mean daily maximum and mean daily minimum outflow DO summarized from measurements collected approximately every 10 minutes over the 2004 through 2017 period.

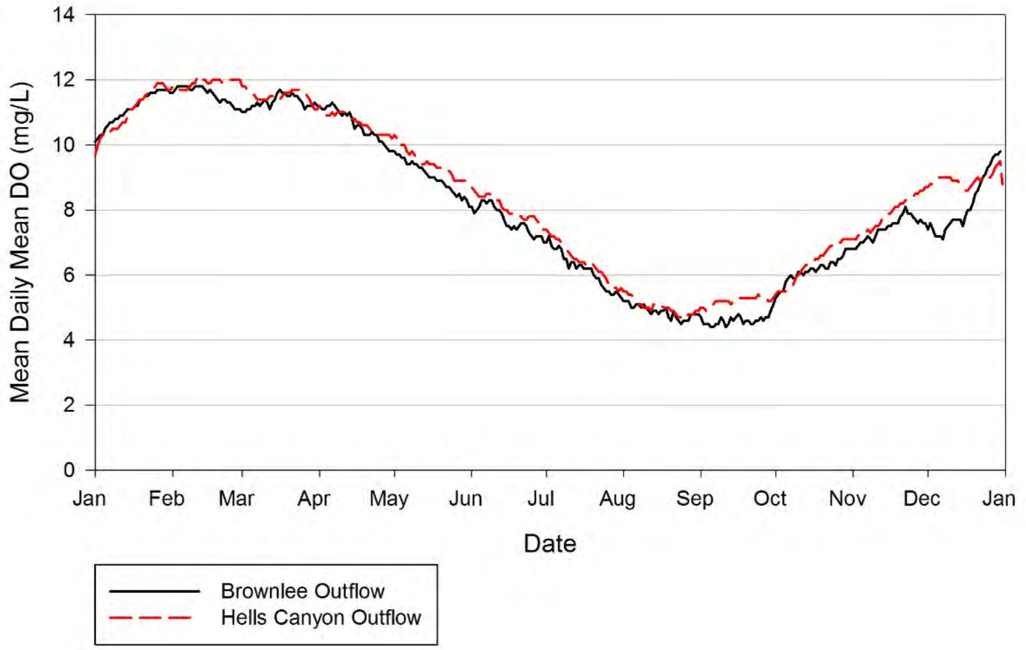


Figure 6.2-13
Mean daily mean DO compared between Brownlee and Hells Canyon outflow DO over the 2004 through 2017 period.

Table 6.2-7
Average change in daily mean DO as water travels from Brownlee outflow to the HCD penstock. for each year of the 2004 through 2017 period. Changes are only summarized during the low DO period (July 1 through December 31).

Year	Average change in DO (mg/L)
2004	0.5
2005	0.5
2006	0.6
2007	0.7
2008	0.6
2009	0.6
2010	0.8
2011	-0.2
2012	0.1
2013	0.3
2014	0.3
2015	0.5
2016	0.2
2017	0.1
Average	**0.4**

Despite the general increase in DO as water passes through Oxbow and Hells Canyon reservoirs, conditions in the outflow from HCD do not always meet downstream criteria. The following steps were used to quantify the annual average DO deficit from criteria at the HCC outflow.

1. Using DO at the HCC outflow for the period of July 1 through October 22, from 2004 through 2017, the DO deficit was calculated by comparing measured data to the 6.5 mg/L cool-water aquatic life DO criteria. Using the cool-water DO criteria as defined in Table 21 (OAR 340-041-0016 Dissolved Oxygen (3)), the dissolved oxygen may not fall below 6.5 mg/l as a 30-day mean minimum. Oregon Administrative rules (340-041-0002 definitions (39)) defines the 30 day mean minimum as follows: "Monthly (30-day) Mean Minimum" for dissolved oxygen means the minimum of the 30 consecutive-day floating averages of the calculated daily mean dissolved oxygen concentration, ” with “daily mean” for dissolved oxygen defined at 340-041-0002(15) as “the numeric average of an adequate number of data to describe the variation in dissolved oxygen concentration throughout a day, including daily maximums and minimums. In this analysis 10 minute readings were used for daily mean calculations. For calculating the mean, concentrations in excess of 100 percent of saturation are valued at the saturation concentration.” Corrections to the daily average values to account for DO saturation (as stated in the standards) were not required because there were only 11 days (in early July 2008, and 2011) when 10-minute DO measurements were above saturation values and the 100%

saturation value was above the criteria so these days were not included in the summary of DO deficits.

2. Using DO at the HCC outflow for the period of October 23 through December 31, from 2004 through 2017, the DO deficit was calculated by comparing measured data to the water column values calculated from IGDO values, as described in Section 6.2.1.2. Using the salmonid spawning criteria 7-D time period described in Table 21, calculate the 7 day mean minimum as defined as OAR 340-041-002 Definitions (73). The 7 day mean minimum is defined as: "Weekly (seven-day) Mean Minimum" for dissolved oxygen means the minimum of the seven consecutive-day floating average of the calculated daily mean dissolved oxygen concentration." There were no periods when an adjustment to saturation was required for this period.
3. The 30-day or 7-day (depending on the period of interest) floating mean of the daily mean DO concentration was calculated for every day and subtracted from the criteria to calculate the deficit. The daily deficits (only for the days where DO was below criteria) were then averaged over the periods (cool-water, salmonid spawning and annually) to calculate average DO deficits.

The period of record for all analysis of measured data is the low DO period (July 1 through December 31) from 2004 through 2017. 2004 was selected as the analytical start date because the SR-HC TMDL was approved in 2004. Because DO conditions could be expected to improve with SR-HC TMDL implementation, post-TMDL data are expected to be more reflective of current and future conditions than pre-TMDL data. Since an average over various periods is being calculated, any gaps in the 10-minute data were filled using linear interpolation prior to calculating daily mean DO. The resulting daily mean dataset (Figure 6.2-14) was then used for the remainder of the calculations.

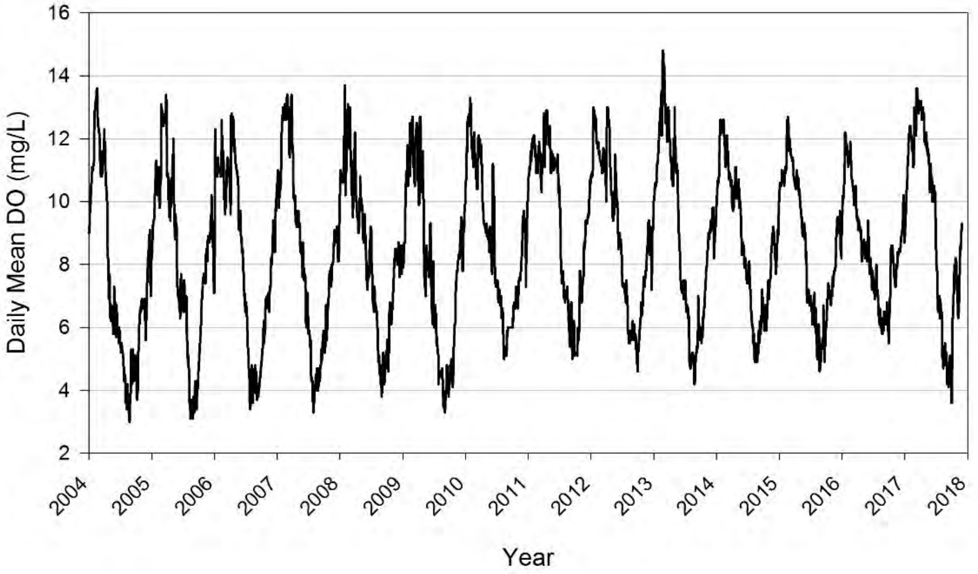


Figure 6.2-14
Daily mean Hells Canyon outflow DO from 2004 through 2017.

During the cool-water life period there are statistically significant increasing trends in the 30-day mean minimum HCC outflow DO conditions (Figure 6.2-15, Table 6.2-8). During the salmonid spawning period there was not a statistically significant increasing trend in the 7 day mean minimum conditions (Table 6.2-8). The average annual DO deficit at the HCC outflow for the most recent 8 years (i.e., 2010 through 2017) was 0.8 and 1.4 mg/L during the cool-water life period and salmonid spawning period, respectively (Table 6.2-9, Figure 6.2-16). The average annual deficits for the cool-water period are lower in the more recent years which reflects the increasing trends in HCC outflow DO.

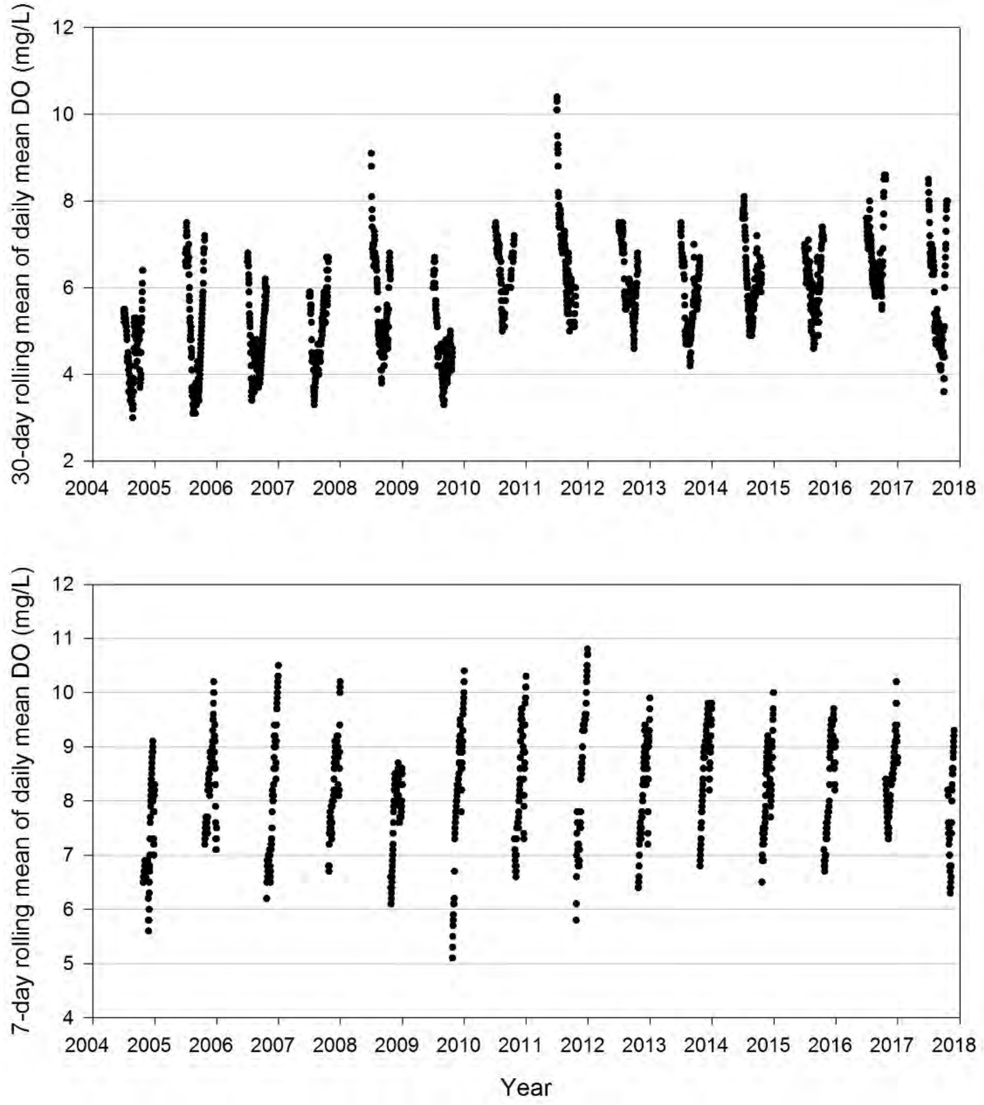


Figure 6.2-15
Data sets for trend analysis and deficit from criteria calculations for the 30 day (top plot) or 7-day (bottom plot) rolling mean of the daily mean at the HCC outflow.

Table 6.2-8
Seasonal Mann-Kendall trend analysis results for HCC outflow DO during the low DO period (July 1 through December 31) for the 30-day, or 7-day rolling mean of the daily mean from July 1 through October 22 (cool-water life period), or October 22 through December 31 (salmonid spawning period), respectively. Both trends are for the years over the 2004 through 2017 period.

Seasonal Mann-Kendall trend results	Cool-water life period	Salmonid Spawning period
N	1.596	948
Mean	5.6	8.2
Minimum	3.0	5.1
Maximum	10.4	10.8
p-value	<0.001	0.099
Slope (mg/L/Yr)	0.14	0.048
Tau	0.47	0.196

Table 6.2-9
Average HCC outflow DO deficits in mg/L during the time frame since SR HC TMDL approval (2004–2017). Deficits were calculated during the low DO period (July 1 through December 31) by subtracting the 30-day (cool-water life period July 1 through October 22) or 7-day (salmonid spawning period October 23 through December 31) rolling mean of the daily means from the criteria.

Year	Cool-water life average DO deficit from criteria (mg/L)	Salmonid Spawning average DO deficit from criteria (mg/L)	Annual average DO deficit from criteria (mg/L)
2004	1.8	2.4	2.1
2005	2.1	1.2	1.7
2006	1.9	1.8	1.9
2007	1.6	1.4	1.5
2008	1.4	1.8	1.6
2009	1.9	1.7	1.8
2010	0.6	1.6	1.0
2011	0.6	1.6	1.1
2012	0.8	1.5	1.1
2013	1.0	1.0	1.0
2014	0.7	1.4	1.0
2015	0.7	1.3	1.0
2016	0.3	1.2	0.8
2017	1.3	1.4	1.3
Average 2004-2017	1.2	1.5	1.4
Average 2010-2017	0.8	1.4	1.0

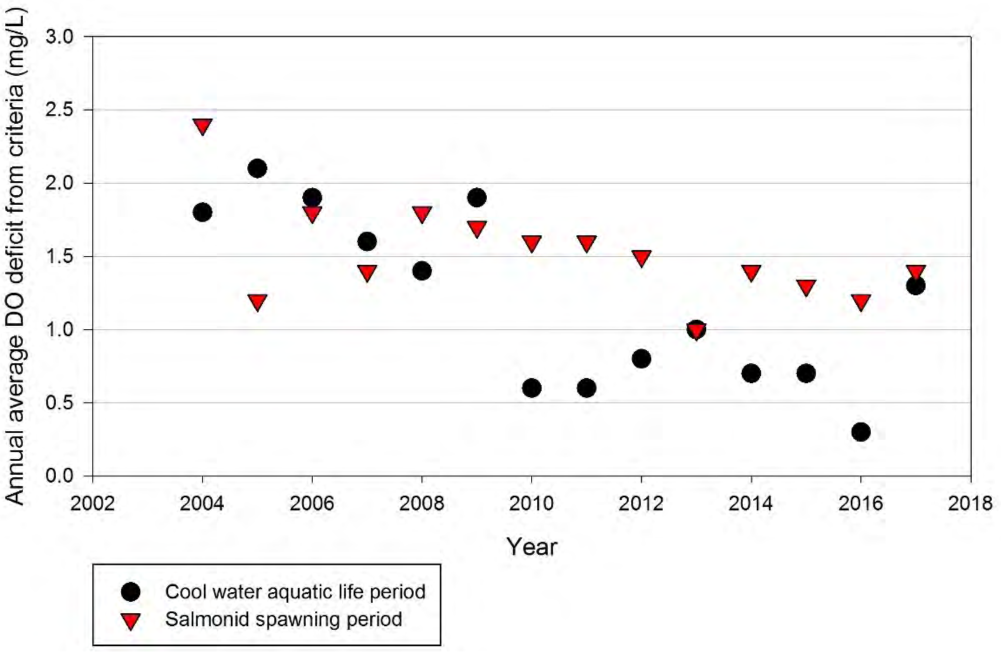


Figure 6.2-16
Average annual DO concentration deficit at HCC outflow. During the cold-water aquatic life period these values are based on a 30-day rolling average of the daily means not less than 6.5 mg/L. During the salmonid spawning period these values are based on the 7-day rolling average of the daily means not less than 9.1-9.6 mg/L as developed in Section 6.2.1.2.

The annual average deficits are representative of DO at the Hells Canyon powerhouse before the water passes through the turbines since measurements are collected from the turbine water intake system. Therefore, these measurements do not include any reaeration through the turbines from the routine addition of smoothing air for operational purposes, or in the turbulent river immediately downstream. Since 2006, IPC has consistently collected instantaneous DO measurements (in addition to the 10 minute measurements summarized for the deficits) from the turbine water intake system and also at the Hells Canyon boat launch about 0.7 miles downstream. Since these two measurements were collected with the same instrument on the same day (usually within 30 minutes of each other) they are very comparable and can be used to estimate reaeration that occurs through the turbines and the first 0.7 miles of river downstream. This comparison shows that, during the cool-water aquatic life period, reaeration averaging 0.4 mg/L is occurring through the turbines and the first 0.7 miles of river downstream. During the salmonid spawning period when DO levels are higher to begin with there is less reaeration occurring with a difference between the medians of 0.2 mg/L. The differences between penstock and the boat launch during both periods are statistically significant and indicate that deficits calculated at the HC penstock are overestimated compared to river conditions immediately downstream of HC Dam. (Figure 6.2-17). Even further downstream through several large rapids reaeration can be 1 to 2 mg/L 10 miles downstream (Figures 6.2-18).

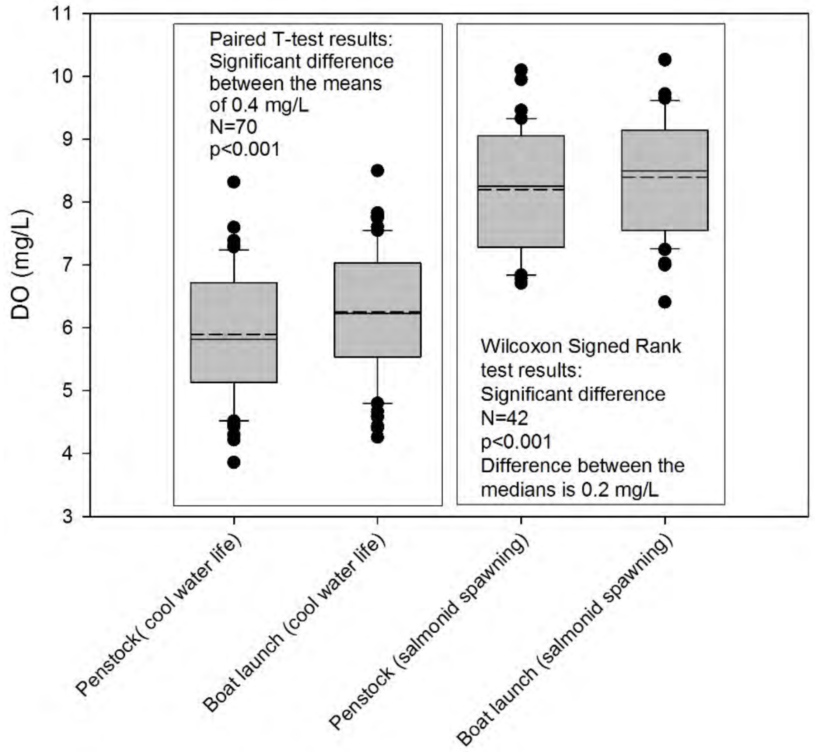


Figure 6.2-17
Box plot comparisons and results of tests for significant differences between instantaneous DO measurements collected at the HCC outflow location (Penstock) in the HC Powerhouse and 0.7 miles downstream at the Hells Canyon boat launch (Boat launch). Measurements were collected with the same instrument on the same day (usually within 30 minutes of each other) approximately every two weeks beginning in 2006. Boxes show the 75th and 25th percentile of the data while the error bars show the 90th and 10th percentile. Dots are each outlier and the solid line shows the median while the dashed line is the average.

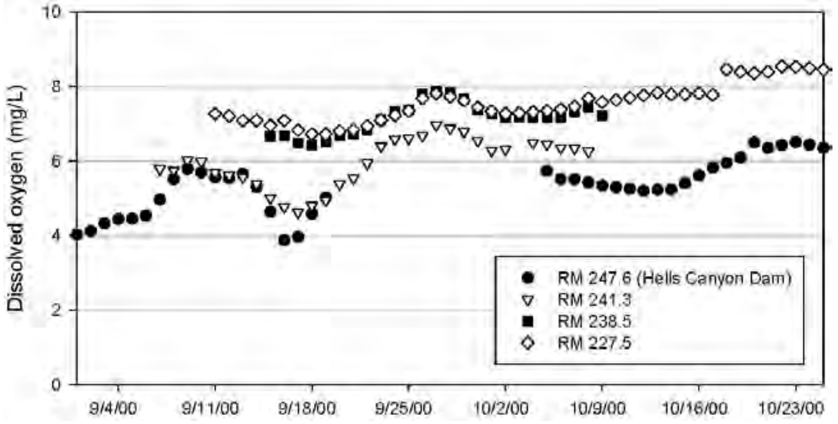


Figure 6.2-18
Daily average DO in mg/L from Hells Canyon Reservoir outflow (HCD) and 3 locations in the Snake River downstream during September and October 2000

6.2.2.1.6. Oxbow Bypass DO

The Oxbow Bypass is a short, 2.5-mile section of the Snake River below Oxbow Dam. The bypass extends from Oxbow Dam (RM 272.5) downstream to the powerhouse (RM 270). A minimum flow of 100 cfs is maintained through the bypass by drawing water from Oxbow Reservoir approximately 30 feet below full pool and passing it over the Oxbow spillway. The Oxbow Bypass is also subject to inundation by Hells Canyon Reservoir due to the backwater effect of HCD. Indian Creek (RM 271.3) is the only perennial tributary to the bypass.

A deep-water pool exists just upstream of the Indian Creek confluence, approximately 1.2 miles downstream of Oxbow Dam. The pool is approximately 50 feet deep and roughly 2 acres in surface area. The 100-cfs flow rate is not enough to completely mix this deep pool and, at times, the pool thermally stratifies during the summer (Myers and Chandler 2003). The thermal stratification results in the deeper, cooler water becoming anoxic during some parts of the summer season. More detail on the water quality of the Oxbow Bypass is available in Technical Report E.3.2-1 of the *New License Application: Hells Canyon Hydroelectric Complex*. The proposed method to prevent anoxic conditions from developing in the deeper water can be found in Section 7.2.3. Destratification Measure for Oxbow Bypass.

6.2.2.2. Modeling to Assess Expected Future Conditions Relative to Standards

To support the FERC license application process, IPC developed CE-QUAL-W2 models for Brownlee, Oxbow, and Hells Canyon reservoirs (Zimmerman et al. 2002). Models were initially developed for 1992, 1994, 1995, 1997, and 1999. These years were selected based on water-year (i.e., flow) conditions combined with data availability for set-up and calibration. The initial calibration effort was focused on 1992, 1995, and 1997 for low, medium, and high water years, respectively. Years 1994 and 1999 represent medium-low and medium-high water years, respectively, and were developed as verification years (i.e., the model settings developed through the calibration of the other years were applied to these years). In 2002, a large data-collection effort by IPC and others provided additional information relative to inflowing Snake River organic matter, including algae (Harrison 2005). Also studied were Brownlee hydrodynamics, temperature stratification, DO dynamics, meteorological conditions, and intake-channel configuration (Botelho et al. 2003; Botelho and Imberger 2007). A 2002 CE QUAL-W2 model was developed using this additional information and considerably improved uncertainty associated with the existing low-water-year model (i.e., 1992). After the 2002 model was developed, many of the updates were applied to the other years.

The modeling analysis presented in this section uses 3 of the 6 years—1995, 1997, and 2002. Average water-year conditions are represented by the 1995 model. The inclusion of 1995 is consistent with SR–HC TMDL development, which focuses on conditions during average water years. The inclusion of 2002 allows an evaluation of the low-water conditions, which are typically when the lowest DO conditions are seen in historical data. The relatively extensive boundary condition data available make 2002 a logical selection for low-water-year analysis. The high-water year (1997) is also included in this analysis because while DO levels were generally higher, they were still below applicable criteria.

The general calibration process for the HCC models is described in Harrison et al. (1999) and Zimmerman et al. (2002). The majority of the calibration effort was focused on conditions in

Brownlee Reservoir where physical and biological processes are more complex. Also, field studies consistently show that conditions in Oxbow and Hells Canyon reservoirs are driven by Brownlee outflow conditions. Model calibration for all the years was re-evaluated following the development of the 2002 model and applying upgrades and improvements to the other years. We used several methods to analyze model output for comparing model runs and improving its calibration. These methods included animations of various water-quality constituents over time, time-series plots of the outflow constituents, and contour and profile plots at various locations and times in the reservoir. We also used an absolute mean error (AME) analysis as a quantitative means of assessing in-reservoir calibration. Measured DO collected at multiple depths and locations in the reservoir was compared with modeled values and summarized to show the overall error over the year. The equation for the AME can be described as follows:

$$AME = \frac{\sum |X_m - X_d|}{N}$$

Where:

X_m = modeled value

X_d = measured value

N = the number of data pairs

Overall, the 1995, 1997, and 2002 models simulated Brownlee in-reservoir DO with an AME of less than 2 mg/L (Table 6.2-10).

Table 6.2-10
CE-QUAL-W2 DO calibration error statistics for Brownlee Reservoir for the 1995, 1997, and 2002 models

Model Year	AME (mg/L) Brownlee In-Reservoir	Water-Year Type
1995	1.41	Medium
1997	1.65	High
2002	1.10	Low

All reservoir models were initially developed based on actual reservoir operational conditions that occurred in each of the years. For the modeling analysis relative to DO, IPC used operations as defined in the FERC FEIS (FEIS operations) and listed in more detail in Section 4.5 Project Operations. This is significant in interpreting model run results because future operations are not absolutely defined at this time. In addition, operational constraints will necessarily have some level of flexibility allowed within the defined constraints. For example, potential future operational requirements detailed in the FERC FEIS differ somewhat from the requirements in the current license, as well as those proposed by IPC in the license application. The FEIS operations used in this analysis include operating Brownlee within 1 foot of flood-control targets on April 15, drafting Brownlee Reservoir to 2,060 feet by August 1 to provide 237,000 acre-feet of flow augmentation, and continuing the fall Chinook Flow Program.

6.2.2.2.1. Reservoir DO Modeling

Long-term reservoir DO conditions were simulated using the CE-QUAL-W2 model. Dissolved phosphorus and organic phosphorus sources (e.g., labile and refractory organic matter) were reduced in the Brownlee Reservoir inflows to simulate how the reservoir would respond to the SR–HC TMDL TP target of 0.07 mg/L (Myers et al. 2003; IDEQ and ODEQ 2004). This was accomplished by reducing dissolved phosphorus and organic phosphorus (organic matter, including algae) from current conditions or baseline boundary conditions so inflowing TP levels did not exceed 0.07 mg/L. In addition, total organic matter (TOM) loads and sedimentation are expected to decrease as watershed management actions are implemented to meet the TP target. As loads decrease and existing TOM decays through natural processes, sediment oxygen demand (SOD) will decrease. The simulated long-term reservoir conditions included reductions in SOD. SOD is simulated in CE-QUAL-W2 using 2 settings, a zero order (SOD) and first order (SED). A response to long-term improvements was simulated by reducing the modeled zero-order SOD to 0.1 grams (g) of oxygen per square meter (m2) per day throughout Brownlee Reservoir. This SOD level is more typical of naturally occurring levels (Cole and Wells 2002). The SED, resulting from the settling of inflowing organic matter, was left at optimized (i.e., current) rates (Harrison et al. 1999). This simulation methodology follows the same method used during the development of the SR–HC TMDL (IDEQ and ODEQ 2004).

CE-QUAL-W2 DO simulation results indicated that when the SR–HC TMDL is fully implemented, DO levels in Brownlee Reservoir are expected to improve dramatically (Figure 6.2-19). These simulation results showed that the greatest improvements in DO conditions are expected to occur in late summer. The simulations included a reduction of algae (and other organic matter components), as anticipated with full implementation of upstream allocations, and an associated decrease in SOD (long-term improvements).

To mitigate the effects of Brownlee Reservoir, as identified in the SR-HC TMDL. IPC will implement Snake River phosphorus-reduction measures to meet the load allocation of 1,125 tons of DO per year in Brownlee Reservoir (IDEQ and ODEQ 2004). The specific methodology and proposals for this implementation can be found in Section 7.2. DO Proposed Measures. For an analysis of long-term conditions, IPC's implementation of the load allocation was not represented in this CE QUAL W2 modeling.

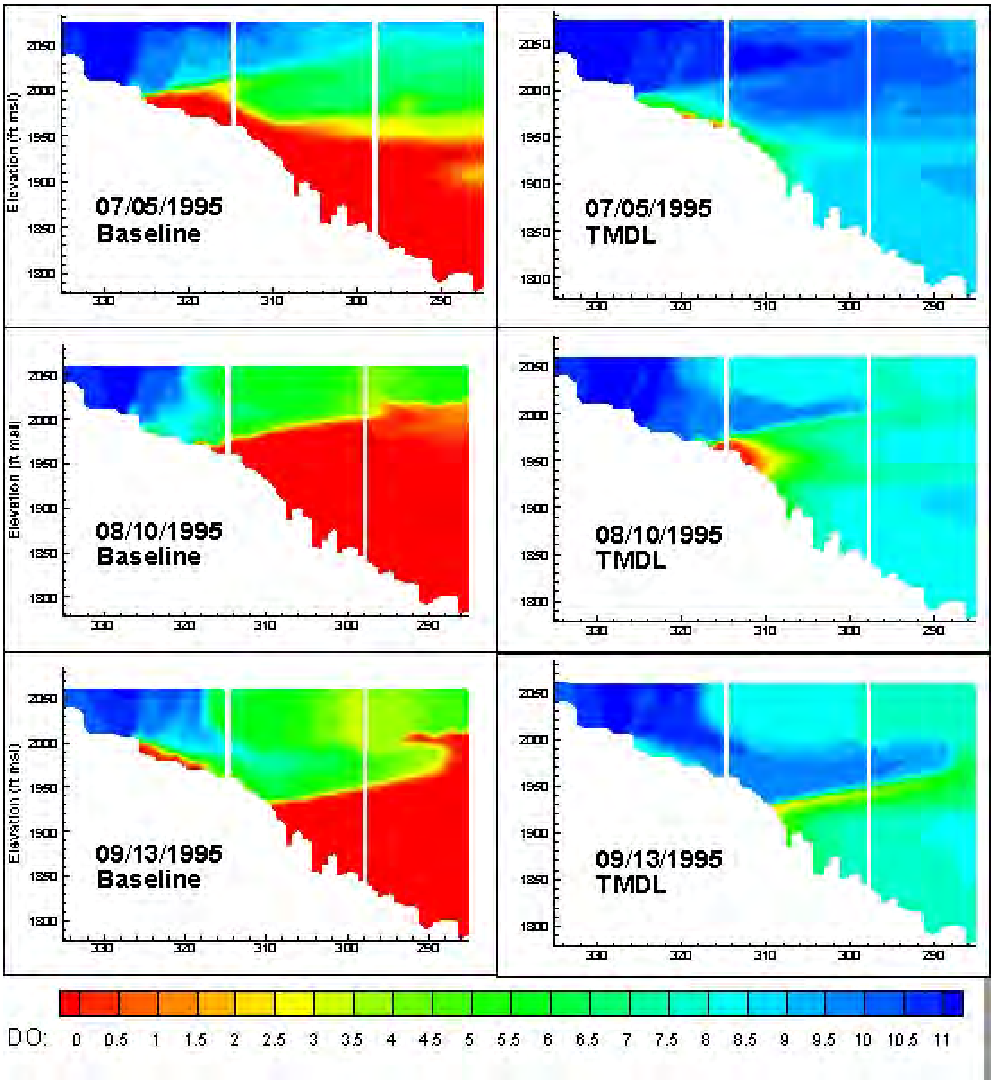


Figure 6.2-19
CE-QUAL-W2 simulated DO in mg/L in Brownlee Reservoir for 1995 current conditions (baseline) and anticipated conditions with full upstream implementation of the SR–HC TMDL (TMDL)

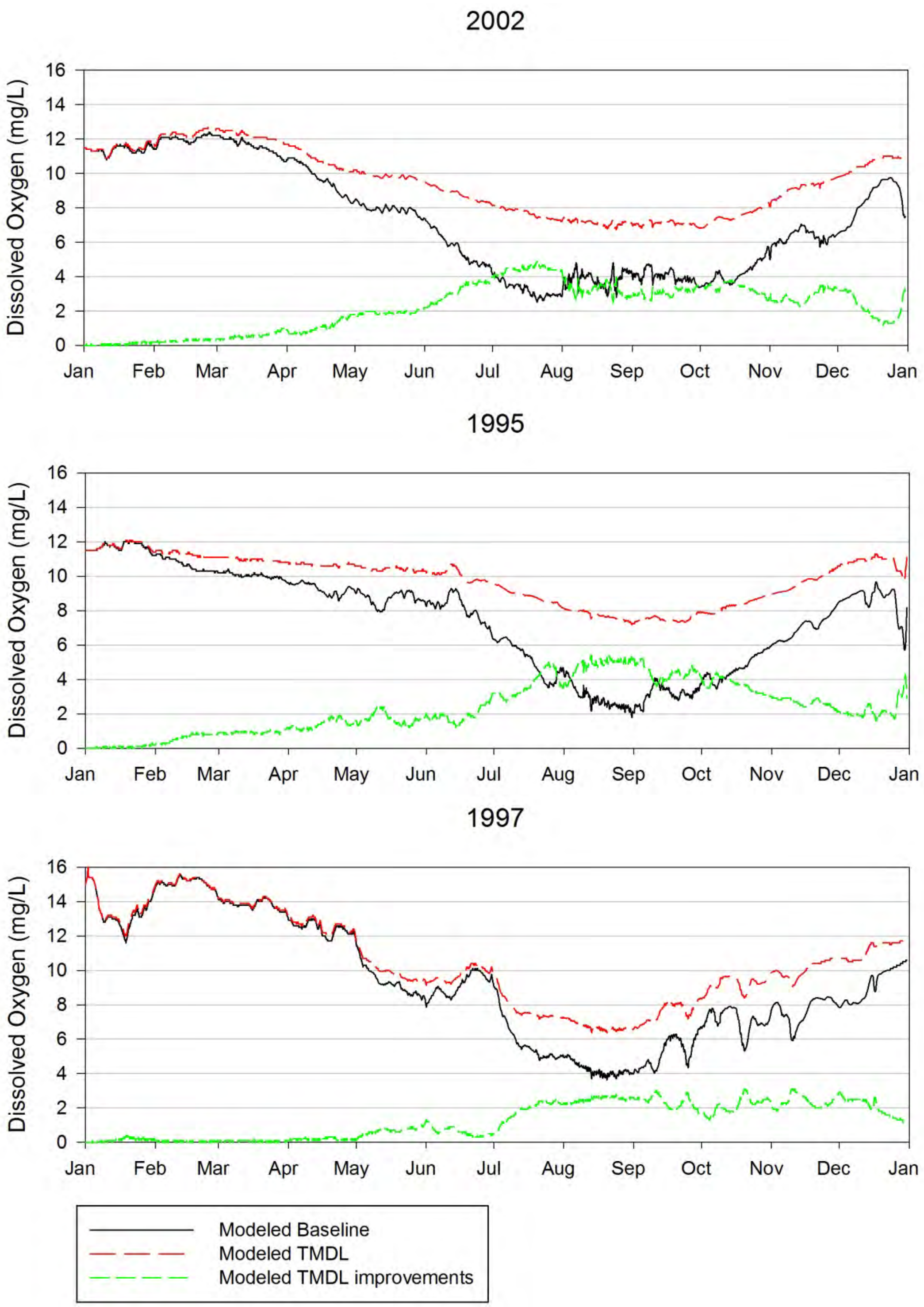
6.2.2.2.2. Outflow DO modeling

The SR–HC TMDL did not address DO downstream of the HCC. The SR–HC TMDL assigned upstream TP allocations so the Snake River flowing into the HCC met aquatic-life criteria and protected those beneficial uses (IDEQ and ODEQ 2004). The SR–HC TMDL did not develop targets or allocations based on more stringent downstream criteria for the protection of salmonid spawning. It did identify that the HCC's contribution to any DO deficit was related only to the impoundments. The water-quality improvements resulting from the full implementation of the SR–HC TMDL include improved DO below the HCC (Figure 6.2-20). The CE-QUAL-W2 model was used to simulate improvements in Hells Canyon Reservoir outflow DO following full upstream SR–HC TMDL implementation. Improvements are based on the difference between simulated HCC outflow DO with current conditions and with full SR–HC TMDL implementation.

To summarize, simulated DO levels below the HCC resulting from full implementation of the SR–HC TMDL were assessed by modifying the Brownlee Reservoir boundary conditions and the CE-QUAL-W2 model (see Section 6.2.2.2.1. Reservoir DO Modeling).

- Reduce inflowing nutrients and organic matter at the Brownlee Reservoir boundary conditions (RM 340) to meet the SR–HC TMDL TP target of 0.07 mg/L.
- Increase inflow DO at the Brownlee Reservoir boundary conditions to meet the SR–HC TMDL DO target of 6.5 mg/L.
- Set the SOD at long-term levels of 0.1 g of oxygen per m^2 per day throughout Brownlee Reservoir.
- Use outflow from the upstream reservoir as the inflow boundary condition to the downstream reservoir (referred to as linked simulations) and set the SOD to 0.1 g of oxygen per m^2 per day.

The linked simulation modeling outflow from the HCC after full implementation of the SR–HC TMDL showed substantial outflow DO improvements over the majority of the year (Figure 6.2-20). The modeled improvements from the SR HC TMDL were summarized by comparing the improvement in the 30-day mean minimum and the 7-day mean minimum for the cool-water aquatic life and salmonid spawning periods, respectively. This summary is similar to and allows comparison with the calculated current HCC outflow DO deficits (see Section 6.2.2.1.5.). The summarized SR HC TMDL improvements show average annual improvements of 3.2 and 2.5 mg/L during the cool-water aquatic life and salmonid spawning period, respectively (Table 6.2-11).



2002

1995

1997

Figure 6.2-20
Comparison of simulated Hells Canyon Reservoir outflow DO in mg/L with current conditions and SR–HC TMDL conditions. TMDL improvements show the difference between the 2 simulations.

Table 6.2-11
Average TMDL DO improvements from 1995, 1997, and 2002 models

Year	Cool-water life average TMDL DO improvement (mg/L)	Salmonid Spawning average TMDL DO improvement (mg/L)	Annual average TMDL DO improvement (mg/L)
2002	3.6	2.6	3.2
1995	4.0	2.5	3.5
1997	2.0	2.3	2.1
Average	3.2	2.5	2.9

6.2.3. HCC Contribution to DO

Brownlee, Oxbow, and Hells Canyon reservoirs affect DO conditions in different ways and magnitude. The effects of each individual reservoir, as well as the HCC, varies among years and will inevitably vary through the term of the new HCC FERC License. IPC used a combination of information and analyses from the SR-HC TMDL, and additional analyses and data beyond the SR-HC TMDL to assess the level of mitigation necessary to offset the effects of the HCC on DO.

The SR HC TMDL defined the contribution of Brownlee Reservoir to degraded DO conditions within the reservoir, and assigned a specific DO load allocation to IPC. The SR-HC TMDL provided a comprehensive and robust analysis of the relative contribution and effects of Brownlee Reservoir on DO conditions within the HCC. A DO load allocation of 1,125 tons per year was established for Brownlee Reservoir. The SR-HC TMDL was approved by EPA and still represents the best available information regarding the effects of Brownlee Reservoir on DO.

The SR HC TMDL did not address DO conditions downstream of Brownlee Reservoir. Subsequent to the SR-HC TMDL approval, IPC has conducted additional analyses as part of the 401 application process to characterize the effects of Oxbow and Hells Canyon reservoirs and DO conditions downstream of the HCC.

6.2.3.1. Brownlee Reservoir

Idaho Power's DO allocation, as established in the SR-HC TMDL (IDEQ and ODEQ 2004), was calculated by IDEQ and ODEQ using a mass balance approach. The analyses relied on available data and on the determination by the DEQs that IPC would focus on the impoundment effects attributed to the reservoirs. This was stated in the SR HC TMDL as follows:

> Because there are both total phosphorus and dissolved oxygen load allocations assigned within different segments of the SR-HC TMDL reach, it must be clearly understood that Upstream Snake River segment (RM 409 to 335) pollutant sources are responsible for those water quality problems occurring in the Upstream Snake River segment. They are not responsible for those water quality problems that would occur if the waters flowing into Brownlee Reservoir met water quality standards and are exclusive to the reservoir. Similarly,

> IPC (as operator of the Hells Canyon Complex) is responsible for those water quality problems related exclusively to impoundment effects that would occur if inflowing water met water quality standards. (SR HC TMDL pg. 450)

The DEQ used a mass balance analysis to determine the reservoir DO deficit after upstream reductions in nutrients. Using a mass balance approach, they set the allocation for two reservoir zones:

> The dissolved oxygen allocation requires the addition of 1,125 tons of oxygen (1.02 x106 kg) into the metalimnion and transition zone of Brownlee Reservoir (approximately 17.3 tons/day (15,727 kg/day)). The total dissolved oxygen mass required to address the loss of assimilative capacity in the metalimnion over this time frame is 1,053 tons (957,272 kg). This is equivalent to an even distribution of 16.2 tons/day (14,727 kg/day) over 65 days. The total dissolved oxygen mass required to address the loss of assimilative capacity in the transition zone over this time frame is 72 tons (65,454 kg). This is equivalent to an even distribution of 3.0 tons/day (2,727 kg/day) over 24 days. (SR HC TMDL pg. 450)

To support this allocation, IPC provided reservoir modeling (SR-HC TMDL Appendix 7) that had been developed with support from Tom Cole/USACOE and Scott Wells/PSU, the model developers. Prior to performing the SR HC TMDL modeling, the model was peer reviewed by agency modelers including: John Yearsley/EPA, Stuart Woods/USGS, and Merlin Bender/USBR. Additionally, prior to using IPC modeling to support the SR HC TMDL allocations, the DEQs, with EPA, performed their own publicly attended modeling review effort that included additional review by stakeholders, agencies, NGOs and others.

Based on this extensive model review effort, the DEQs concluded:

> Although it was recognized in all peer reviews that no model will ever be a perfect fit for any system, all reviewers from all of the peer review efforts indicated that they felt confident with the manner in which the model had been validated and applied to the Hells Canyon Complex (SR-HC TMDL pg. 300).

The DEQ review process included assessment of the CE-QUAL-W2 model formulation, boundary and initial condition settings, parameterization, and calibration. And while the model continues to evolve, it should be noted that the organic matter and sediment modeling approaches used to model Brownlee to support the SR HC TMDL are consistent with the most current public release version of CE-QUAL-W2. The sediment modeling approach used both a zero-order model (SOD) and a first order model (SED) to represent current and future organic matter degradation. Other more research oriented sediment diagenesis models were and are available, including an option for sediment diagenesis in the current public release version of CE QUAL W2. However, to our knowledge this option has not been extensively tested and broadly applied. Therefore, the analyses and determination relative to the effects of Brownlee Reservoir that is contained within the EPA-approved SR HC TMDL remains viable, and in fact, represents the best available information regarding the contribution of Brownlee Reservoir to degraded DO conditions within the reservoir.

6.2.3.2. Oxbow and Hells Canyon Reservoirs

Because Oxbow and Hells Canyon reservoirs were not explicitly assigned a level of responsibility for DO conditions within the HCC. The SR HC TMDL did not define the level of DO effects associated with those specific projects. Therefore, IPC used DO data that has been collected over the past 14 years to characterize the effects of Oxbow and Hells Canyon reservoirs on DO. Based on the long-term data set, Oxbow and Hells Canyon reservoirs appear to have a slight overall positive effect on DO when inflowing levels of DO are compared to outflowing DO levels.

6.2.3.3. Downstream

Currently HCD outflow DO is below applicable criteria beginning in July through the end of the December (Figure 6.2-13). As discussed previously, the current DO deficits from criteria are primarily a result of degraded conditions in Brownlee Reservoir that are resulting from excessive levels of inflow nutrient and organic matter and processes occurring within Brownlee Reservoir. DO concentrations at Brownlee outflow carry through Oxbow and Hells Canyon reservoirs with a slight increase in DO overall (Figure 6.2-13). This supports that as DO conditions in Brownlee Reservoir and Brownlee outflow improve, the outflow DO from the HCC will also improve. There are indications that improvements in both the HCC outflow DO and Brownlee Reservoir inflowing TP are currently occurring. DO conditions during the cold-water aquatic life period at the HCC outflow (Table 6.2-8) are trending up, while at the same time, TP concentrations flowing into Brownlee Reservoir are decreasing (Figure 6.1-10). While inflowing TP concentrations still do not meet the SR HC TMDL target of 0.07 mg/L, the declining trend may indicate that efforts to improve conditions upstream of Brownlee as envisioned in the SR HC TMDL are being implemented and are effective. While not a direct linkage to inflowing TP concentrations, the improvements in HCC outflow DO follow a complementary trajectory.

Modeling indicates that if these trends continue, when the SR HC TMDL is fully implemented, DO may meet the applicable criteria at Hells Canyon outflow without any additional efforts by IPC. This is based on comparing the annual average deficits currently measured (Table 6.2-9) to the average modeled SR HC TMDL improvements (Table 6.2-11). Based on discussions with the DEQ, despite the modeled SR HC TMDL improvements the DEQs have expressed a desire to address current annual average HCC outflow DO deficits downstream of HC Dam due in part to offset the potential long time frame expected for the effects of full SR HC TMDL implementation to be realized. IPC estimated the magnitude of the DO deficits downstream of HC Dam that need to be addressed currently by using the measured annual average DO deficits after incorporating the reaeration that is occurring through the HC turbines and immediately downstream of the dam. The measured annual average deficits IPC used are the average values from the most recent 8 years of data which is appropriate given the improving trends in DO and TP conditions. These values are 0.8 and 1.4 mg/L (Table 6.2-9), are reduced by the reaeration occurring through the HC turbines and downstream of 0.4 and 0.2 mg/L (Figure 6.2-17), to result in 0.4 and 1.2 mg/L as annual average DO deficits to be addressed currently during the cool-water aquatic life and salmonid spawning periods, respectively.

IPC proposes to implement distributed aeration at the Brownlee Powerhouse, which is currently partially underway (see Section 7.2. DO Proposed Measures), that will be operated to add as much additional DO as possible whenever incoming DO to Brownlee Powerhouse is less than applicable criteria below HCD. This will address IPC's proposed DO supplementation goal of 0.4 and 1.2 mg/L during the cool-water aquatic life and salmonid spawning period, respectively. Both these requirements will be calculated as an annual average DO uptake at the Brownlee Powerhouse. This level of aeration offsets the current downstream DO deficits, incorporates reaeration that is occurring immediately downstream of HCD, addresses the uncertainty in the time frame for full upstream SR HC TMDL implementation and provides assurance that downstream standards will be met in the future.

6.2.3.3. Oxbow Bypass

The deep pool in the Oxbow Bypass was not specifically included in DO simulations following full SR–HC TMDL implementation. Currently, this deep pool becomes thermally stratified and anoxic conditions occasionally develop in the deep, cooler water during the summer season. Improved DO conditions in Oxbow and Hells Canyon reservoirs following SR–HC TMDL implementation suggest anoxic conditions may no longer develop in this pool. However, this is not known to be the case. Therefore, IPC will address the development of anoxic conditions in the deep pool in the Oxbow Bypass. Specific measures to accomplish this are described in Section 7.2. DO Proposed Measures.

6.3. TDG

TDG is a measure of the sum of partial pressures of all dissolved gases in water, including water vapor. Typically, in most natural waters, TDG is a measure of how much nitrogen, oxygen, argon, carbon dioxide, and water vapor are dissolved in a given amount of water. Although slightly elevated TDG levels can occur naturally, a TDG saturation of 100% means the water is saturated relative to atmospheric conditions. Levels exceeding 100% of saturation, or supersaturation, can be detrimental, or even lethal, to aquatic life.

Gas supersaturation downstream of large-scale hydroelectric projects typically occurs when air becomes entrained in water released over a spillway and plunges deep into a stilling basin. The hydrostatic pressure at depth causes entrained atmospheric gases to be absorbed into solution. This process creates the supersaturation of gases relative to surface or atmospheric pressures. Also, oxygen production by aquatic plants through photosynthesis can cause supersaturated conditions (Goldman and Horne 1983).

The solubility of atmospheric gases in water is primarily affected by temperature and pressure. While increased temperature decreases the solubility of gases in water, increased pressure on a liquid enhances its capacity to hold dissolved gases. Pressure at depth, caused by greater hydrostatic head, allows deeper water to hold more dissolved gases than shallow water. Each meter of depth increases the solubility of the dissolved gases to compensate for approximately 10% of the supersaturation (Weitkamp and Katz 1980). Consequently, the depth distribution of the organisms determines the effects of TDG levels on aquatic life. For example, a surface measurement of 120% of saturation corresponds to a compensated effect to aquatic life of 110% of saturation 1 m below the surface. In reservoirs and large rivers with elevated TDG levels, such as the HCC and Snake River downstream, little of the water volume is likely to have supersaturation gas effects on aquatic organisms (Weitkamp 1974).

The Oregon *2012 Integrated Report* (ODEQ 2014) does not have the Snake River or the HCC reservoirs listed as impaired by TDG (Table 5.1-1). Idaho's *2012 Integrated Report* (IDEQ 2014) listed TDG in category 4a as a pollutant impairing beneficial uses with a TMDL completed and approved in Oxbow and Hells Canyon reservoirs and the Snake River downstream of HCD to the confluence with the Salmon River (Table 5.1-2). A loading analysis performed by the IDEQ and ODEQ for the SR–HC TMDL identified that elevated TDG levels in the Snake River from Brownlee Dam to the confluence with the Salmon River were the result of releasing water over spillways of dams in the HCC, stating spills at Brownlee Dam and HCD were the sources of elevated TDG (IDEQ and ODEQ 2004). As such, the entire load was allocated to IPC. The load allocation is less than 110% of saturation at the edge of the aerated zone and applies to each location where spill occurs except when flow exceeds the 10-year, 7-day (7Q10) average flood.

6.3.1. TDG Standards and SR–HC TMDL Targets

Oregon and Idaho both have numeric criterion not to exceed 110% of saturation at atmospheric pressure at the point of sample collection (OAR 340-041-0031(2))[28] and IDAPA 58.01.02.250.01.b.). This criterion does not apply with respect to excess flows. In Oregon, the criterion does not apply when flows exceed the 7Q10 average flood. In Idaho, the director of the IDEQ has the authority to specify the applicability of the gas supersaturation criterion with respect to excess flow (IDAPA 58.01.02.300.01.a.).[29] The SR–HC TMDL identified excess flow as the Oregon standard and the point of sample collection as the edge of the aerated zone (IDEQ and ODEQ 2004).

6.3.2. Conditions Relative to TDG

Spilling at the HCC projects is almost exclusively involuntary, occurring usually as a result of flood-control constraints or high-runoff events (IDEQ and ODEQ 2004). Spilling typically occurs between December and July in higher water years when Snake River flows exceed the project's flood-storage capacity, as mandated by the USACE, or the hydraulic capacity of generation turbines. Other unusual situations, including emergencies or unexpected unit outages, can induce a spill episode at any of the projects.

Spilling water at any of the 3 projects within the HCC can increase TDG to supersaturation levels that exceed the 110% of saturation criterion. TDG levels were measured immediately downstream of the spillway and do not necessarily represent levels at the edge of the aerated zone. During spills above 3,000 cfs at Brownlee Dam, TDG levels in spilled water consistently exceeded the 110% of saturation criterion and were measured as high as 128% (Figure 6.3-1). TDG levels downstream of the spillway were significantly higher than reservoir levels

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[28] Oregon also has a 105%-of-saturation criterion specific to hatchery-receiving waters and waters less than 2 feet deep that does not apply to the HCC.

[29] With respect to gas supersaturation, the IDEQ director also has the authority to 1) direct all known and reasonable measures to be taken to ensure the protection of fishery resources and 2) require operational procedures or project modifications not to contribute to increased mortalities of juvenile migrants or impose serious delays in adult migrant fishes (IDAPA 58.01.02.300).

(P < 0.005). The configuration of the Brownlee Powerhouse and spillway creates separation of spill and turbine flows. Monitoring at the bridge immediately below Brownlee Dam indicates limited mixing of spill and powerhouse flows at that location until spill flows reached 35,000 cfs (Exhibit 6.3-1). Assuming full hydraulic capacity of the turbines (approximately 35,000 cfs), this flow (i.e., approximately 70,000 cfs) was higher than the 7Q10 average flood flow of 67,898 cfs. Exhibit 6.3-1 also indicated TDG levels measured below Brownlee Dam can be higher than the maximum of 128% measured in 1997 and 1998, with little dissipation downstream through Oxbow Reservoir.

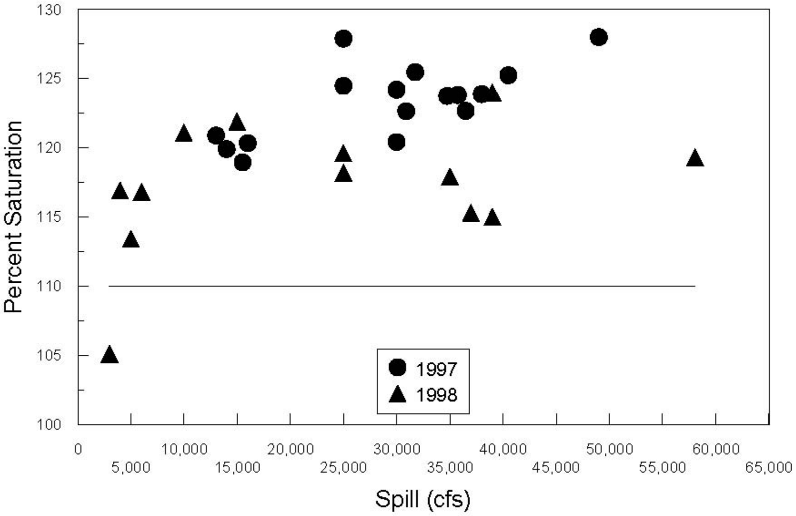

Figure 6.3-1
The relationship of spill in cfs and TDG percent of saturation measured downstream of Brownlee Dam, 1997–1998. (Note: Add 35,000 cfs to spill to estimate the total Snake River flow. The TDG percent of saturation is measured near the spillway prior to mixing with turbine flow.)

TDG levels measured in the spill of Oxbow Dam were similar to those measured in the spill of Brownlee Dam and exceeded the criterion (Figure 6.3-2). In 1997 and 1998, the TDG levels measured at Oxbow Dam did not necessarily represent independent Oxbow Dam spill events, as water was also being spilled at Brownlee Dam. TDG levels in Oxbow Reservoir ranged upwards to 125% of saturation. Evaluation of these data and data collected downstream of Oxbow Dam indicated increases and decreases in TDG levels were measured (Figure 6.3-3). The largest increase in saturation (approximately 20%) occurred during a spill rate of 12,000 cfs. The largest decrease in saturation (approximately 13%) occurred during a spill rate of 2,000 cfs. At Oxbow Dam, spill rates less than 2,000 cfs and greater than 24,000 cfs lowered TDG levels in the spilled water, while spill rates between 5,000 and 24,000 cfs increased TDG levels. Seattle Marine Laboratories (1972) found that dissolved nitrogen (DN) levels decreased on all days sampled as a result of spill at Oxbow Dam, but they did not address rates of spill.

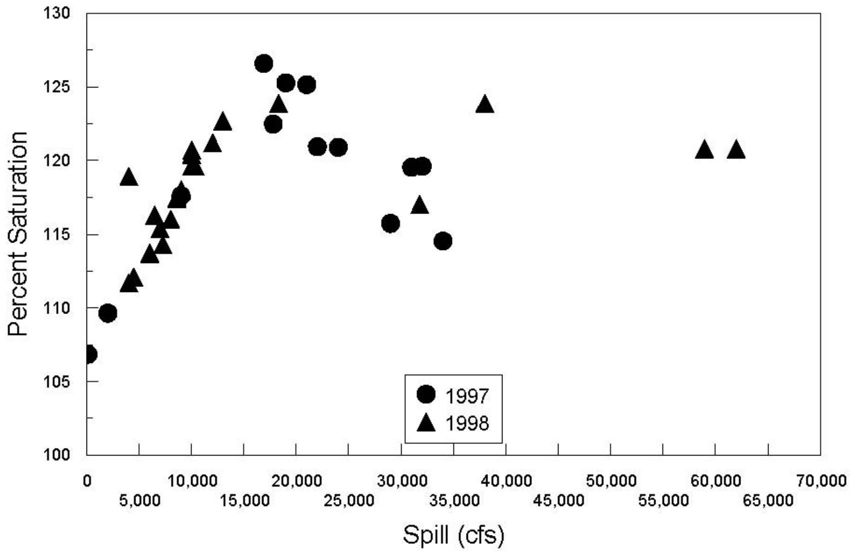

Figure 6.3-2
The relationship of spill in cfs and TDG percent of saturation measured downstream of Oxbow Dam, 1997–1998. (Note: Add 28,000 cfs to spill to estimate the total Snake River flow. The TDG percent of saturation is measured near the spillway prior to mixing with turbine flow.)

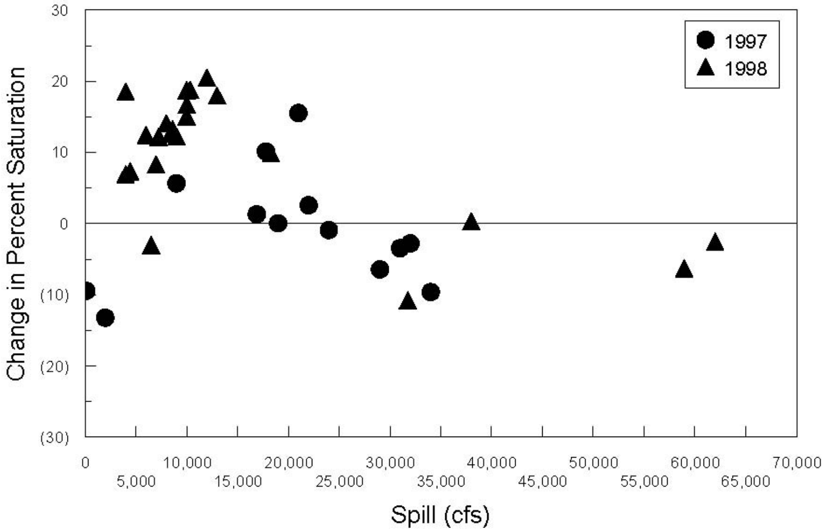

Figure 6.3-3
Change in TDG percent of saturation above and below Oxbow Dam over a range of spill in cfs, 1997–1998. (Note: Parenthetic numbers indicate a decrease in TDG levels below Oxbow Dam.)

Monitoring in 2006 allowed an evaluation of spill at Oxbow Dam independent of Brownlee Dam spill (i.e., when Oxbow Reservoir forebay TDG levels were less than 110% of saturation). These data showed that when the Oxbow Reservoir forebay was below the criterion, spill at Oxbow Dam increased TDG levels to approximately 128% of saturation in the bypassed reach (Figure 6.3-4). As in 1997 and 1998, similar patterns of increases and decreases in TDG levels resulting from spill at Oxbow Dam were also measured (Exhibit 6.3-1).

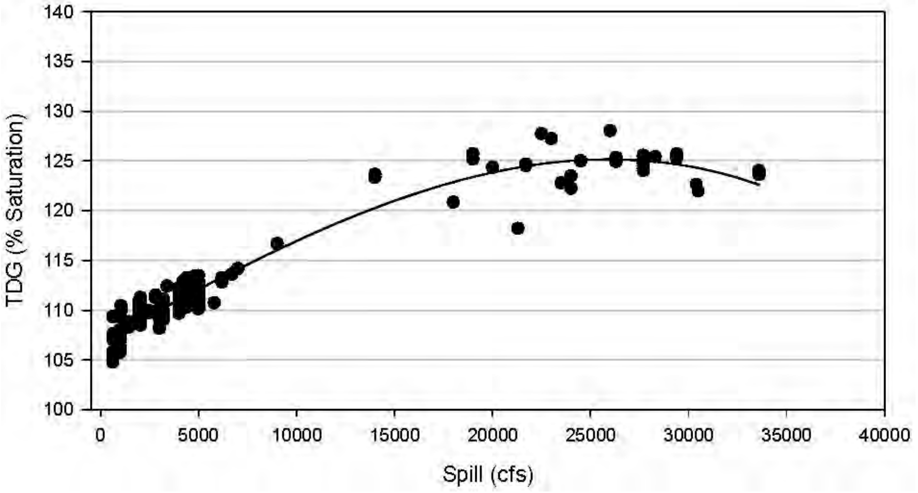

Figure 6.3-4
The relationship of spill in cfs and TDG percent of saturation (% saturation) at Oxbow Dam in 2006 when inflow water to the Oxbow spillway was less than 110% of saturation

TDG levels in the HCD tailwater were significantly higher than reservoir levels during periods of spill ($P < 0.005$), ranging up to 133% of saturation (Figure 6.3-5). Hourly measures taken in 1999 ranged up to 136% of saturation, showing a clear relationship between spill and TDG levels despite considerable variability in TDG at similar spill rates (Figure 6.3-6). Nearly all rates of spill produced TDG levels exceeding the criterion. Supersaturation declined in the Snake River as water flowed downstream of HCD (Figure 6.3-7). Levels in excess of 110% of saturation persisted downstream to the confluence with the Salmon River (RM 188) when spilling approximately 20,000 cfs or greater at HCD. More detail on HCC TDG is available in Technical Report E.2.2-4 (Myers and Parkinson 2003), which accompanied the *New License Application: Hells Canyon Hydroelectric Complex*.

The daily average flow from HCD from 1968 through 2003 was used to generate a flow-duration curve (Figure 6.3-8). The 7Q10 average flood, as calculated below HCD, is 71,498 cfs. This represents less than 1% of the flows at HCD. Similar average flood statistics were estimated for both Oxbow and Brownlee dams by subtracting major tributary flows. The 7Q10 average flood is 69,062 cfs at Oxbow Dam and 67,898 cfs at Brownlee Dam.

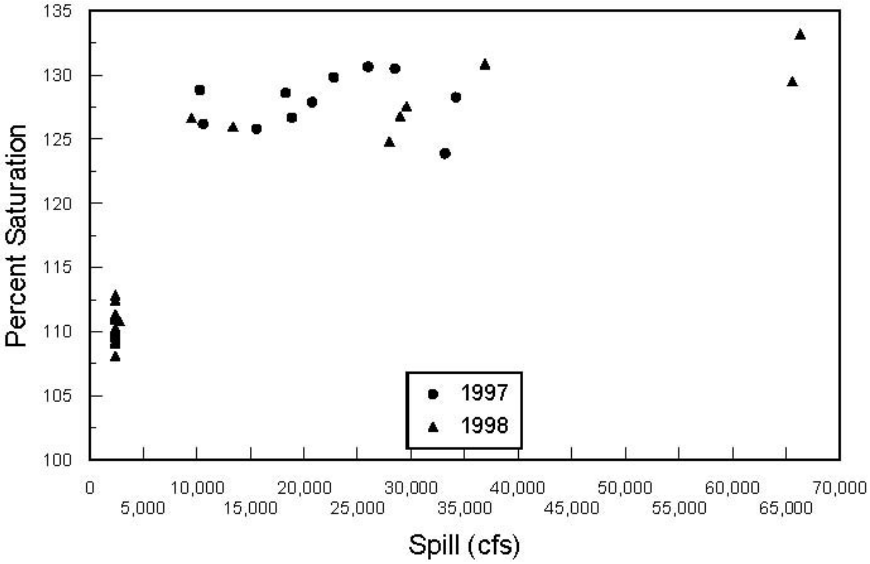

Figure 6.3-5
The relationship of spill in cfs and TDG percent of saturation measured at the Hells Canyon boat launch downstream of HCD, 1997–1998. (Note: Add 30,500 cfs to spill to estimate the total Snake River flow. These data are presumed to represent a mix of turbine and spill waters.)

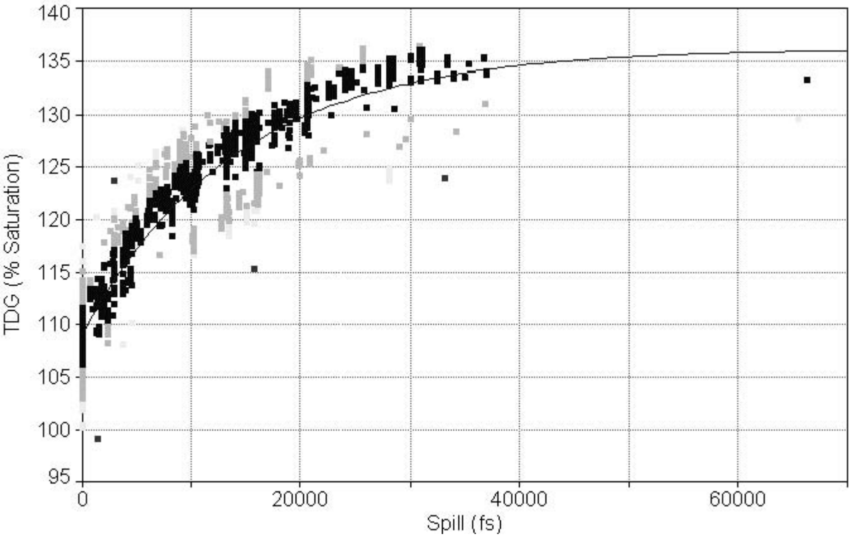

Figure 6.3-6
The relationship of spill in cfs and TDG percent of saturation (% saturation) measured below HCD from March 3–July 20, 1999. (Note: Add 30,500 cfs to spill to estimate the total Snake River flow. These data are presumed to represent a mix of turbine and spill waters.)

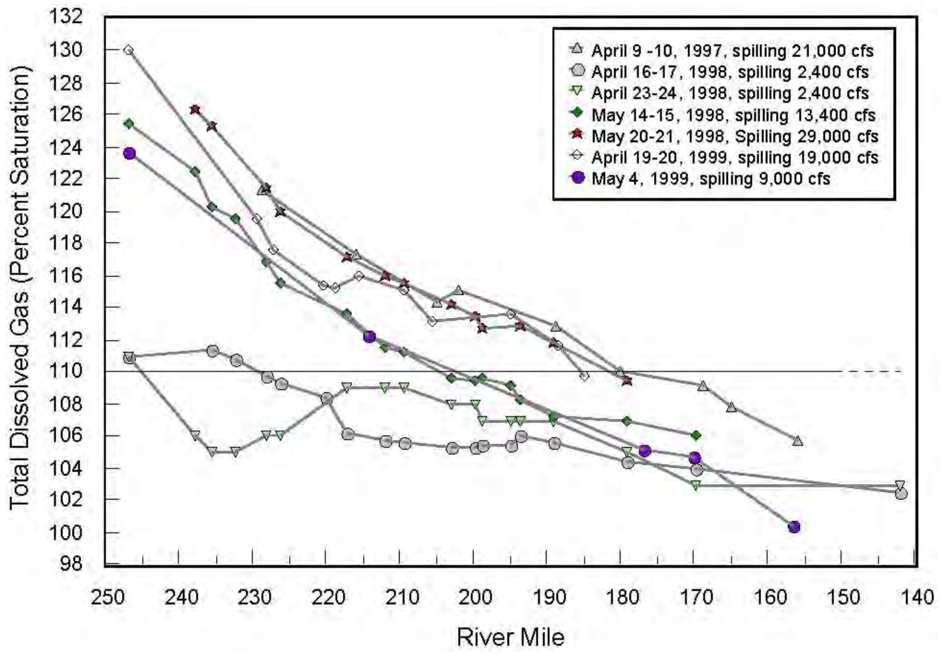

Figure 6.3-7
Downstream dissipation of TDG in the Snake River within Hells Canyon relative to the 110% saturation criterion. (Note: Add 30,500 cfs to spill to estimate the total Snake River flow. The TDG percent of saturation can be a combination of gas dissipation and mixing with turbine flows.)

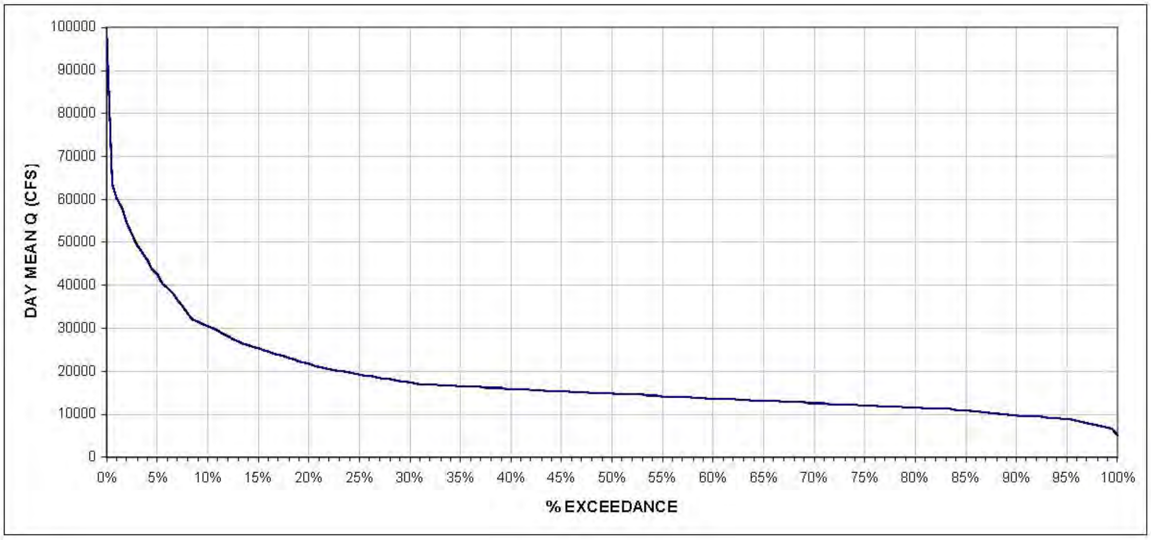

Figure 6.3-8
HCD daily average flow (day mean Q) in cfs flow-duration curve in percent of exceedance for the October 1968–February 2003 period of record

6.3.3. HCC Contribution to TDG

The SR–HC TMDL defined the load allocation for TDG as less than 110% of saturation at the edge of the aerated zones below Brownlee, Oxbow, and Hells Canyon dams (IDEQ and ODEQ

2004). The load applies to all flows not exceeding the 7Q10 average flood. The entire load was allocated to IPC because the SR–HC TMDL identified spill at Brownlee Dam and HCD as the sources of elevated TDG in the reach.

IPC recognizes that spillway releases from the HCC projects elevate TDG levels that have the potential for negative effects on aquatic life. External symptoms of gas-bubble trauma (GBT) have been observed on returning adult anadromous salmonids captured at HCD during periods of spill. These fish must migrate through the lower Columbia and Snake River hydroelectric projects on their way to HCD. The effects of Columbia River elevated TDG levels on fish have been well documented (McGrath et al. 2006).

No symptoms of GBT have been observed on juvenile SRFC salmon collected downstream of the HCC in sampling conducted by the U.S. Fish and Wildlife Service (FWS) (W. Connor, FWS, pers. comm.). The uppermost sampling location was approximately 20 miles downstream of HCD (RM 227.6). TDG levels measured near that location in April and May from 1997 through 1999 during spill over 9,000 cfs ranged from approximately 116 to 122% of saturation (Figure 6.3-7). The lack of GBT symptoms observed in juvenile SRFC salmon in Hells Canyon corroborated recent literature. McGrath et al. (2006) reviewed recent research on the effects of TDG levels on migratory juvenile and adult salmonids in the Columbia River. They concluded the newer research supports the previous research, indicating short-term exposure of up to 120% of saturation does not produce significant effects on migratory juvenile or adult salmonids when compensating depths are available. Weitkamp (2008) made a similar conclusion after summarizing the available literature from 1980 to 2007.

HCC resident fish were monitored for signs of GBT during spill in spring 2006 (Exhibit 6.3-1). GBT symptoms were observed only when TDG levels were greater than 120% of saturation within at least 12 hours prior to sampling. Severe GBT signs were observed when TDG exceeded 125% of saturation (daily average near 130%). Again, these results corroborated the research reviewed in McGrath et al. (2006) and Weitkamp (2008).

Under current operations, IPC minimizes spilling water. Therefore, further decreasing spill flow to manage TDG levels is not possible. Spilling water typically occurs only in association with high spring runoff events, USACE-mandated flood-control operations, or unplanned equipment failure.

6.4. Nuisance Algae

Algae are vitally important to freshwater ecosystems, and most species neither reach nuisance levels nor become harmful to human and animal health. Oregon has listed Brownlee Reservoir and the Snake River upstream as water-quality limited due to nuisance algal growths (Table 5.1-1). Idaho has listed similar waters as water-quality limited due to DO and TP (Table 5.1-2). The SR–HC TMDL presented data on excessive TP concentrations in the Snake River inflow to Brownlee Reservoir and reported nuisance algal growths have been routinely observed in the Snake River and the upper end of Brownlee Reservoir (IDEQ and ODEQ 2004). The IDEQ and ODEQ concluded the excessive nutrients were not wholly attributable to natural sources and established a 0.07-mg/L TP target, which correlated to a 14-µg/L average chlorophyll *a* concentration, for the protection of designated aquatic-life uses.

Additionally, a 30-µg/L nuisance threshold is not to be exceeded more than 25% of the time. Since water quality needed to protect aquatic life is likely more stringent than water quality needed to protect water supply and recreation uses, the targets were assumed to also be protective of these uses.

A harmful algal bloom (HAB) can occur when certain types of microscopic algae are present in high concentrations and produce toxic substances that harm people, pets, and livestock. HABs are most often caused by cyanobacteria. Cyanobacteria are a type of photosynthetic bacteria of the Cyanophyta taxon commonly referred to as blue-green algae. Cyanobacteria can grow as single-celled organisms, as a colony that may look like strands, or bunched together in mats or spherical clusters. When cyanobacteria begin to grow rapidly (e.g., when nutrients, temperature, pH, and light are conducive to exuberant growth) a cyanobacteria bloom can result. These blooms can appear as visible green, blue-green, or reddish brown foam, scum, or mats that float on or near the water surface. Depending on the species present, these blooms or the subsequent bloom die-off can be associated with toxins being present, representing a threat to human and animal health.

6.4.1. Nuisance Algae Criterion and Standards, SR–HC TMDL Targets, and HAB Guidance Levels

Oregon has numeric criterion for nuisance algal growths. Specifically, natural lakes that do not stratify, reservoirs, rivers, and estuaries may not exceed 15 µg/L (OAR 340-041-0019(1)(B)). Upon determination by the ODEQ that the criterion is exceeded, the ODEQ may conduct studies to describe water quality, determine the probable causes of the exceedance and beneficial-use impact, and develop a proposed control strategy for attaining compliance where technically and economically practicable (OAR 340-041-0019(2)(a)) (i.e., the ODEQ may develop a TMDL and water-quality management plan). Idaho has narrative criteria. Specifically, IDAPA 58.01.02.200.06 states, "waters of the state shall be free from excess nutrients that can cause visible slime growths or other nuisance aquatic growths impairing designated beneficial uses."

The SR–HC TMDL established a TP target not to exceed 0.07 mg/L (IDEQ and ODEQ 2004). This nutrient target correlated to a 14-µg/L chlorophyll *a* mean growing season (May through September) concentration that was established as the nuisance algae target. Further, chlorophyll *a* concentrations were not to exceed a nuisance threshold of 30 µg/L more than 25% of the time.

Since there is an SR–HC TMDL target and an Oregon numeric criterion for nuisance algal growths, IPC evaluated historic data to determine the most stringent of the two. Using historic data, IPC evaluated the reduction needed to lower the maximum chlorophyll *a* measured in the Snake River inflow to Brownlee Reservoir to the Oregon numeric criterion for nuisance algal growths of not to exceed 15 µg/L. The needed percent reduction was then equally applied to all the historic measured values. Comparing the mean growing season concentrations indicated that if chlorophyll *a* was reduced sufficiently to meet Oregon's criterion, the SR–HC TMDL target of 14 µg/L would also be met. The conclusion is that Oregon's criterion is more stringent than the SR–HC TMDL TP target not to exceed 0.07 mg/L, which correlated to a 14-µg/L chlorophyll *a* mean growing season (May through September) concentration that was established as the nuisance algae target (IDEQ and ODEQ 2004). Therefore, IPC evaluated data relative to the Oregon numeric criterion for nuisance algal growth of not to exceed 15 µg/L.

The Oregon Health Authority Public Health Division (OPHD) has guideline values for issuing and lifting public health advisories (OPHD 2016). These include a combined cell count of all toxigenic species, excluding *Aphanizomenon flos-aquae,* of >100,000 cells/mL, *Microcystis* or *Planktothrix* >40,000 cells/mL, or cyanotoxin concentrations as listed in Table 6.4-1. Currently, the IDHW has no HAB action levels, however, IDEQ has developed guidelines for issuing and lifting HAB public health advisories (Table 6.4-2).

Table 6.4-1
Provisional health-based guideline values in µg/L for cyanotoxins in Oregon's recreational waters (OPHD 2016)

Anatoxin-a	Cylindrospermopsin	Microcystin	Saxitoxin
20	20	10	10

Table 6.4-2
Provisional recreational guideline thresholds for cyanotoxins in Idaho's recreational waters (IDEQ 2017a)

Microcystin		Cylindrospermopsin	
Concentration (µg/L)	Cell Count (cells/mL)	Concentration (µg/L)	Cell Count (cells/mL)
4	20,000	8	40,000

96

6.4.2. Conditions Relative to Nuisance Algae and HABs

Nuisance algal growths are often defined by chlorophyll *a* concentration or cell density. However, certain algae taxonomic groups, for example blue-green algae, have been identified as having possible harmful effects. Therefor, the following sections discuss algae conditions relative to both concentration and community structure.

The OPHD and IDHW are the state agencies that issue public health advisories. OPHD (2017), based on an IDHW listing, issued a HAB advisory for Brownlee Reservoir near Morgan Creek in 2017, however, IDHW listed the entirety of the reservoir (IDEQ 2017b). IDHW also issued advisories for parts, or the entirety, of Brownlee and Hells Canyon reservoirs in 2016.

6.4.2.1. Algal Biomass

Algal biomass is often estimated using chlorophyll *a* measures. Because algal cell volumes and weights vary by orders of magnitude (Reynolds 1984), biomass estimates can indicate different trends compared to density measurements (e.g., high densities in areas with low biomass).

Chlorophyll *a* measured in the Snake River immediately upstream of Brownlee Reservoir (RM 345.6) and in the inflow to the reservoir (RM 335 to 340) indicated nuisance algal growths. This corroborated routine observations as reported in the SR–HC TMDL of nuisance algal growth in the Snake River and the upper end of Brownlee Reservoir (IDEQ and ODEQ 2004).

Figure 6.4-1 illustrates the 15-µg/L chlorophyll *a* criterion was exceeded nearly two-thirds of the time, and the SR–HC TMDL nuisance threshold of 30 µg/L was exceeded about 40% of the time between 2002 and 2014 in the Snake River immediately upstream of Brownlee Reservoir (RM 345.6). Median chlorophyll *a* concentrations during 2002 (Figure 6.4-2) were comparable to those measured in the inflow to Brownlee Reservoir (RM 335–340). The difference in the median values were not statistically different (P = 0.383). It may be assumed that median chlorophyll *a* concentrations in the Snake River are similar to those measured in the inflow to the Brownlee Reservoir.

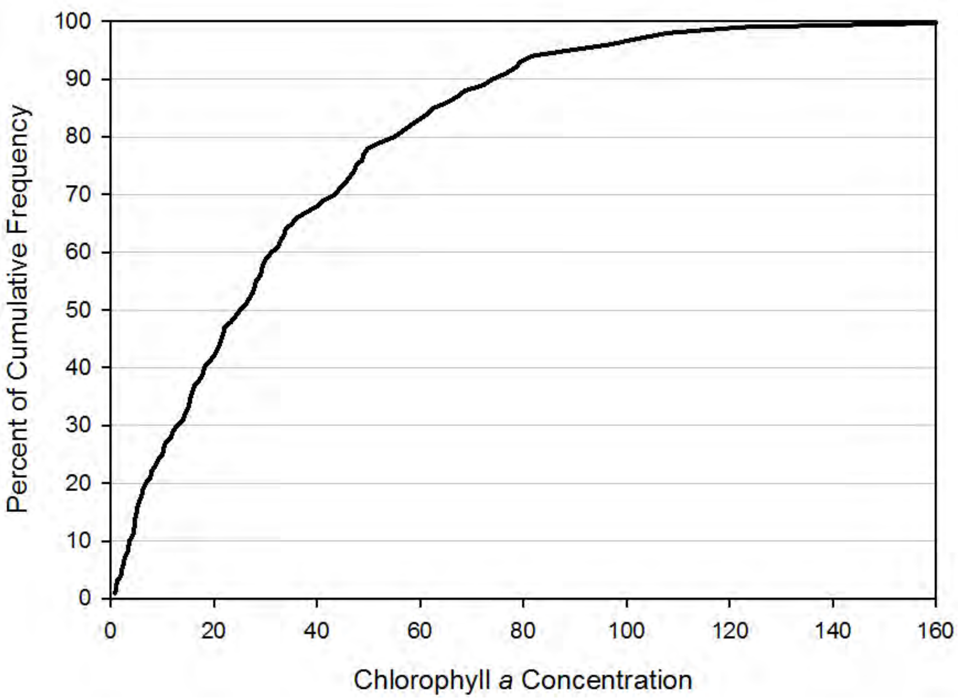

Figure 6.4-1
The percent of cumulative frequency for chlorophyll *a* concentrations in µg/L collected from 2002 through 2014 from the Snake River immediately upstream of Brownlee Reservoir (RM 345.6; N = 333)

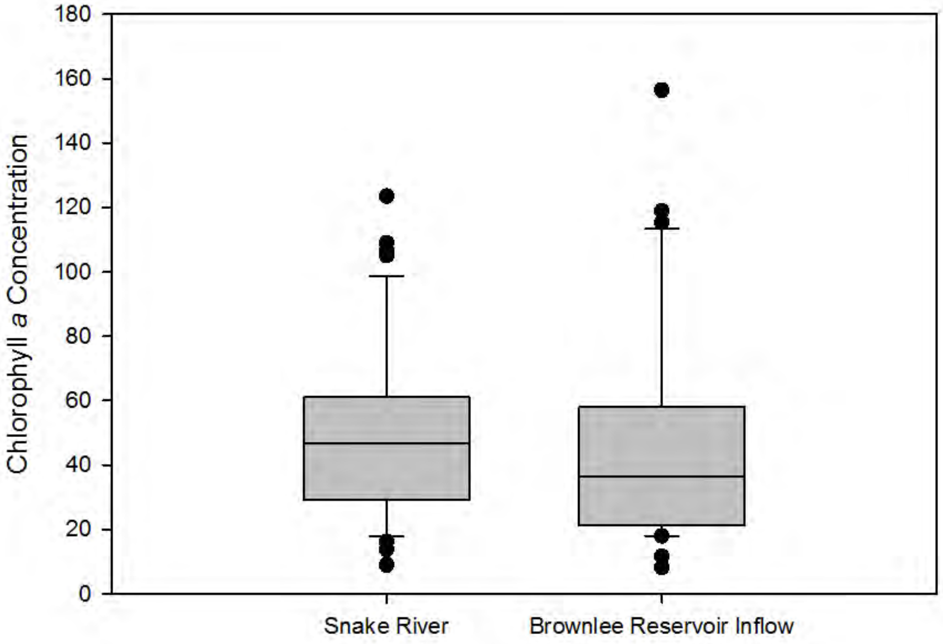

Figure 6.4-2
Interquartile ranges (the box represents the median and the 75th and 25th percentiles; the lines represent the 90th and 10th percentiles) for chlorophyll *a* concentrations in µg/L from the Snake River immediately upstream of Brownlee Reservoir (RM 345.6; N = 43) and in the Brownlee Reservoir inflow (RM 335–340; N = 33) during 2002

Brownlee Reservoir chlorophyll *a* surface measurements (i.e., less than 2.5 m) showed a general decreasing trend from the riverine zone (approximately RM 334 to RM 324) through the transition zone (approximately RM 324 to RM 308) and into the lacustrine zone (Figure 6.4-3). Low chlorophyll *a* concentrations were thereafter maintained downstream throughout the HCC. A maximum chlorophyll *a* concentration of 3,637 µg/L was measured on August 14, 2002, at RM 325. This value was determined to be valid based on the reported pheophytin *a* concentration and the Optical Density ratio of 664 to 665 nanometer light (APHA 1999). This value likely represents sampling of an algal bloom occasionally observed in this area.

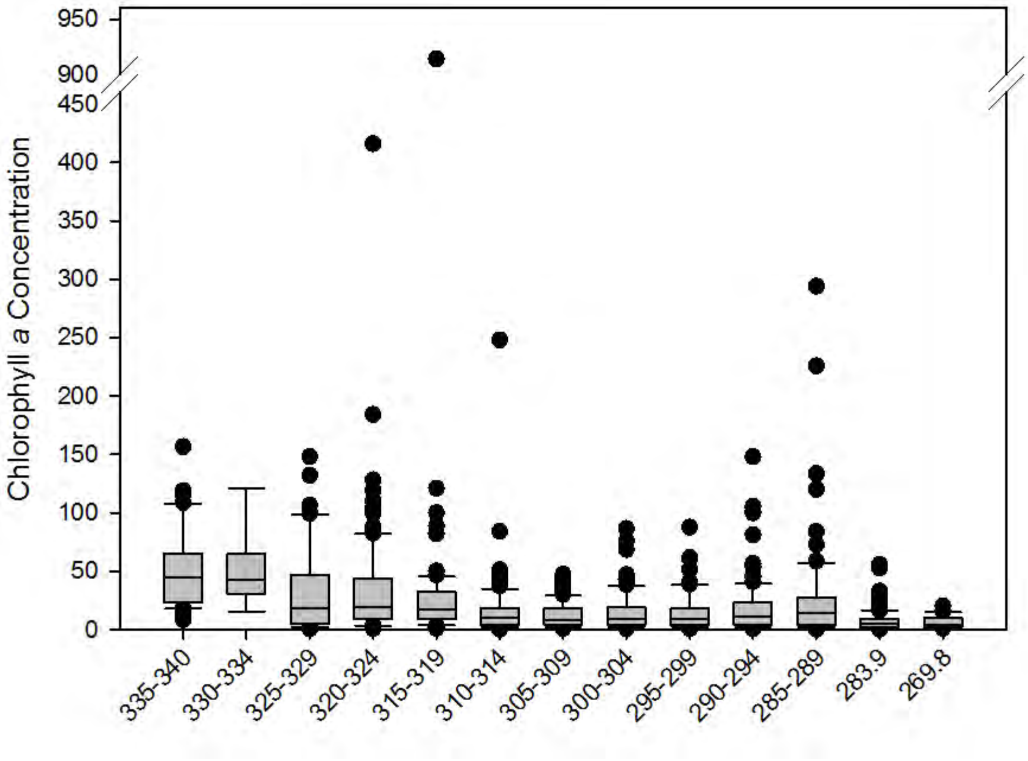

Figure 6.4-3
Interquartile ranges (the box represents the median and the 75th and 25th percentiles; the lines represent the 90th and 10th percentiles) for surface chlorophyll *a* concentrations in µg/L measured year-round from 2002 through 2014, throughout the HCC. The x-axis represents river miles grouped into 5-mile intervals. Concentrations at RM 283.9 represent inflow to Oxbow Reservoir and RM 269.8 represent inflow to Hells Canyon Reservoir.

While much reduced relative to the upper end of Brownlee Reservoir, elevated chlorophyll *a* concentrations (i.e., relative to the criterion) persist through to the discharge of the HCC. While not as frequent as in the Snake River immediately upstream of Brownlee Reservoir, chlorophyll *a* concentrations in the HCC discharge (RM 247) exceeded the 15-µg/L numeric criterion about 7% of the time, and rarely (<1% of the time) was the SR–HC TMDL nuisance threshold of 30 µg/L exceeded between 2002 and 2014 (Figure 6.4-4).

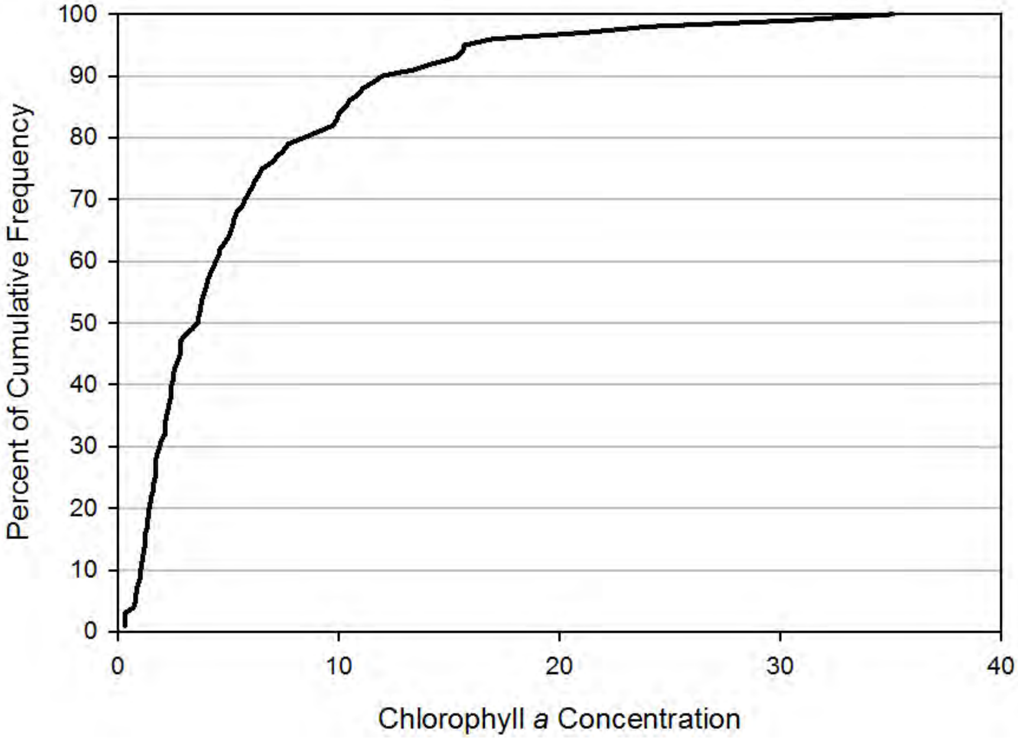

Figure 6.4-4
The percent of cumulative frequency for chlorophyll *a* concentrations in µg/L collected from 2002 through 2014 from the Snake River immediately downstream of the HCC (RM 247; N = 133)

6.4.2.2. Algal Communities

Chrysophyta taxa, originally including all forms of diatoms and multicellular brown algae, dominated spring assemblages throughout the HCC during 1993 and 1994, with the highest algal cell densities in the upper section of Brownlee Reservoir from RM 305 to RM 329 (Myers et al. 2003). More detail on algal communities of the HCC reservoirs is available in Technical Report E.2.2-2 of the *New License Application: Hells Canyon Hydroelectric Complex*. An assemblage shift occurred from spring to summer, resulting in heavy dominance by blue-green algae; predominately the species *Aphanizomenon flos-aquae*. High densities of blue-green algae were measured in Brownlee Reservoir at RM 285 and RM 290 during August 1991 and again in Brownlee Reservoir at RM 320 and in Hells Canyon Reservoir at RM 249 during the summer of 1993 and 1994. In the fall, a general assemblage shift back to Chrysophyta taxa was observed throughout the HCC, with the highest densities in the upper section of Brownlee Reservoir. However, blue-green algae still were dominant lower in Brownlee Reservoir at RM 312 and RM 302. This corroborated observations reported in the SR–HC TMDL of diatom species dominating in faster-moving water with less stratification and blue-green algae species becoming more prevalent as water slowed (IDEQ and ODEQ 2004).

6.4.2.3. Harmful Algae Blooms

Thick surface scums of blue-green algae have been observed in the upper end of Brownlee Reservoir, especially in low water years. *Aphanizomenon flos-aquae* is a species of blue-green algae commonly found in fresh waters. OPHD (2016) reported that although some studies have shown this species to produce toxins in other parts of the world, subsequent evaluations of that work show the species either was or likely was misidentified. Further, they stated *Aphanizomenon flos-aquae* is excluded from calculation of combined cell counts of toxigenic species for issuing public health advisories.

IPC enumerated algal cell density in the HCC during 1993 and 1994. Table 6.4-3 provides the mean cell density for cynaobacteria excluding *Aphanizomenon flos-aquae.* Data indicate there is risk of HABs occurring throughout the HCC during the summer and into the fall in Brownlee Reservoir.

Table 6.4-3
Toxigenic cyanobacteria mean density in thousands of cellsper mL for Brownlee, Oxbow, and Hells Canyon reservoirs in 1993 and 1994

	Brownlee			Oxbow			Hells Canyon		
	April	**July**	**October**	**April**	**July**	**October**	**April**	**July**	**October**
Anabaena flos-aquae	7	329	0	0	0	0	0	645	0
Anabaena spiroides	0	149	0	0	44	0	0	77	0
Oscillatoria sp.	0	0	0	0	0	1	0	0	0
Oscillatoria geminata	0	715	0	0	75	0	0	418	13
Oscillatoria limnetica	0	0	120	0	0	0	0	0	12
Microcystis aeruginosa	0	0	0	0	0	0	0	0	0
Phormidium mucicola	0	0	0	0	0	0	0	0	0
Total	**7**	**1,193**	**120**	**0**	**119**	**1**	**0**	**1,140**	**25**

HABs were observed in both Brownlee and Hells Canyon reservoirs during the summer of 2016 and in Brownlee Reservoir in 2017. *Aphanizomenon*, *Lyngbya*, and *Microcystis* were the dominant genera in 2016. Both cell counts and the concentration of the toxin Microcystin were the basis for the health alert. *Microcystis flos aqua* was the dominant taxon in 2017.

6.4.3. HCC Contribution to Nuisance Algae and HABs

6.4.3.1. Modeling Algae in Brownlee Reservoir

CE-QUAL-W2 (Cole and Wells 2002), a 2-dimensional model, was used to assess algal biomass in Brownlee Reservoir. Version 3.1 allows for model applications with multiple algal groups; however, estimating boundary conditions and optimizing performance requires considerable data and effort. For example, modeling community shifts under SR–HC TMDL conditions would require some estimate of the community shift in the Snake River inflow to Brownlee Reservoir. The current Brownlee Reservoir model application has not been set up and optimized for multiple groups because of this added complexity. Instead, available data and literature were used to predict shifts in the algal community structure with full implementation of the SR–HC TMDL.

6.4.3.1.1. CE-QUAL-W2 Algal Biomass Simulations with SR–HC TMDL Implementation

The CE-QUAL-W2 model simulated Brownlee Reservoir algae with full implementation of the SR–HC TMDL. This included reducing nutrients and organic matter inflow to Brownlee Reservoir (approximately 69% reduction in TP, nitrogen, and organic matter) and reducing SOD (set at 0.1 g of oxygen per m^2 per day). Selected simulation conditions from the optimized model showed predicted algal biomass compared to measured data (Figure 6.4-5). The model predicted chlorophyll *a* concentrations well on June 6, 1995; under-predicted concentrations on both May 3, 1995, and August 9, 1995; and over-predicted concentrations in the upper end of the transition zone on July 5, 1995. Simulated conditions indicated the model represented general algal processes, as indicated by dynamic algal biomass estimates, not just settling (Figure 6.4-6). These processes were illustrated by increased concentrations downstream of the inflow and reduced concentrations further downstream.

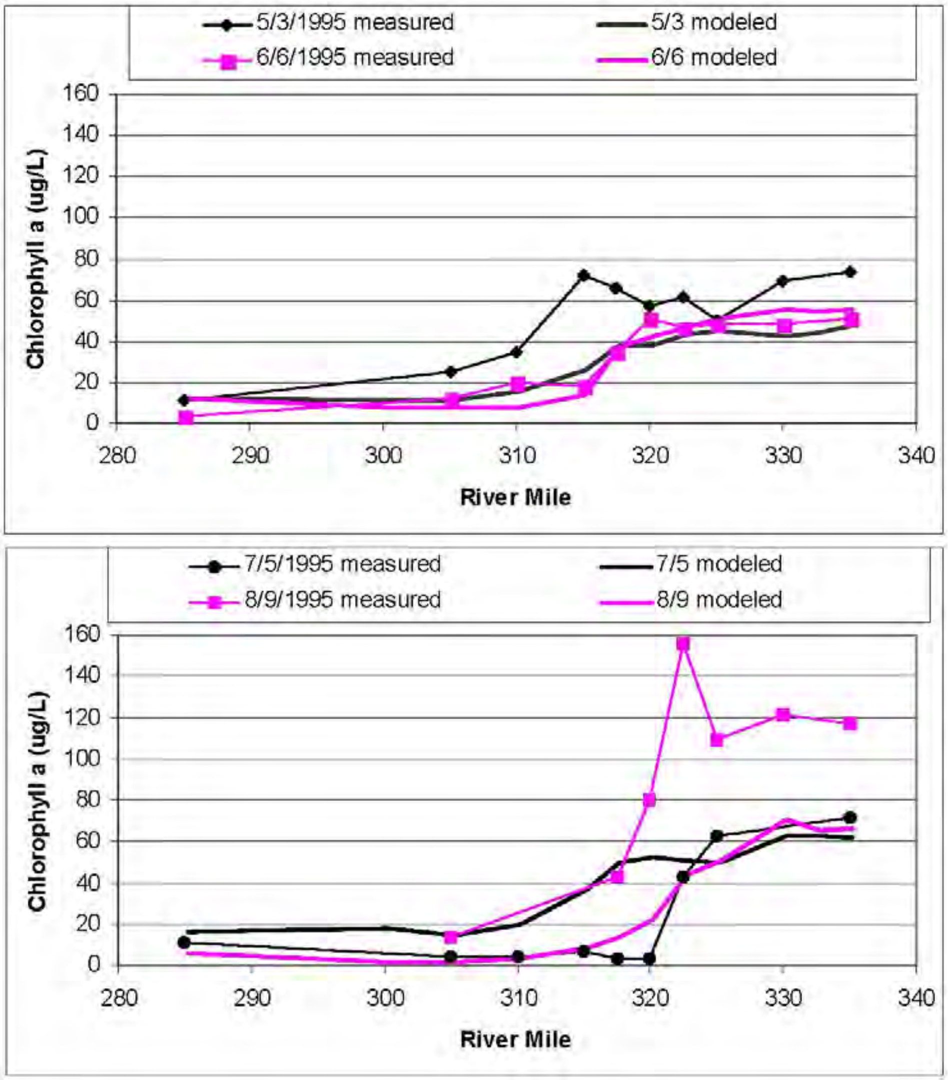

Figure 6.4-5
Baseline simulation results showing modeled and measured chlorophyll *a* concentrations in µg/L in the surface layer of Brownlee Reservoir for selected dates in 1995

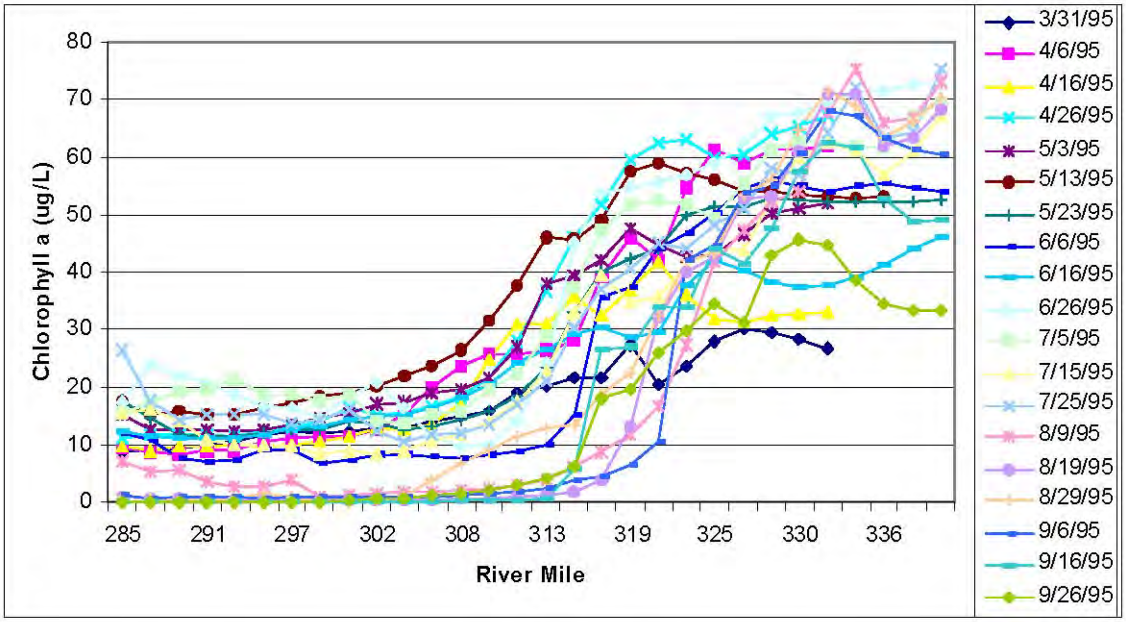

Figure 6.4-6
Modeled surface chlorophyll *a* concentrations in µg/L in Brownlee Reservoir from March 31–September 26, 1995

6.4.3.1.2. Predicted Algal Community Structure

Diatoms tend to dominate in more riverine conditions, especially in the spring. In eutrophic systems, blue-green algae tend to dominate in lower-velocity waters, like the lacustrine zone, with taxa, such as *Microcystis*, *Anabaena*, and *Aphanizomenon*, forming blooms in still, windless conditions (Reynolds 1984). This is caused partly by differences in density and buoyancy. However, Webb (1964) concluded that the Snake River above Brownlee Reservoir carried heavy loads of organic matter in the form of suspended algae, dominated by blue-green algae (*Anabaena*, *Pediastrum*, *Spirogyra*, *Aphanizomenon*, *Staurastrum*, and *Anacystis*), that were produced in the 120-mile reach upstream of Brownlee Reservoir. Worth (1994) observed *Anabaena* and *Microcystis* in the Snake River above Brownlee Reservoir in 1992.

Potential changes in Brownlee Reservoir algal taxa after implementation of the SR–HC TMDL would depend partly on changes that occurred upstream in the Snake River. Because these changes are highly speculative and would have to be set in the model as boundary conditions, algal taxa shifts in Brownlee Reservoir cannot be fully modeled.

6.4.3.2. Nuisance Algae and HAB Reasonable Assurance

The SR–HC TMDL did not establish nuisance algae allocations (IDEQ and ODEQ 2004). Rather, the SR–HC TMDL presented an analysis that develops a TP target of 0.07 mg/L to attain the mean growing season chlorophyll *a* target of 14 µg/L and a nuisance threshold of 30 µg/L, not to be exceeded more than 25% of the time, for the Snake River and the HCC. The Snake River TP target provides reasonable assurance the upstream boundary will not exceed the chlorophyll *a* target and threshold levels, and the community structure will shift toward less problematic taxa (e.g., blue-green algae) and, therefore, a reduced risk of HABs.

The optimized CE-QUAL-W2 model was used to simulate full implementation of the SR–HC TMDL. The simulations showed maximum chlorophyll *a* concentrations would be less than 30 µg/L (Figure 6.4-7). This was consistent with the conclusions in the SR–HC TMDL that state "…the 0.07 mg-TP/L target will eliminate the large peaks in chlorophyll *a* observed in the upper part of the reservoir" (IDEQ and ODEQ 2004). May through September average concentrations were as high as approximately 20 µg/L through the transition zone. More importantly, chlorophyll *a* concentrations did not increase in Brownlee Reservoir. It is expected that if the 14 µg/L chlorophyll a target was met at the inflow to Brownlee Reservoir, chlorophyll *a* concentrations would not exceed the target in the reservoir.

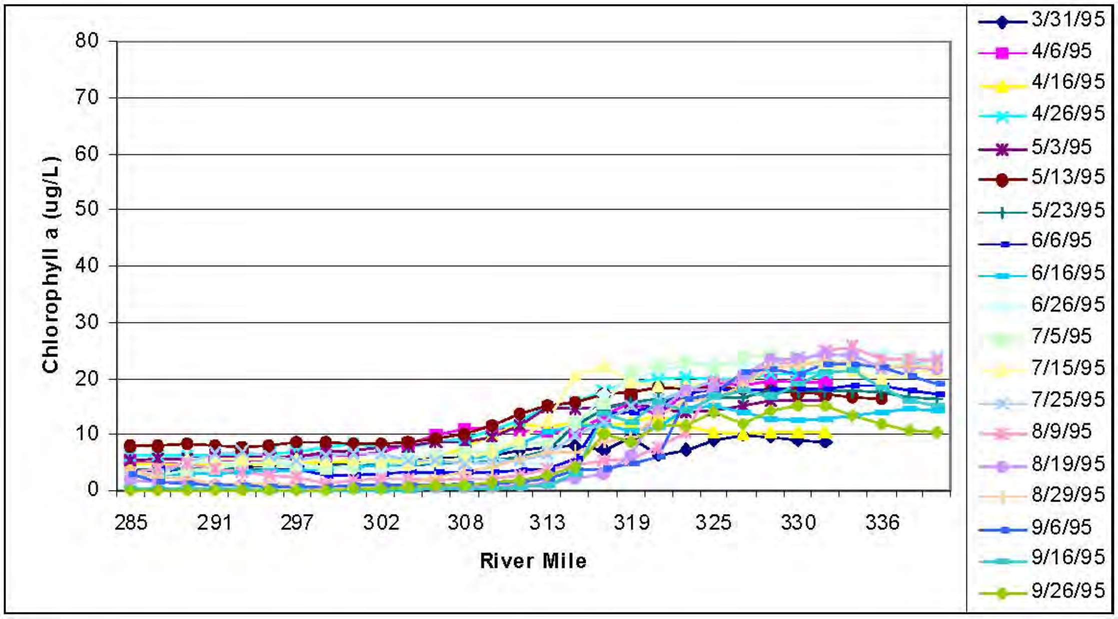

Figure 6.4-7
Modeled surface chlorophyll *a* concentrations in µg/L in Brownlee Reservoir from March 31–September 26, 1995, with full SR–HC TMDL implementation

Further, IPC evaluated data from both impounded and unimpounded waters of the Snake River to determine nuisance chlorophyll *a* concentration thresholds and targets. IPC's findings indicated a nuisance threshold of approximately 30 µg/L and a target between 15 µg/L and 20 µg/L would provide reasonable assurance that designated beneficial uses would be protected in the southwest Snake River and Brownlee Reservoir (Hoelscher 2002). This corroborated with the CE-QUAL-W2 model simulated conditions.

Reduced algae levels following full implementation of the SR–HC TMDL are reasonably assured to protect beneficial uses in the Snake River and the HCC. Lower nutrient loads could result in a shift from blue-green algae to green algae (or other groups) during the summer; however, changes in the HCC algal taxa would depend partly on changes that occurred upstream in the Snake River. Because these changes are highly speculative and would have to be set in the model as boundary conditions, algal taxa shifts in Brownlee Reservoir cannot be fully modeled. Therefore, IPC's proposal includes measures to monitor algal community structure and HABs during recreational periods throughout the HCC as described in Section 7.4. HAB Proposed Measures.

6.5. pH

Oregon has not listed pH as a pollutant limiting the mainstem Snake River (Table 5.1-1). Idaho originally listed Brownlee Reservoir water quality as impaired by pH, as well as the Snake River upstream to the Oregon and Idaho border. As a result of the SR–HC TMDL analysis, Idaho removed pH from the CWA § 303(d) list (Table 5.1-2). The SR–HC TMDL concluded pH CWA § 303(d) listings are not supported by the available data (IDEQ and ODEQ 2004):

> Based on these findings, the SR–HC TMDL process recommends that the mainstem Snake River from RM 409 to 347 and from RM 335 to 285 [Brownlee Reservoir] be delisted for pH by the State of Idaho.

6.5.1. pH Standards and SR–HC TMDL Targets

Oregon's criteria for pH in the mainstem Snake River basin are 7.0 to 9.0 SUs (OAR 340-041-0124). However, waters impounded by dams existing on January 1, 1996, having pH values that exceed the criteria are not in violation of the standard if the ODEQ determines the exceedance would not occur without the impoundment, and all practicable measures have been taken to bring the pH in the impounded waters into compliance (OAR 340-0410-0021(2)). Idaho's criteria for pH in fresh waters are 6.5 to 9 SUs (IDAPA 58.01.02.250.01.a.).

A pH range of 7 to 9 SUs has been established as the target for the SR–HC TMDL to support aquatic life (IDEQ and ODEQ 2004). This target applies year-round from RM 409 throughout the HCC to RM 188.

6.5.2. Conditions Relative to pH

Most of the pH concentrations measured throughout the HCC were within the SR–HC TMDL target range of 7 to 9 SUs (Figure 6.5-1). Values less than 7 SUs were less common than values greater than 9 SUs (Table 6.5-1). This corroborated the SR–HC TMDL findings that the lowest pH value observed in Brownlee Reservoir was 7.4 SUs, while the highest was 9.6 (IDEQ and ODEQ 2004). Almost all pH measures were within the target range in Oxbow Reservoir, while exceedances increased slightly in Hells Canyon Reservoir.

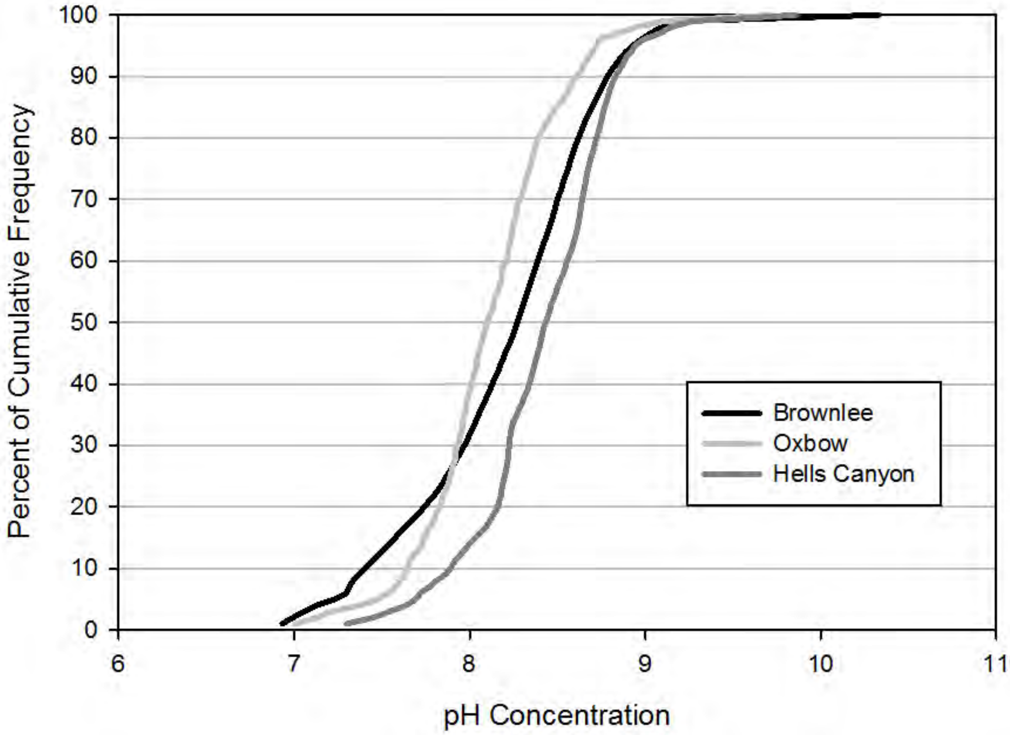

Figure 6.5-1
Percent of cumulative frequency curves for pH concentration in SUs as measured in Brownlee, Oxbow, and Hells Canyon reservoirs from 1990 through 2014

Table 6.5-1
Percent exceedance of pH concentration measures in SUs for the Snake River upstream of the HCC; Brownlee, Oxbow, and Hells Canyon reservoirs; and the HCC discharge from 1990 through 2014

		Percent of pH Concentration Measures		
	N	Less Than 7	Greater Than 9	Total
Snake River Upstream	1,080	1.1	17.6	18.7
Brownlee Reservoir	134,062	2.1	3.5	5.6
Inflow	512	1.8	12.1	13.9
Riverine	3,800	1.5	14.2	15.7
Transition	33,964	2.1	6.5	8.6
Lacustrine	96,056	2.2	2.0	4.1
Oxbow Reservoir	1,604	0.7	1.6	2.3
Hells Canyon Reservoir	15,910	0.1	3.9	4.0
Snake River Downstream	815	2.3	1.2	3.5

Brownlee Reservoir receives inflowing water from the Snake River, and the frequency of pH concentrations above and below the target range was similar in the inflow and riverine zones to the Snake River upstream (Figure 6.5-2). The other zones of Brownlee Reservoir had exceedances of the target range (Table 6.5-1), although they were less than 10% of the measurements, and the frequency of exceedance decreased with both distance and depth from the Snake River inflow. Overall, pH concentrations were moderated through the HCC as illustrated by the substantially lower level of values outside the target range in the Snake River immediately downstream of the HCC as compared to the Snake River upstream (Figure 6.5-3).

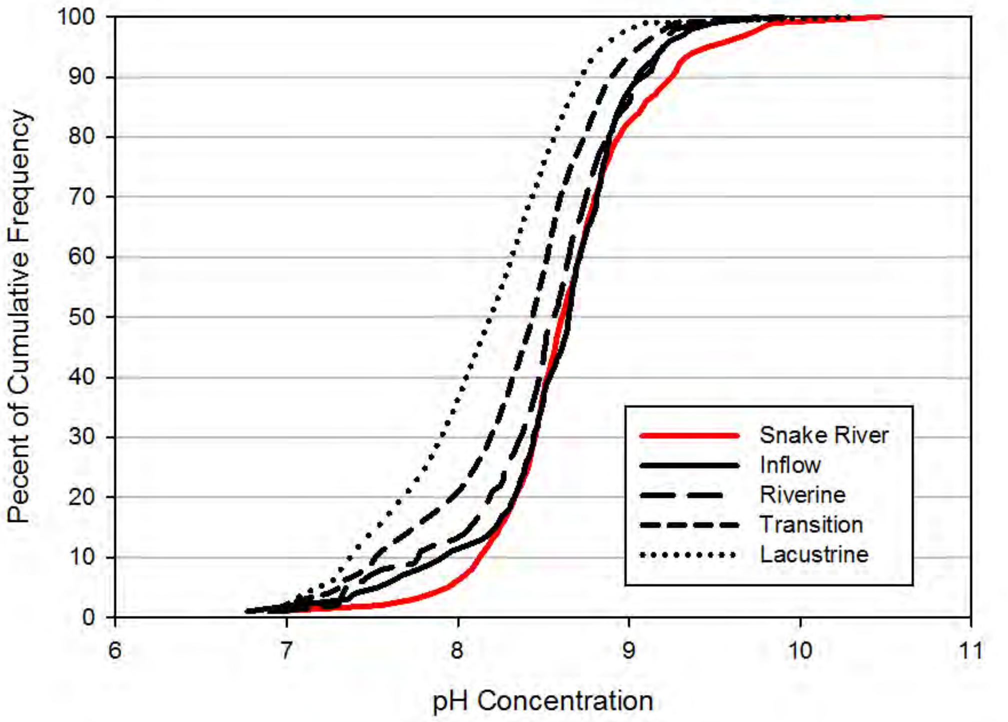

Figure 6.5-2
Percent of cumulative frequency curves for pH concentration in SUs in the Snake River immediately upstream of Brownlee Reservoir and throughout the reservoir zones from 1990 through 2014

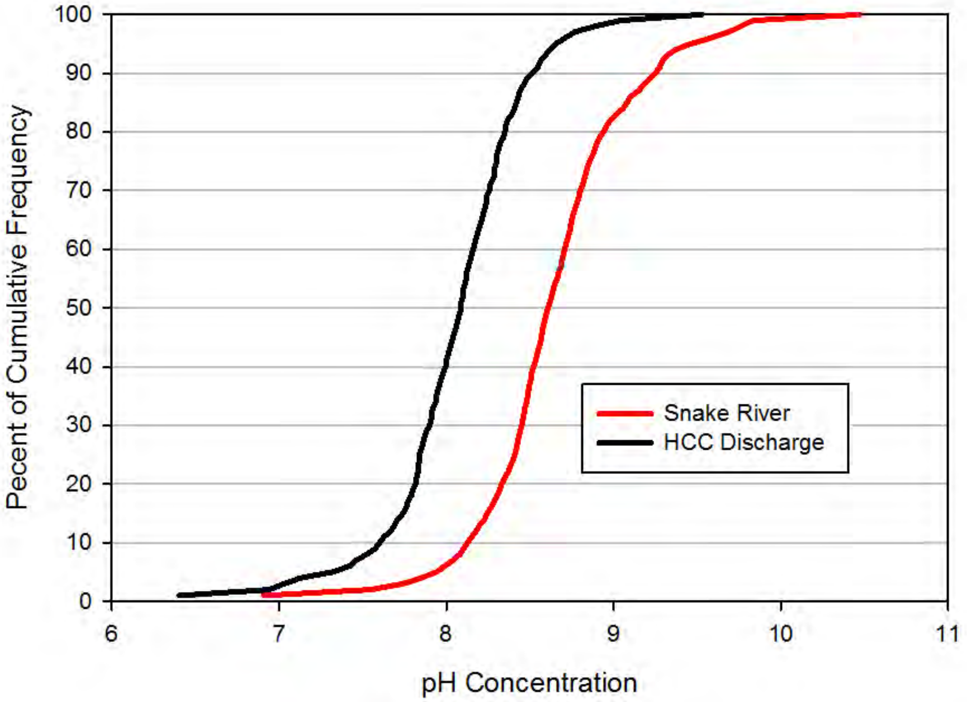

Figure 6.5-3
Percent of cumulative frequency curves for pH concentration in SUs as measured in the Snake River immediately upstream of the HCC and in the Snake River downstream from 1990 through 2014

6.5.3. HCC Contribution to pH

The pH of natural waters is governed to a large extent by the interaction of hydrogen ions (H+) arising from the dissociation of carbonic acid (H_2CO_3) and hydroxide ions (OH^-) produced during the hydrolysis of bicarbonate (HCO_3^-). Carbonic acid formed from the hydration of dissolved carbon dioxide (CO_2) solubilizes calcium-rich rock, producing calcium bicarbonate ($Ca(HCO_3)_2$) that exists in solution (as Ca^{2++} and HCO_3^-) in equilibrium with carbon dioxide ($H_2CO_3^-$) and carbonate ion (CO_3^{2-}). When this equilibrium is disrupted by the removal of carbon dioxide, calcium bicarbonate enters into another important equilibrium reaction resulting in the precipitation of calcium carbonate ($CaCO_3$) (Wetzel 2001). Evidence of calcium carbonate precipitation is commonly seen on substrate in the Snake River (e.g., white calcium carbonate deposits [marl] on the rocks).

These reactions increase the pH concentration when carbon dioxide is removed during photosynthesis. Wetzel (2001) stated the rate of calcium carbonate precipitation is slow unless increases are induced by photosynthetic carbon dioxide removal. When the rate of precipitation is rapid, it results in a temporary supersaturation of calcium and bicarbonate. To maintain equilibrium, supersaturated bicarbonate reacts with hydrogen ions to form carbonic acid and dissociates to release hydroxide ions. Both of these reactions (i.e., a decrease in hydrogen or an increase in hydroxide) increase pH.

In addition to the above process, pH change can be affected through changes in alkalinity following nutrient assimilation during photosynthesis. Since alkalinity is associated with a charge balance, the assimilation of ammonium (NH_4^+), nitrate (NO_3^-), and hydrogen phosphate ion (HPO_4^{2-}) ions are accompanied by the uptake or release of hydrogen and hydroxide ions through alkalinity changes (Stumm and Morgan 1995). Therefore, the assimilation of ammonium, nitrate, and hydrogen phosphate ion is accompanied by the assimilation of hydrogen ions, lowering the hydrogen ion concentration and increasing pH.

In summary, 2 key biochemical processes occurring in the Snake River are associated with photosynthesis that cause pH to increase 1) the removal of carbon dioxide (inorganic carbon) occurring when algae grow and 2) the removal of nutrients also occurring when algae grow.

Exceedance of the pH targets in the HCC appears related to inflowing Snake River water with elevated primary productivity. Data collected in the Snake River upstream of Brownlee Reservoir (RM 345.6) indicated that as chlorophyll *a* increased (a surrogate for algal biomass), the pH concentration also increased (Figure 6.5-4). A linear regression of these data showed, when daily average chlorophyll *a* concentrations were greater than 60 µg/L—a common occurrence in the Snake River inflow to Brownlee Reservoir—daily average pH values were above the 9 SU target. The SR–HC TMDL set a chlorophyll *a* target of 14 µg/L, with a nuisance threshold of 30 µg/L not to be exceeded more than 25% of the time (IDEQ and ODEQ 2004). Daily average pH levels are predicted to drop to approximately 8.6 SUs when chlorophyll *a* concentrations are near the SR–HC TMDL nuisance threshold target and are predicted to be slightly lower when the 14 µg/L target is achieved.

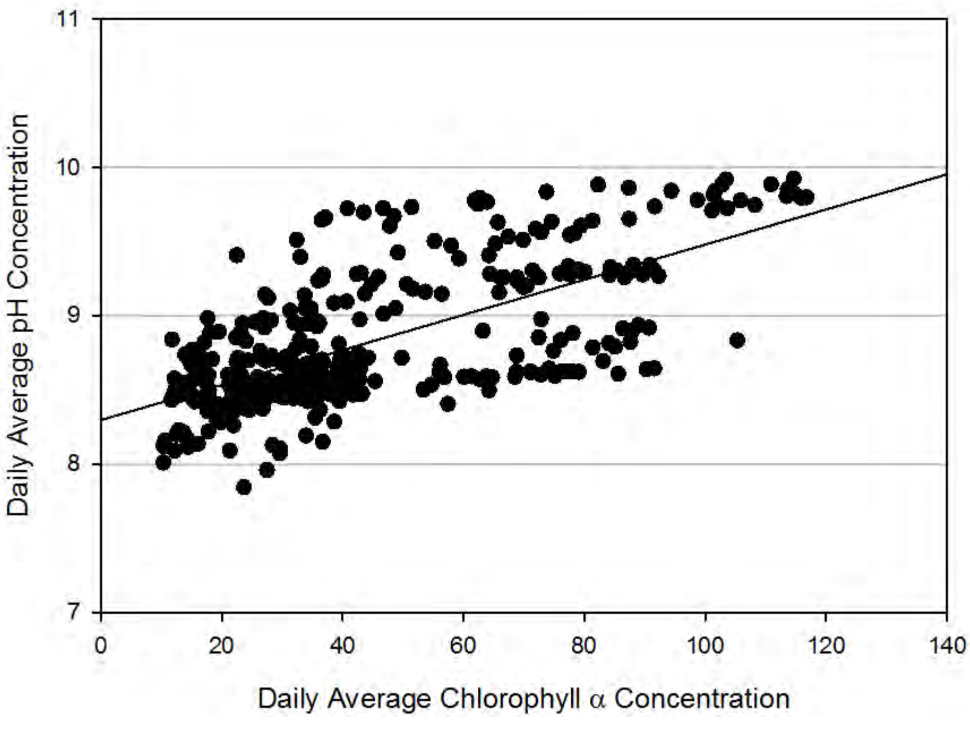

Figure 6.5-4
Upstream Snake River linear regression ($R^2 = 0.4678$) for daily average pH concentration in SUs and daily average chlorophyll *a* concentration in µg/L, as calculated using a chlorophyll *a* concentration and relative fluorescence unit correlation, at RM 345.6 for data collected from April 2002–July 2003

The variability and relatively low correlation evident in the chlorophyll *a* and pH regression is due to natural variability and the presence of other factors that contribute to pH changes, such as the alkalinity, reaeration rate (related to velocity and depth), algal growth rate (varies by season and daily climatic conditions), and benthic productivity (photosynthesis by periphyton and macrophytes). Benthic productivity may be a primary source of variability in the relationship between water-column chlorophyll *a* and pH. Periphyton and attached macrophytes are abundant in the Snake River upstream of Brownlee Reservoir, especially during low water conditions. The SR–HC TMDL noted that reductions in attached periphyton and macrophyte growth were anticipated with the implementation of the TP target (IDEQ and ODEQ 2004).

6.5.3.1. Modeling pH

Various models are available to simulate pH in natural systems. Most models are based on the equilibrium chemistry for carbonate systems, as discussed in Section 6.5.3. HCC Contribution to pH. Among these, a simplistic mass balance model (Chapra 1997) and the more sophisticated CE-QUAL-W2 model (Cole and Wells 2002) were used to demonstrate the link between elevated algal biomass and high pH. The CE-QUAL-W2 model, being a 2-dimensional model, requires additional information, including initial boundary conditions and assumptions regarding alkalinity and total inorganic carbon (TIC). The importance of knowing initial boundary conditions and assumptions will also be demonstrated.

6.5.3.1.1. Mass Balance Model

The mass balance model assumes TIC varies due to respiration, photosynthesis, and atmospheric exchange (Chapra 1997). Respiration and photosynthesis, respectively, increase or decrease the carbon dioxide in solution. Based on this change, atmospheric exchange occurs at rates proportional to a transfer coefficient proportional to the transfer coefficient for oxygen. Because atmospheric exchange lags respiration or photosynthesis, there is a net increase or decrease in TIC, producing a local equilibrium. A steady-state pH is calculated for any alkalinity after the new TIC is known. This is referred to as steady-state pH based on the local equilibrium assumption that reactions between inorganic carbon species are faster than atmospheric and biotic reactions. The steady-state pH would represent the maximum pH when photosynthesis rates are at peak levels.

The mass balance model was used to estimate pH for various rates of photosynthesis and 2 levels of alkalinity. Results from the mass balance model indicated lower rates of photosynthesis produced lower steady-state pH values (Figure 6.5-5). The model also showed that changes in alkalinity affected steady-state pH. Snake River data reported by the USGS (2003) showed alkalinity can range from 100 to 200 mg/L (as calcium carbonate). This was comparable to the 2 to 4 micro equivalent per liter curves shown for the mass balance analysis. As stated previously, algae growth can induce changes in alkalinity through the removal of nutrient ions (i.e., the assimilation of nitrate and hydrogen phosphate). Lower nutrient-removal rates and pH values would be anticipated with lower rates of photosynthesis through the implementation of the nutrient TMDL.

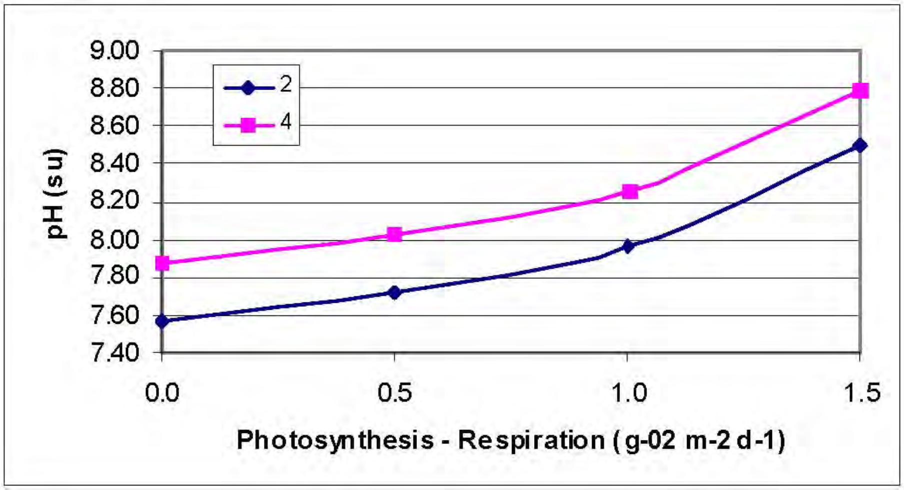

Figure 6.5-5
Modeled steady-state pH values in SUs at photosynthesis-dominated rates and 2 rates of alkalinity in micro-equivalents per liter. (Note: 1 micro-equivalent per liter is equal to 50 mg/L as calcium carbonate). The initial conditions assume TIC levels have increased due to respiration at 1.5 grams of oxygen per m^2 per day (g-02 m-2 d-1). Model based on Chapra (1997).

6.5.3.1.2. CE-QUAL-W2 Model

The CE-QUAL-W2 model algorithms for pH are based on a total carbon balance and carbon dioxide equilibrium with the atmosphere (Cole and Wells 2002). The model applies the following assumptions when modeling pH:

1. **Alkalinity is conservative.** However, instances are observed in the Snake River and Brownlee Reservoir where this is not the case.
    - Precipitation of calcium carbonate has been observed in the Snake River (e.g., white calcium carbonate deposits on the rocks). Referred to as marl, these deposits form when aqueous carbon dioxide is in equilibrium with the atmosphere and carbon dioxide is removed due to photosynthesis (Wetzel 2001). This results in a temporary excess of bicarbonate, which reacts with calcium.
    - There is the potential for carbonate release from anoxic and anaerobic sediments.
    - Alkalinity can decrease during photosynthesis with an uptake of ammonia, increase during respiration with the release of ammonia, or increase during photosynthesis with an uptake of nitrate (Stumm and Morgan 1995).
2. **Calcium and magnesium carbonate do not contribute to alkalinity.** Again, observations in the Snake River indicate this is not the case.
    - Calcium levels are relatively high in the Snake River.
    - Precipitated marl is commonly observed on substrate.

3. **Acidity is only due to carbonic acid concentration.** In the Snake River and most natural waters, organic and inorganic ions can contribute to acidity, including ammonium, HPO_4, and organic ligands.

In addition to the above assumptions, IPC would need to develop boundary conditions to model pH using the CE-QUAL-W2 model. These would include alkalinity, total dissolved solids (TDS), and TIC. These constituents were not routinely monitored during the years simulated with the CE-QUAL-W2 model. Therefore, the development of boundary conditions to model pH using the Brownlee Reservoir applications of the CE-QUAL-W2 model would be difficult.

More importantly, how these boundary conditions change with nutrient and algae reductions after the implementation of the SR–HC TMDL would require further assumptions. For example, to develop necessary boundary conditions for TIC, the alkalinity and pH would have to be assumed. The TIC and alkalinity would then be used in the model to predict pH.

As an alternative to pH simulation using the Brownlee Reservoir CE-QUAL-W2 model application, pH was simulated using the CE-QUAL-W2 model setup as an open system (i.e., a batch reactor). This batch reactor (single cell) application only requires initial conditions. Diel data collected in the Snake River (RM 345.6) upstream from Brownlee Reservoir indicated chlorophyll *a* concentrations in mid-July 2002 ranged from approximately 30 to 60 µg/L and pH ranged from approximately 7.9 to 8.3 SUs. To simulate this general range of algae, initial algal biomass conditions were set at 4 mg/L, which corresponds to 60 µg/L of chlorophyll *a* (assuming 1 mg/L algae equals 15 µg/L of chlorophyll *a*). Other initial conditions were estimated using data collected upstream of Brownlee Reservoir on the Snake River in summer 2002. Brownlee Reservoir model meteorological data were used to represent solar inputs and temperatures. There were no inflows or outflows in this application.

6.5.3.1.2.1. pH Simulations with Varying Algal Levels

Simulated maximum pH varied with differing initial conditions for algal biomass, resulting in maximum pH values occurring when algal levels were highest (Table 6.5-2). However, there is only a slight change in average pH levels.

Table 6.5-2
pH values in SUs resulting from CE-QUAL-W2 simulations of varying algal biomass initial conditions

	Initial Condition			Algal Growth Rate	pH	
	Algal Biomass	Alkalinity	TIC		Average	Maximum
Simulation 1	4.00	100.00	23.40	4.00	8.64	8.85
Simulation 2	2.00	100.00	23.40	4.00	8.64	8.74
Simulation 3	1.00	100.00	23.40	4.00	8.66	8.74

Simulation results showed daily algal biomass fluctuations with maximums occurring in response to maximum photosynthesis rates (Figure 6.5-6). Corresponding pH and TIC fluctuations also occurred (figures 6.5-7 and 6.5-8). For these simulations, TIC was set to produce levels that remained relatively constant over the period (i.e., at equilibrium with algae, alkalinity, and the atmosphere). Consistent with levels observed in the Snake River, alkalinity was set at 100 g/m^3 as calcium carbonate (USGS 2003).

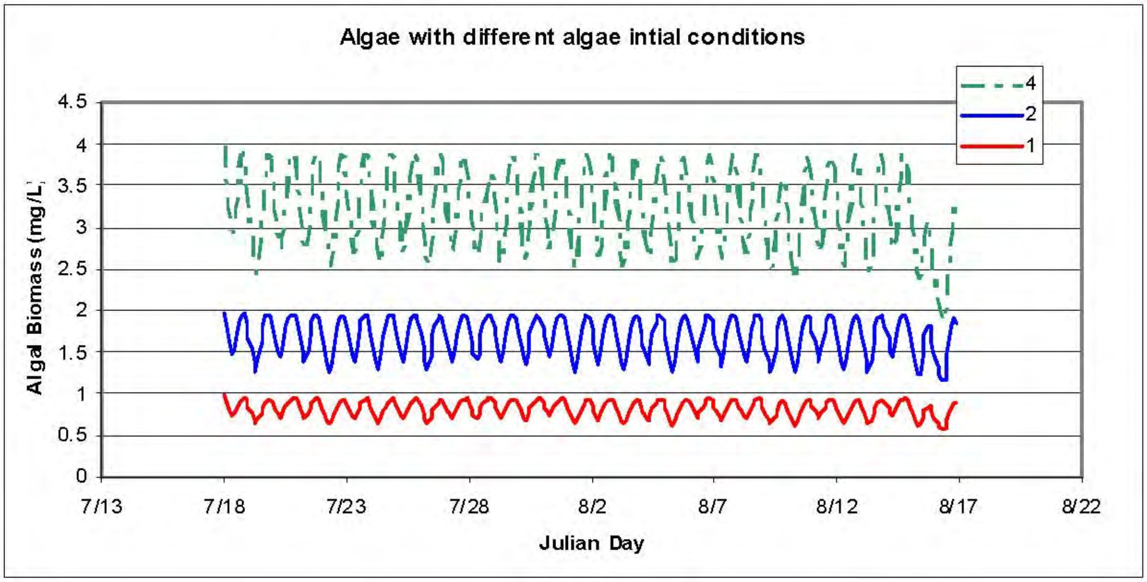

Figure 6.5-6
Algal biomass in mg/L with algal biomass initial conditions varying from 1 to 4 mg/L (i.e., approximately 15–60 µg/L of chlorophyll *a*)

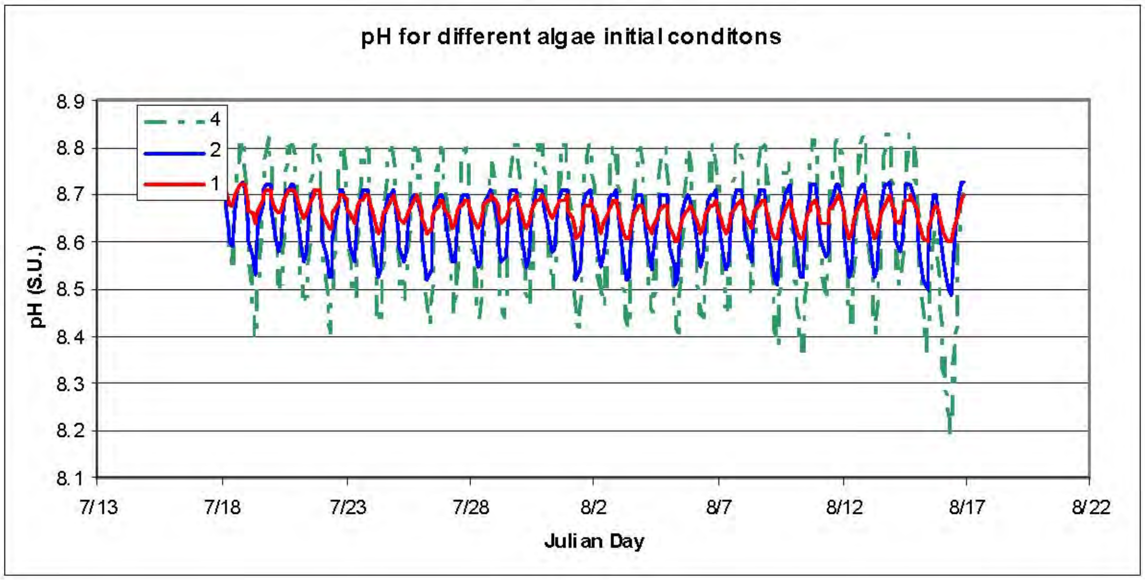

Figure 6.5-7
pH values in SUs with algal biomass initial conditions varying from 1 to 4 mg/L (i.e., approximately 15–60 µg/L of chlorophyll *a*)

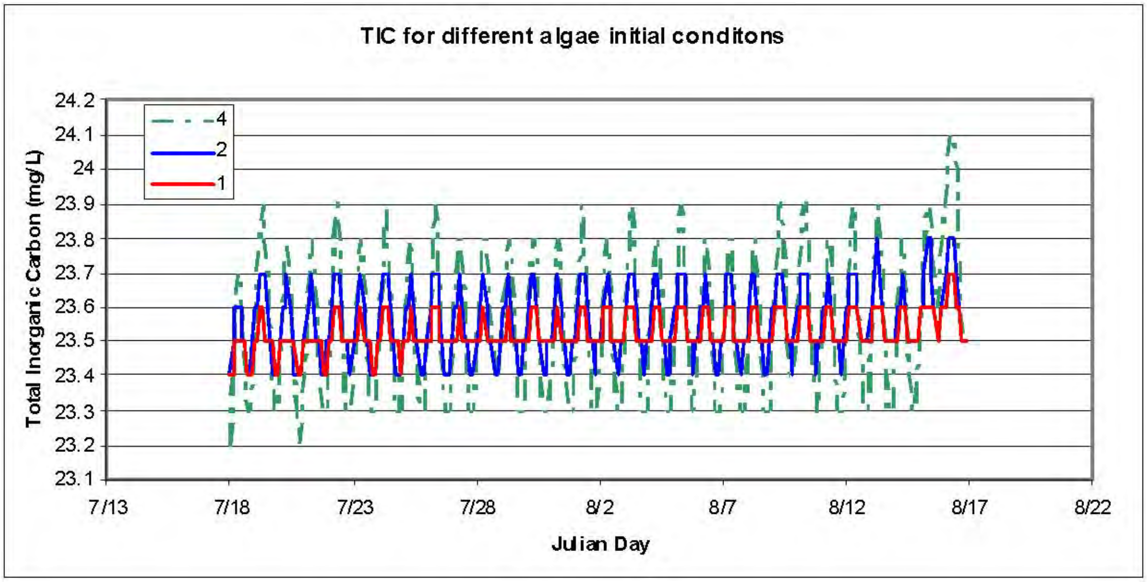

Figure 6.5-8
TIC in mg/L with algal biomass initial conditions varying from 1 to 4 mg/L (i.e., approximately 15–60 µg/L of chlorophyll *a*)

6.5.3.1.2.2. pH Simulations with Varying Algal Growth Rates

The CE-QUAL-W2 model simulation results (Table 6.5-3 and figures 6.5-9 and 6.5-10) showed the related daily range of algae as chlorophyll *a* and pH for mid-July with 2 growth rates (4 and 2 per day, respectively). The algal growth rate was set at 4 per day to simulate the relatively large daily fluctuation (Figure 6.5-9) representative of those observed in the measured data.
This growth rate was double the rate used in the 1995 Brownlee Reservoir optimized model application (Harrison et al. 1999).

Table 6.5-3
pH values in SUs resulting from CE-QUAL-W2 simulations of varying algal growth-rate initial conditions

	Initial Condition			Algal Growth Rate	pH	
	Algal Biomass	Alkalinity	TIC		Average	Maximum
Simulation 1	4.00	100.00	23.40	4.00	8.64	8.85
Simulation 2	4.00	100.00	23.40	2.00	8.61	8.74

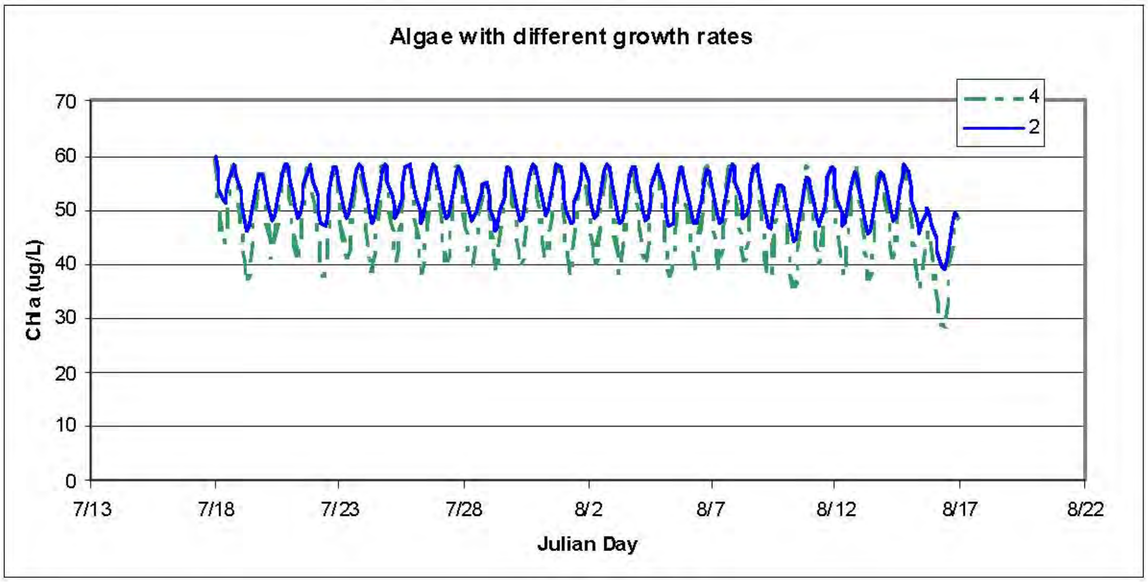

Figure 6.5-9
Algal biomass as measured by chlorophyll *a* (Chl *a*) in µg/L with algal growth rate initial conditions of 2 and 4 per day

These results showed that algal growth rates also affected pH levels. In the model, algal biomass was multiplied by the growth rate. Thus, a higher algal biomass can drive a higher rate of photosynthesis and higher pH values if other factors are not limiting (e.g., light and nutrients) (Table 6.5-3). Higher algal biomass produced higher pH values. This was consistent with the mass balance model results (Figure 6.5-5).

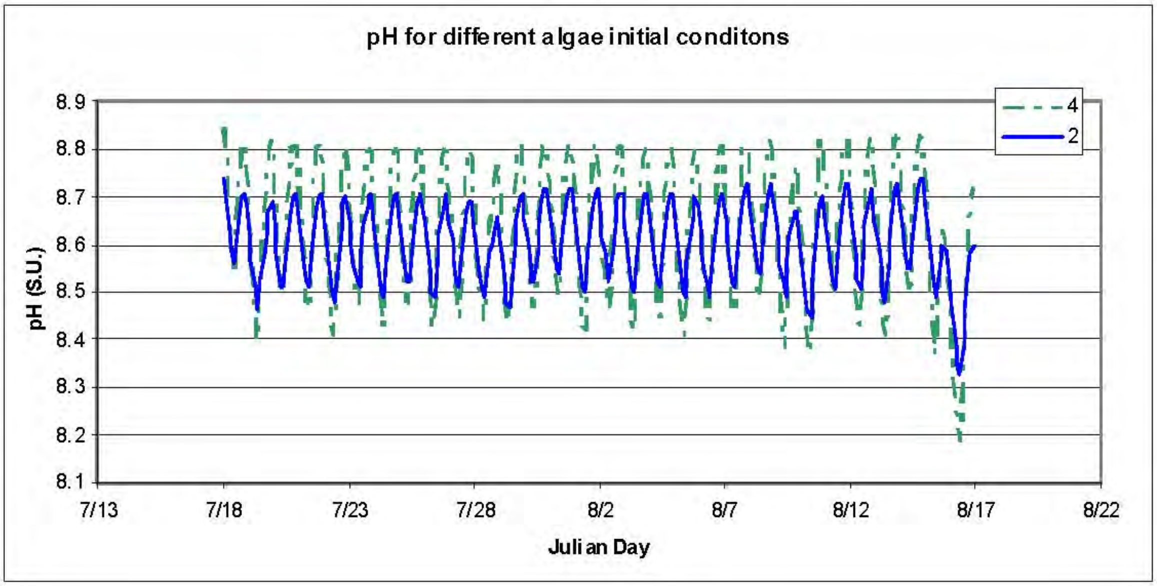

Figure 6.5-10
pH values in SUs with algal growth rate initial conditions of 2 and 4 per day

6.5.3.1.2.3. pH Simulations with Varying Alkalinity

The effects of alkalinity on pH values were modeled while keeping algae conditions constant (Table 6.5-4). The higher alkalinity produced slightly lower maximum pH values (figures 6.5-11 and 6.5-12). However, average pH was higher with the higher alkalinity because minimum pH values were higher. The mass balance model (Figure 6.5-5) showed higher, steady-state pH values when alkalinity was higher, as would be expected. Changes in alkalinity can occur with nutrient assimilation by algae, a process not included in the CE-QUAL-W2 model (Cole and Wells 2002).

Table 6.5-4
pH values in SUs resulting from CE-QUAL-W2 simulations of varying alkalinity initial conditions

	Initial Condition			Algal Growth Rate	pH	
	Algal Biomass	Alkalinity	TIC		Average	Maximum
Simulation 1	4.00	10.00	2.20	4.00	7.93	9.01
Simulation 2	4.00	20.00	4.60	4.00	8.09	8.90
Simulation 3	4.00	30.00	7.20	4.00	8.18	8.84
Simulation 4	4.00	40.00	9.20	4.00	8.30	8.86
Simulation 5	4.00	100.00	23.20	4.00	8.60	8.85

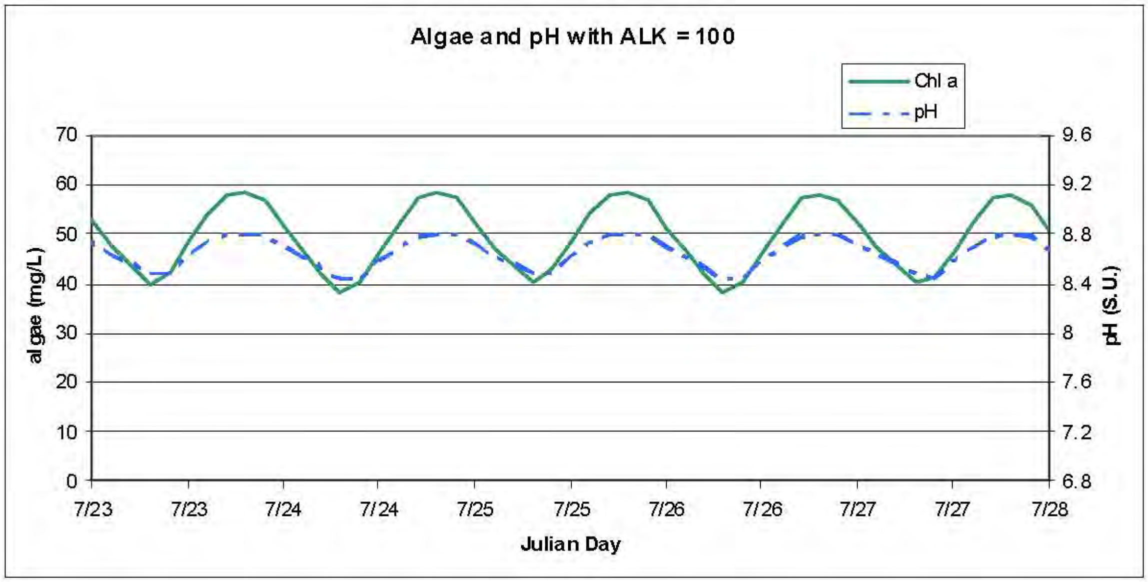

Figure 6.5-11
Algae in mg/L and pH in SUs with alkalinity equal to 100, algal biomass initial conditions of 4 mg/L, and an algal growth rate of 4 per day

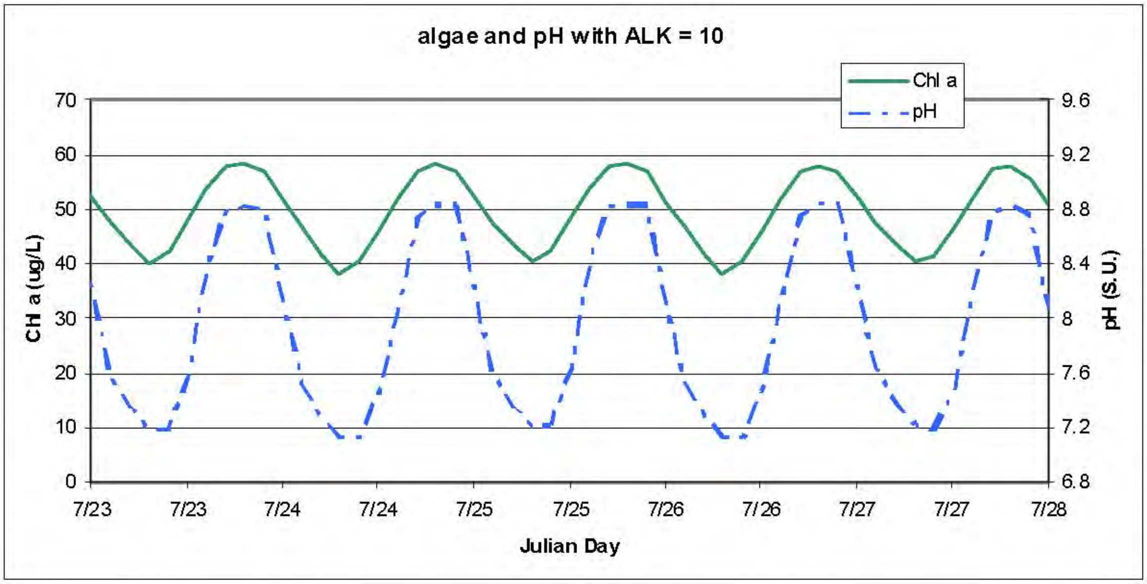

Figure 6.5-12
Chlorophyll *a* (Chl a) in µg/L and pH in SUs with an alkalinity equal to 100 and algal biomass initial conditions of 4 mg/L and an algal growth rate of 4 per day

6.5.3.2. pH Reasonable Assurance

IPC was not issued a pH allocation as part of the SR–HC TMDL (IDEQ and ODEQ 2004). Rather, nuisance algal targets and TP allocations to support the targets were expected to provide reasonable assurance that the few pH exceedances would be ameliorated. The SR–HC TMDL presented an analysis that developed a TP target of 0.07 mg/L for the stated purpose of attaining the mean growing season chlorophyll *a* target of 14 µg/L and a nuisance threshold of 30 µg/L, not to be exceeded more than 25% of the time for the Snake River and the HCC. When reduced primary production is realized, following full implementation of the SR–HC TMDL and attainment of both TP and chlorophyll *a* targets, the potential for pH values above targets will decrease.

This SR–HC TMDL conclusion was supported by IPC's modeling, which demonstrated lower maximum pH values are expected as algal levels and growth rates are reduced. As stated previously, algal growth can induce changes in alkalinity through the removal of nutrient ions (i.e., the assimilation of nitrate and hydrogen phosphate ions). With lower rates of photosynthesis through the implementation of the nutrient TMDL, lower nutrient-removal rates and a lower pH would be anticipated. While model boundary conditions are variable and future conditions difficult to predict, it is apparent that management actions designed to reduce algae production in the Snake River upstream of Brownlee Reservoir can have a positive influence on pH values, lowering maximum values and the potential for an exceedance of the pH targets.

6.6. Toxics

The SR–HC TMDL identified mercury as a toxic of concern (IDEQ and ODEQ 2004). Oregon has listed the Snake River from the Oregon and Idaho border through the HCC downstream to the Oregon and Washington border as impaired for mercury (Table 5.1-1).

Similarly, Idaho has listed Brownlee and Hells Canyon reservoirs as impaired for mercury (Table 5.1-2). The OHA (OHA 2013) has issued a fish-consumption advisory for Brownlee Reservoir, and the IDHW (IDHW 2013) has issued fish-consumption advisories for Brownlee and Hells Canyon reservoirs. The SR–HC TMDL also identified DDT (total-DDT [t-DDT]), DDD, DDE, 2 environmental metabolites of t-DDT, and dieldrin as toxics of concern (IDEQ and ODEQ 2004). Similar to mercury, pesticides have a diffuse and widespread legacy. Both t-DDT and dieldrin have been banned for use (t-DDT in 1973 and dieldrin in 1987). More detail on metals and pesticides in fish tissue and bed sediments of the HCC reservoirs is available in Technical Report E.2.2-2 of the *New License Application: Hells Canyon Hydroelectric Complex*.

Of the toxics of concern identified in the SR–HC TMDL and through subsequent study, mercury remains a primary concern. The SR–HC TMDL identified the primary sources of the total mercury in Brownlee Reservoir as legacy mining and natural loading, both associated with geological deposits within the Owyhee and Weiser river watersheds, and air deposition (IDEQ and ODEQ 2004). The SR–HC TMDL determined a mercury TMDL for this stretch of the Snake River is needed, which will be the basis for load and waste load allocations for nonpoint and point sources, respectively, contributing to mercury in these waters (SR–HC TMDL at page 255). However, because of insufficient data, no action has been taken on that TMDL at this time.

The cycling of mercury among its many pools and forms in aquatic environments is complex. Mercury in the aquatic environment can be converted by bacteria to a more toxic form called methylmercury. Inorganic mercury and toxic bioaccumulative methylmercury compounds are partitioned among the sediment, water, and biota pools in both organic and inorganic and dissolved and particulate forms. The majority of inorganic mercury is typically stored in sediments (Meili 1997). Concentrations of methylmercury and proportions of methylmercury to inorganic mercury depend on the balance of methylation, demethylation, and chemical stabilization in the system. Methylmercury is formed by the methylation of inorganic mercury in the presence of organic matter. Methylation is thought to be a microbial process highly dependent on sulfate-reducing and potentially methanogenic bacteria in anoxic conditions, although it can also occur in oxic conditions (Miskimmin et al. 1992). Demethylation, which is also controlled directly by microbial activity or abiotically by sunlight, is highest in oxic photic zones (Meili 1997).

Organic matter concentrations and cycling exert a strong control on the transport and transformations of mercury in aquatic environments. Concentrations of methylmercury and total mercury typically increase with the concentration of DOC (Driscoll et al. 1994). Other important parameters influencing the cycle include concentrations and redox states of iron, manganese, chloride, and sulfur compounds.

6.6.1. Toxics Standards and SR–HC TMDL Targets

Oregon and Idaho have promulgated narrative standards and numeric criteria for toxics. Oregon's narrative standards prohibit the introduction of potentially harmful toxic substances above natural background levels (OAR 340-041-0033(2)) and the creation of tastes, odors, or toxic conditions deleterious to fish or other aquatic life or that affect the potability of drinking water or the palatability of fish or shellfish (OAR 340-041-0007(10)). Oregon water-quality standards (OAR 340-041-002(67)) define a toxic substance as follows:

> Those pollutants or combinations of pollutants, including disease-causing agents, that after introduction to waters of the state and upon exposure, ingestion, inhalation, or assimilation either directly from the environment or indirectly by ingestion through the food chains will cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations in any organism or its offspring.

Idaho narrative standards similarly prohibit toxic substances in concentrations that impair beneficial uses (IDAPA 58.01.02.200.02). Idaho water-quality standards (IDAPA 58.01.02.010.102) similarly define a toxic substance as the following:

> Any substance, material or disease-causing agent, or a combination thereof, which after discharge to waters of the State and upon exposure, ingestion, inhalation or assimilation into any organism (including humans), either directly from the environment or indirectly by ingestion through food chains, will cause death, disease, behavioral abnormalities, malignancy, genetic mutation, physiological abnormalities (including malfunctions in reproduction) or physical deformations in affected organisms or their offspring. Toxic substances include, but are not limited to, the one hundred twenty-six (126) priority pollutants identified by EPA pursuant to Section 307(a) of the federal Clean Water Act.

The toxics criteria for human health are based in part on the fish-consumption rate. In 2004, Oregon adopted human-health criteria based on the EPA's CWA § 304(a) guidance values. These criteria were calculated using EPA's default fish-consumption rate of 17.5 g/day, a rate that represents the 90th percentile of consumers and nonconsumers based on a national U.S. Department of Agriculture (USDA) consumption study (1994–1996 and 1998 *Continuing Survey of Food Intakes by Individuals*).

In June 2010, the EPA disapproved Oregon's 2004 human-health criteria. Oregon undertook a negotiated rulemaking and promulgated new rules and, in 2011, the EPA subsequently approved Oregon's revised human-health criteria for toxics based on the fish-consumption rate of 175 g/day.

In 2006, Idaho adopted the EPA's recommended consumption rate of 17.5 g fish/day of freshwater or estuarine fish. The EPA disapproved this fish consumption rate in 2012. The EPA's disapproval of Idaho's human-health toxics criteria includes Idaho's criteria for toxics of concern in the Hells Canyon reach of the Snake River, DDT, DDE, DDD, and dieldrin. The EPA's disapproval does not apply to Idaho's criterion for methylmercury because that criterion was not included in the criteria submitted by Idaho in 2006 and disapproved by the EPA in 2012. However, because Idaho's standard for methylmercury is based on the EPA's recommended fish-consumption rate of 17.5 g/day, a change to the fish consumption rate will ultimately impact Idaho's methylmercury standard. This accounts for the current different methylmercury fish-tissue criteria of Idaho's 0.3 mg/kg to Oregon's 0.04 mg/kg, a significantly more stringent standard.

Oregon's human-health criteria for toxic pollutants are established in OAR 340-041-0033 Table 40, and criteria for aquatic life are provided in tables 20, 33A, and 33B. Table 6.6-1 lists Oregon's numeric criteria for mercury, methylmercury, t-DDT, DDD, DDE, and dieldrin for the protection of human health and aquatic life. Table 6.6-2 similarly lists Idaho's numeric criteria (IDAPA 58.01.02.210).

Table 6.6-1
Oregon human-health and aquatic-life criteria applicable to the Snake River for mercury, methylmercury, t-DDT, DDD, DDE, and dieldrin in mg/kg of fish-tissue concentration and µg/L water-column concentration. Human-health criteria were taken from OAR 340-041-0033 Table 40 and aquatic-life criteria from tables 20, 33A, and 33B.

	Human Health		Aquatic Life	
Pollutant	**Water + Organism**	**Organism Only**	**Acute**	**Chronic**
Mercury	–	–	2.40 µg/L	0.012 µg/L
Methylmercury	–	0.0400000 mg/kg	–	–
t-DDT	0.0000220 µg/L	0.0000220 µg/L	1.10 µg/L	0.001 µg/L
DDD	0.0000310 µg/L	0.0000310 µg/L	–	–
DDE	0.0000220 µg/L	0.0000220 µg/L	–	–
Dieldrin	0.0000053 µg/L	0.0000054 µg/L	0.24 µg/L	0.056 µg/L

Table 6.6-2
Idaho human-health and aquatic-life criteria applicable to the Snake River for mercury, methylmercury, t-DDT, DDD, DDE, and dieldrin in mg/kg of fish-tissue concentration and µg/L water-column concentration. Criteria were taken from IDAPA 58.01.02.210.

	Human Health		Aquatic Life	
Pollutant	**Water + Organism**	**Organism Only**	**Acute**	**Chronic**
Mercury	–	–	2.1 µg/L	0.0120 µg/L
Methylmercury	–	0.300000 mg/kg	–	–
t-DDT	0.000220 µg/L	0.000220 µg/L	1.1 µg/L	0.0010 µg/L
DDD	0.000310 µg/L	0.000310 µg/L	–	–
DDE	0.000220 µg/L	0.000220 µg/L	–	–
Dieldrin	0.000052 µg/L	0.000054 µg/L	2.5 µg/L	0.0019 µg/L

Some of the SR–HC TMDL toxic substance targets vary from Oregon's and Idaho's numeric criteria. Total mercury targets were similar (not to exceed 0.012-µg/L water-column concentration), while methylmercury targets were different (not to exceed 0.35 mg/kg in fish tissue) (IDEQ and ODEQ 2004). Only water-column concentrations were established for pesticides: not to exceed 0.000024 µg/L t-DDT, 0.00083 µg/L DDD, 0.00059 µg/L DDE, and 0.00007 µg/L dieldrin.

6.6.2. Conditions Relative to Toxics

Most of the available information on toxic-substance concentrations in the HCC, until very recently, focused on fish tissue and bed sediment. Currently, there are no numeric criteria applicable to bed sediments. IPC will present information on toxic substance concentrations in bed sediments only to frame the natural loading and legacy mining issues discussed in the SR–HC TMDL (IDEQ and ODEQ 2004) and by Brandt and Bridges (2007).

Several researchers reported concentrations of inorganic trace elements other than mercury and organic compounds other than t-DDT and dieldrin. Generally, none of the trace elements or organic concentrations exceeded criteria (Clark and Maret 1998; Essig and Kosterman 2008; Harrison et al. 2012[30]; Fosness et al. 2013[31]). An assessment of existing data on mercury concentrations in fish tissue, water column, and bed sediments of the HCC reservoirs is available in Harris and Beals (2013)[32].

Additionally, heavy metal and organochlorine pesticide contamination was studied in bald eagles (*Haliaeetus leucocephalus*) nesting in the HCC. Researchers reported that all adult feather samples collected in the HCC had levels of mercury that exceeded the accepted level of concern (Bechard et al. 2005). Nevertheless, the levels of mercury contamination reported did not appear lethal, and all bald eagles sampled were breeding successfully. All nestling blood samples collected in the HCC contained measurable levels of t-DDT and dieldrin. Again, the results did not indicate that organochlorine pesticide contamination occurred at levels sufficiently high to cause reproductive failures or other toxic effects in bald eagles in the HCC.

6.6.2.1. Fish Tissue

6.6.2.1.1. Mercury and Methylmercury

Many researchers have reported mercury and methylmercury concentrations in fish tissue collected in the HCC as well as throughout the Snake River watershed (Clark and Maret 1998; Adams 2008; Essig and Kosterman 2008; and Essig 2010). While most of these studies reported samples exceeding criteria, there are limitations to making meaningful conclusions due to insufficient sample size or composited samples, mixtures of whole body and muscle tissue, fish species across trophic levels, and varying fish sizes (Essig and Kosterman 2008; Essig 2010; Harris and Beals 2013).

Clark and Maret (1998) reported that mercury concentrations in fish collected in Brownlee Reservoir at the Burnt River ranged from an average of 0.273 mg/kg wet weight in white crappie fillets to an average of 0.325 mg/kg wet weight in channel catfish fillets. Common carp (*Cyprinus carpio*) average liver concentrations (0.315 mg/kg) also exceeded the Oregon and Idaho criterion but are not usually consumed. Stone (2006a) reported a mean Brownlee Reservoir-wide concentration of methylmercury in smallmouth bass fillets (0.633 mg/kg). He also reported a high degree of variability among the sampling sites.

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[30] Harrison et al. (2012) is provided with this application as Exhibit 6.6-1.

[31] Fosness et al. (2013) is provided with this application as Exhibit 6.6-2.

[32] Harris and Beals (2013) is provided with this application at Exhibit 6.6-3.

Essig and Kosterman (2008) reported methylmercury contamination in piscivorous fish from both Brownlee and Hells Canyon reservoirs. Brownlee Reservoir black crappie and catfish had average fish-tissue concentrations of 0.317 mg/kg and 0.388 mg/kg, respectively. Concentrations reported for fish in Hells Canyon Reservoir were 0.561 mg/kg in crappie, 0.556 mg/kg in catfish, and 0.471 mg/kg in smallmouth bass.

In spring 2013, IPC collected fish-tissue samples for methylmercury from 30 smallmouth bass in each of the HCC reservoirs, Brownlee, Oxbow, and Hells Canyon and from 30 smallmouth bass from the Snake River below HCD. Smallmouth bass were collected across a range of sizes representing 6 size groups (<100 millimeters [mm], 101–150 mm, 151–200 mm, 201–250 mm, 251–300 mm, and 301–350 mm). The methylmercury levels in smallmouth bass muscle tissue generally increased with size and ranged from 0.026 µg/g in Oxbow Reservoir to 0.75 µg/g in Hells Canyon Reservoir (Figure 6.6-1). Of the smallmouth bass sampled, 8 met Oregon's human-health criteria for methylmercury, and 112 exceeded Oregon's criteria. The 8 that met Oregon's methylmercury criteria were from Oxbow Reservoir and the Snake River below HCD and were from the <100 mm size group. Eighty-two of the smallmouth bass sampled met Idaho's methylmercury criteria, while 38 smallmouth bass exceeded Idaho's criteria. All of the smallmouth bass in the size groups less than 200 mm were below the Idaho criteria.
The methylmercury levels found in the bass muscle tissue are an issue because the data indicate an exceedance of both Idaho and Oregon water-quality criteria for methylmercury in fish tissue.

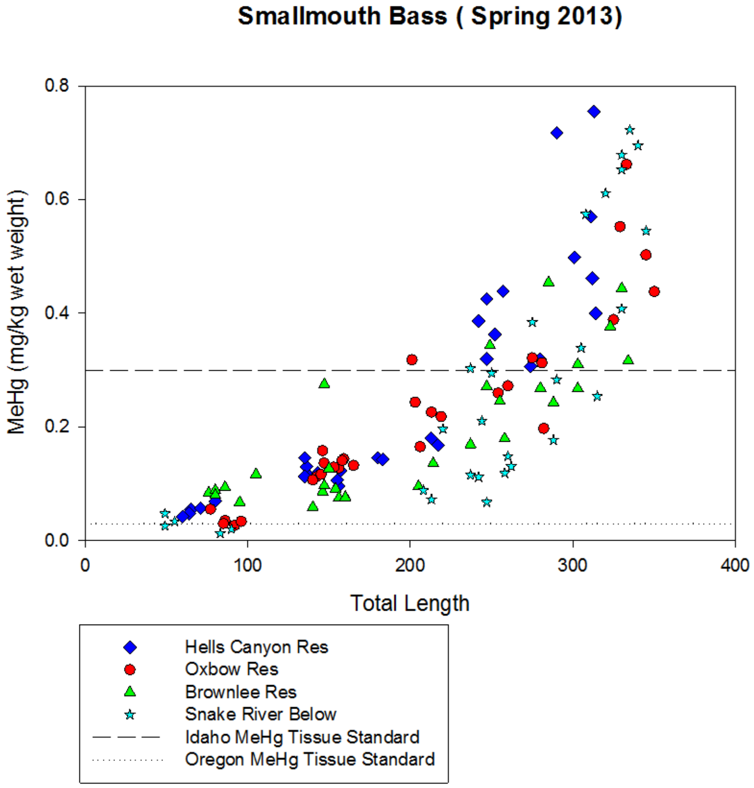

Figure 6.6-1
Smallmouth bass methylmercury tissue concentrations, spring 2013

As a follow-up to the spring 2013 analysis, IPC collected 24 individual smallmouth bass in fall 2013 between 250 and 300 mm at each of the following locations: below Swan Falls Dam, Snake River below the confluence of the Boise River, Snake River at the inflow to Brownlee Reservoir, the upper end of Brownlee Reservoir, the forebay of Brownlee Dam, the forebay of Oxbow Dam, the forebay of HCD, the river below HCD and the Snake River in the vicinity of Pittsburg Landing, and the Snake River in the vicinity above the confluence of the Salmon River. The purpose of these data were to better understand the distribution and trend of methylmercury within fish tissue in the Snake River above, within, and below the HCC reservoirs. As depicted in Figure 6.6-2, levels of methylmercury generally increase in fish tissue downstream through the HCC reservoirs, with some of the higher levels observed within Hells Canyon Reservoir. Generally, levels decline downstream of HCD, with some of the higher levels immediately below HCD.

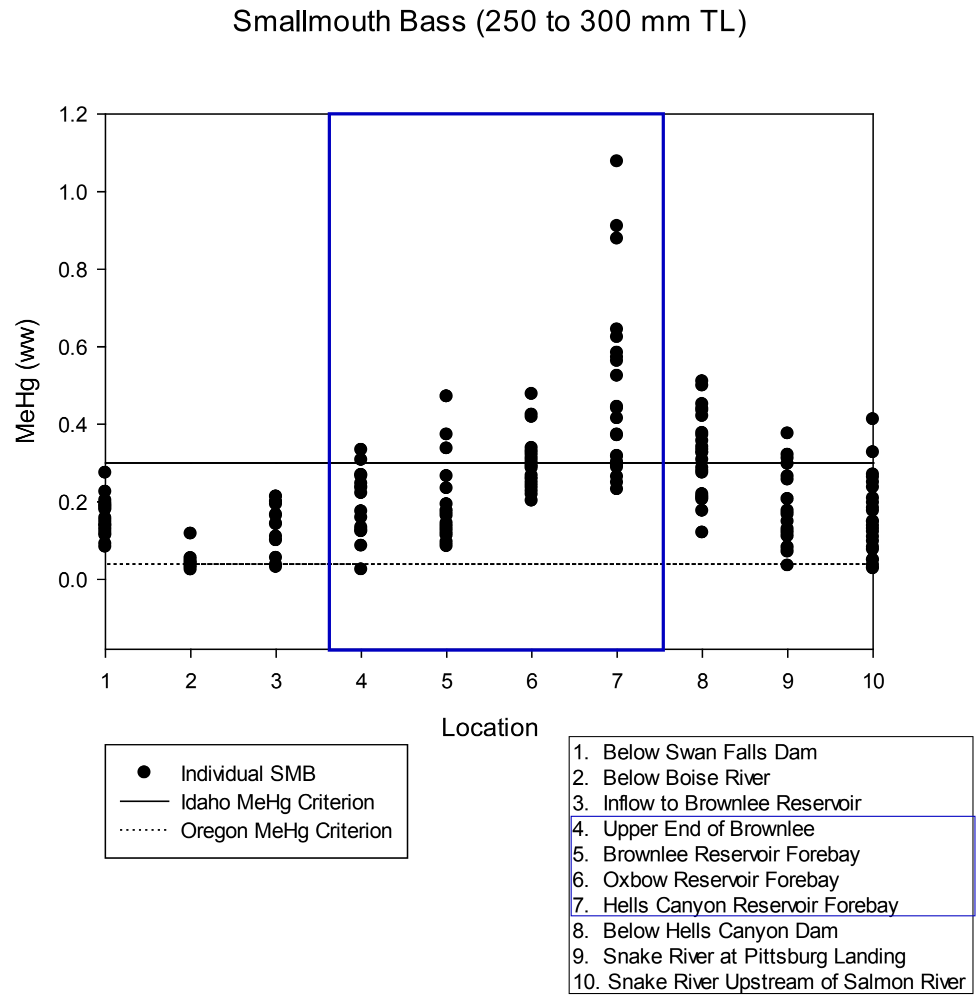

Figure 6.6.-2
Longitudinal distribution of methylmercury (mg/kg; wet weight) levels of tissue samples from individual smallmouth bass between 250 and 300 mm total length (TL) from Snake River locations ranging from below Swan Falls Dam (RM 458) to upstream of the confluence of the Salmon River (RM 188).

Three different life stages of SRFC salmon were analyzed for levels of methylmercury. These include the egg, fry, and adult life stages. A sample size of 30 fry were collected from 3 entrapment pools in the Snake River at RM 190.3 (n = 12), 199.3 (n = 14), and 227.3 (n = 4). Fry ranged in size from 42 to 60 mm TL. Because of their small size, whole fish rather than just muscle tissue was analyzed. As expected, methylmercury levels in these fish were very low, ranging from 0.0024 to 0.0073 mg/kg of methylmercury (wet weight; Figure 6.6-3. Adults and eggs were collected from spawned broodstock at Lyons Ferry Hatchery in fall 2013. Tissue was collected from 30 females, and a sample of eggs was collected from each female. Methylmercury levels in the eggs were low, ranging from 0.0005 to 0.0072 mg/kg methylmercury (wet weight; Figure 3). Adult SRFC salmon were all below the Idaho human-health fish tissue criterion but were more variable, ranging from 0.029 to 0.21 mg/kg of methylmercury with a median value of 0.087 mg/kg wet weight (Figure 6.6-3).

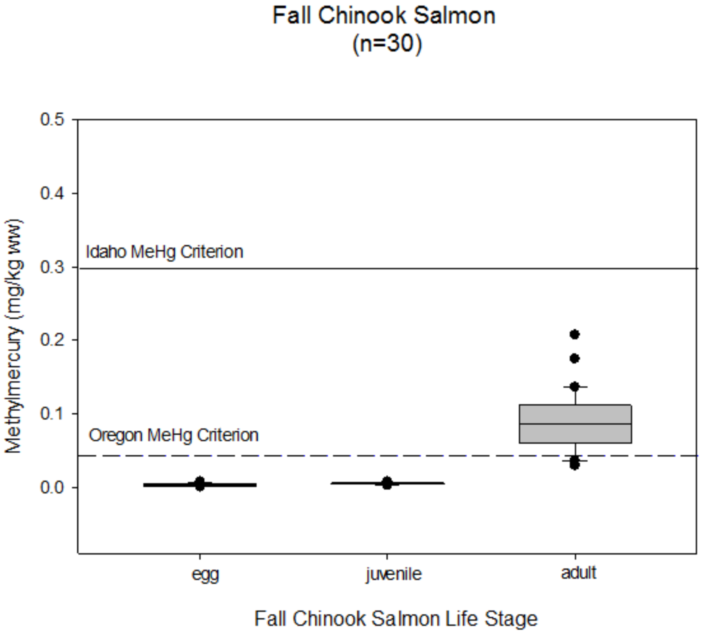

Figure 6.6-3
Box plots of methylmercury (mg/kg wet weight) showing the median, 10th, 25th, 75th, and 90th percentile levels (horizontal lines) with outlier points for eggs, fry, and adult SRFC salmon relative to the Idaho human-health fish tissue criterion.

In summer 2014, a bull trout mortality event occurred in the vicinity of and within the ODFW spring Chinook salmon trap on the mainstem Imnaha River (near Gumboot Creek). A total of 29 individuals were collected during this event ranging in size from 375 mm to 730 mm TL. This allowed an opportunity to obtain muscle tissue samples for methylmercury analysis. Generally, methylmercury levels increase with size, with some of the larger individuals exceeding the Idaho methylmercury human-health tissue criterion (Figure 6.6-4). All of the bull trout sampled exceeded the Oregon human health fish-tissue criteria. Levels of methylmercury ranged from 0.076 to 0.383 mg/kg methylmercury (wet weight).

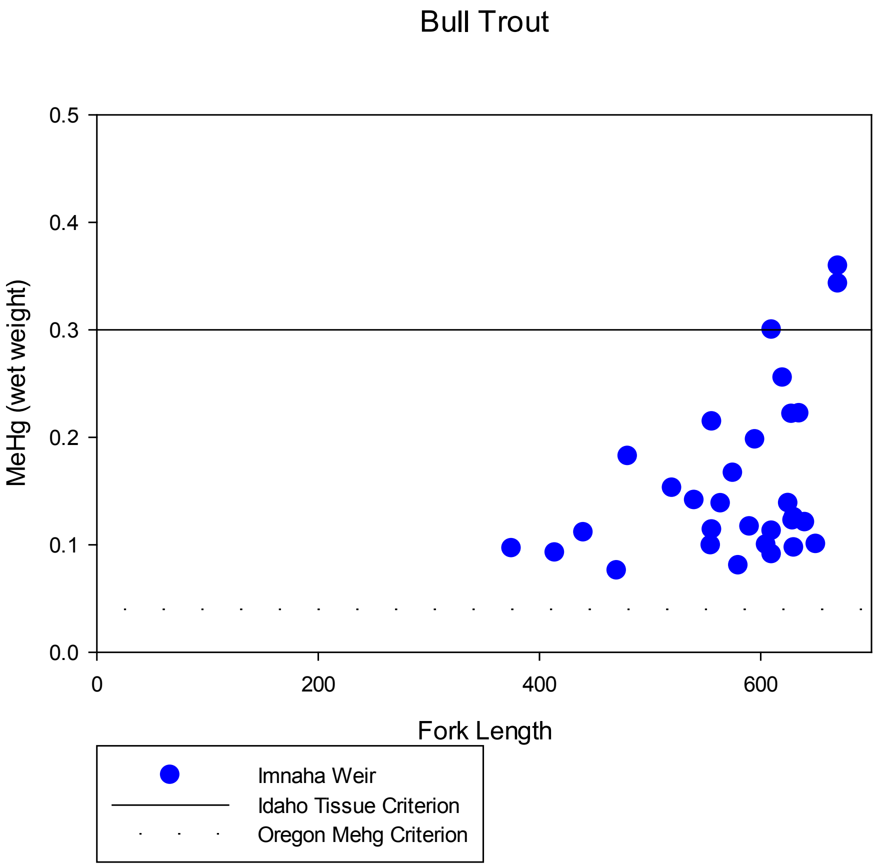

Figure 6.6.-4
Scatter plot of methylmercury levels (mg/kg, wet weight) of individual bull trout collected in the vicinity of the ODFW spring Chinook salmon trap (near the confluence of Gumboot Creek) relative to the Idaho human-health tissue criterion.

In 2014, IPC collected tissue samples using dermal plugs from the dorsal musculature of white sturgeon from areas between Swan Falls Dam (RM 458 to Noble Island [RM 445]; n = 25), the upper portion of Brownlee Reservoir (n = 4) and below HCD (n = 29), within the vicinity of Pittsburg Landing. In addition, IPC had collected muscle tissue samples from incidental mortalities of white sturgeon found in the river below CJ Strike Dam (n = 7) and below Swan Falls Dam (n = 2) during 2012 and 2013. Most white sturgeon sampled exceeded the Idaho human health fish tissue criterion; all white sturgeon exceeded the Oregon human health fish tissue criterion. Generally, methylmercury increases with fish size among areas above and below HCD, with some of the larger individuals having relatively high levels (Figure 6.6-5). Methylmercury levels generally are greater below HCD based on fish size (Figure 6.6-5). However, age-at-length relationships for white sturgeon above and below the HCC are different. Generally fish of the same age are larger above the HCC than below the HCC. Growth models for each of the two areas (Bates et al. 2014) were used to assign ages to each of the sampled sturgeon. Sturgeon of similar ages from both areas were similar in their levels of methylmercury (Figure 6.6-6). This suggests that Snake River white sturgeon have elevated levels of methylmercury and may bioaccumulate at similar levels based on age regardless of location.

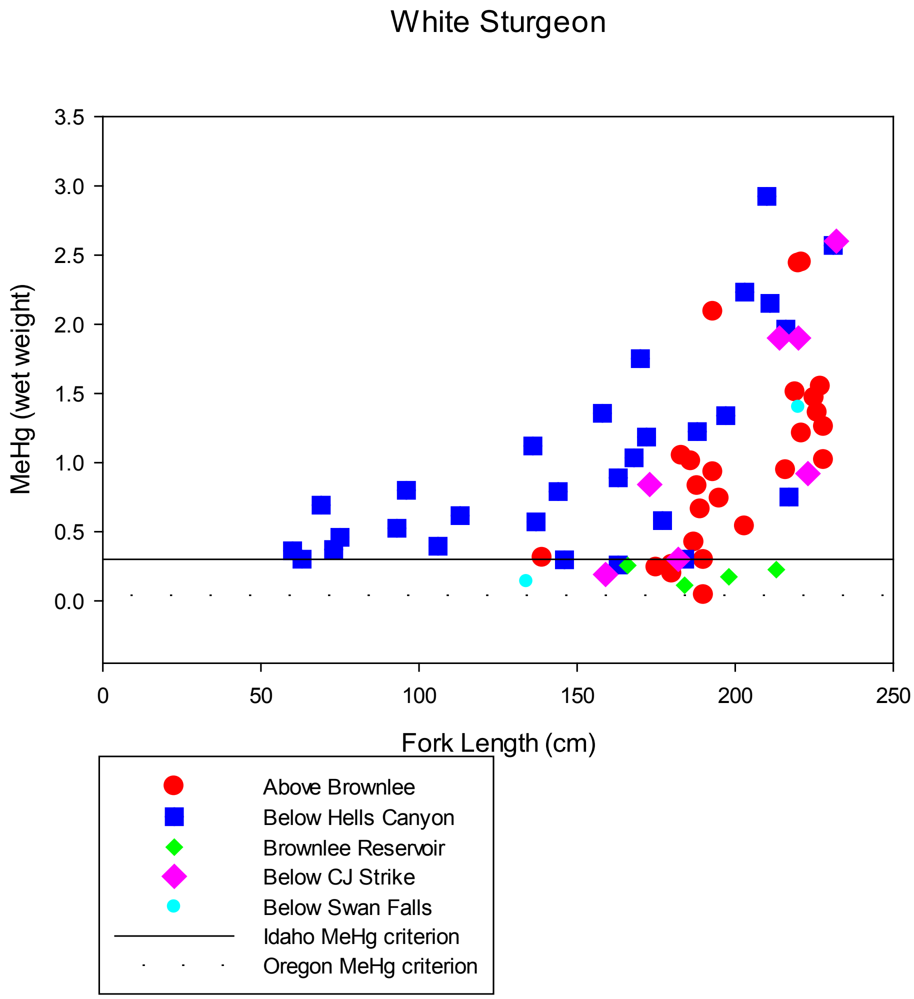

Figure 6.6-5
Scatter plot of methylmercury levels (mg/kg, wet weight) relative to the fork length of individual white sturgeon from dermal muscle plugs in the dorsal musculature above Brownlee Dam, Brownlee Reservoir, and below HCD upstream of Pittsburg Landing. Additional samples are included in the plot that were collected from incidental observed mortalities in 2012 and 2013 below C. J. Strike Dam (n = 7, purple diamonds) and below Swan Falls Dam (n = 2, light-blue circles) relative to the Idaho human-health tissue criterion.

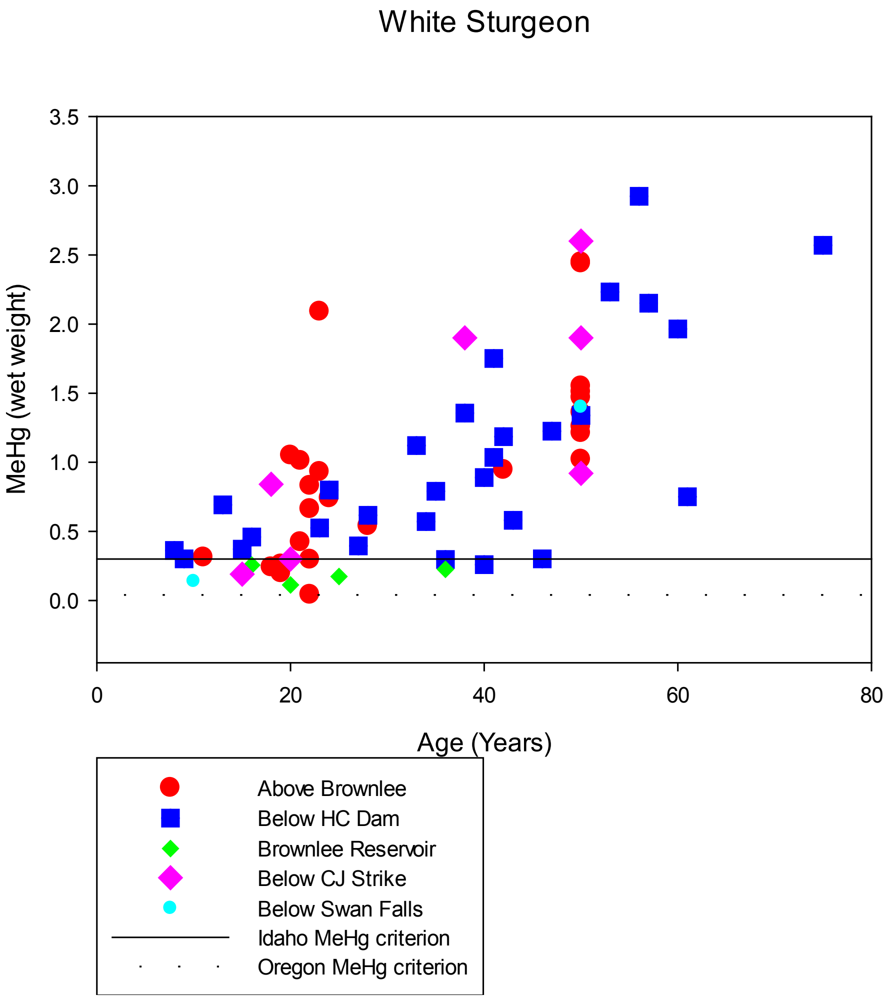

Figure 6.6-6
Scatter plot of methylmercury levels (mg/kg, wet weight) relative to the estimated age (years) of individual white sturgeon from dermal muscle plugs in the dorsal musculature above Brownlee Dam, Brownlee Reservoir, and below HCD upstream of Pittsburg Landing. Additional samples are included in the plot that were collected from incidental observed mortalities in 2012 and 2013 below C. J. Strike Dam (n = 7, purple diamonds) and below Swan Falls Dam (n = 2, light-blue circles) relative to the Idaho human health tissue criterion.

6.6.2.1.2. Pesticides and Organic Compounds

Clark and Maret (1998) also reported detectable concentrations of organochlorine compounds in sportfish fillets collected in Brownlee Reservoir. Concentrations of t-DDT and dieldrin exceeded a cancer-risk screening value of 10-6 as established by the EPA.

6.6.2.2. Water Column

In 2010 and 2011, IPC sampled the Brownlee Reservoir water column for 470+ toxics based on a list developed in collaboration with the FWS, IDEQ, ODEQ, and others (Harrison et al. 2012). This study sampled Brownlee Reservoir's hypolimnion and discharge for organic and inorganic toxics concentrations. The results from Brownlee Dam discharge samples, which represent water primarily drawn from the upper and middle levels of the reservoir (i.e., epilimnion and metalimnion), were compared with the results from samples collected in the lower depths of Brownlee Reservoir (i.e., hypolimnion). In general, concentrations of most of the parameters tested, including most inorganic toxics and all organic toxics, were lower in the hypolimnion compared to the discharge. However, this trend did not apply to select inorganic toxics, including chromium, ammonia, or mercury, where levels of chromium, ammonia, and mercury were higher in the hypolimnetic waters.

6.6.2.2.1. Mercury and Methylmercury

Many have sampled total mercury through the water column in Brownlee Reservoir. All reported maximum concentrations less than either chronic or acute aquatic-life criteria (Stone 2006b; Brandt and Bridges 2007; Harrison et al. 2012; and Fosness et al. 2013).

Harrison et al. (2012) reported the highest methylmercury concentration of 2.9 ng/L (0.0029 µg/L) in the hypolimnion of Brownlee Reservoir in fall 2011. Both Fosness et al. (2013) and Harrison et al. (2012) show higher concentrations near the bottom of the reservoir and in the hypolimnion, which is in contrast to a maximum methylmercury concentration of 0.1 ng/L (0.0001 µg/L) measured in the discharge from Brownlee Reservoir (Harrison et al. 2012). This contrast suggests methylmercury accumulates in the deeper waters of Brownlee Reservoir throughout the year. Harris and Beals (2013) reported the methylmercury concentration and the percent of mercury in the form of methylmercury in the hypolimnion were significantly elevated when compared to the mean and median values nationally.

Fosness et al. (2013) partitioned Brownlee Reservoir mercury and methylmercury between dissolved and particulate forms. Generally, dissolved mercury was highest in the reservoir epilimnion, while particulate mercury was highest in the hypolimnion. Total mercury appeared to decrease longitudinally through the reservoir. Dissolved and particulate methylmercury were highest in deeper waters. Fosness et al. (2013) reported a maximum value of 0.7 ng/L (0.0007 µg/L) near the bottom of the reservoir in spring 2012.

In 2013, IPC initiated a collaborative study effort with the USGS to better understand mercury dynamics in the HCC. The collaborative study is scoped for a 7- to 10-year timeline that began in 2014. The goals of the study are three-fold and employ an adaptive science strategy based on findings as the study moves forward.

The first goal is to define key processes and factors controlling spatial and temporal trends of mercury and methylmercury in surface water, sediment, and biota in the HCC. This goal is designed to define the key mercury processes for the HCC that influence methylmercury production, accumulation in the water column, and availability to biota. Specific areas of study relative to this goal include processes and factors that influence the uptake of methylmercury by biota at the base of the food web and dissolved and particulate organic carbon concentrations and composition. This goal will also help define the important spatial zones where these processes occur (e.g., epilimnion, thermocline, hypolimnion, sediments) and the important temporal periods during which uptake by biota may occur (e.g., spring runoff, summer, fall reservoir destratification). Processes and factors influencing the accumulation of methylmercury at the upper levels of the food web will also be studied, such as the relative importance of benthic vs. pelagic pathways and variations of food web structure across the HCC. The adaptive science strategy throughout the study will allow for the modification of the study based on previous findings and also the potential to observe how the processes are affected by different water-column conditions (e.g., temperature and DO structure, see Section 6.1. Temperature and 6.2. DO) that occur among different water years.

The information gathered through the first goal will be synthesized in the second goal, which is to develop a predictive model of the HCC that includes dominant processes of methylmercury production and bioaccumulation, and allows for scenario testing. The third goal includes developing applied science to help define the outcomes of various resource management alternatives to reduce methylmercury exposure to HCC food webs.

Currently this study combines integrated sampling that includes “repeat” sampling at fixed sites within the HCC and at inflow and outflow locations with “intensive” sampling campaigns at key times of the year. The objective of the repeat sampling is to assess temporal and spatial patterns in a subset of parameters (e.g., Total mercury, methylmercury, DOC, nutrients, zooplankton) and monitor the temperature and DO conditions in the HCC over the year. The repeat sampling is occurring biweekly or monthly. The objective of the intensive sampling is to provide detailed process-oriented measurements associated with mercury cycling in the water column and sediments to support model formulation (e.g., methylation, demethylation, volatilization, organic carbon composition) and detailed bioaccumulation data from zooplankton. Currently, the intensive sampling occurs twice a year.

6.6.2.2.2. Pesticides and Organic Compounds

Harrison et al. (2012) showed relatively low levels of toxic organic compounds throughout the water column in Brownlee Reservoir. The vast majority of over 470 analyzed compounds were reported as not detected. Seven compounds were reported as detected: 1) atrazine, 2) degradate desethyl atrazine, 3) alpha-chlordane, 4) chlorpyifos, 5) DDE, 6) dieldrin, and 7) endosulfan sulfate. All organic concentrations were below criteria established for the protection of aquatic life. Only DDE, dieldrin, and chlordane were near or above human-health criteria. These pesticides were detected below the limit of quantification and, therefore, the reported concentrations are only estimates that indicate the presence of the compound. Comparing levels of these compounds to established criteria is difficult because laboratory detection limits are higher than criteria, but results do show the presence of these compounds. Similar to t-DDT and dieldrin, chlordane has been banned for use since 1983.

6.6.2.3. Bed Sediment

6.6.2.3.1. Mercury and Methylmercury

Many researchers have reported detectable concentrations of mercury and methylmercury in Brownlee Reservoir bed sediments. Maximum reported total mercury concentrations were similar among the studies: 0.13 mg/kg (Clark and Maret 1998), 0.14 mg/kg (CH2MHill 2000), and 0.103 mg/kg (Fosness et al. 2013). Harris and Beals (2013) reported these values were within the range observed in northwest regional data. Reported methylmercury concentrations of 0.018 mg/kg (Fosness et al. 2013) were, however, higher than those reported in the region.

Current data from Brownlee Reservoir indicate Brownlee Reservoir sediments have average levels of total mercury but high levels of methylmercury (Harris and Beals 2013; Krabbenhoft 2012). For example, the median Brownlee Reservoir sediment concentration for total mercury is 82.1 ng/g, compared to an average for Idaho reservoirs of approximately 50 ng/g and approximately 85 ng/g for Washington state reservoirs (Figure 6.6-7). However, the median sediment methylmercury concentration (top 2 cm) for Brownlee Reservoir is 12.5 ng/g compared to methylmercury concentrations in Idaho, Oregon, and Washington reservoirs that range from approximately 0.5 to 1.7 ng/g (Figure 6.6-8).

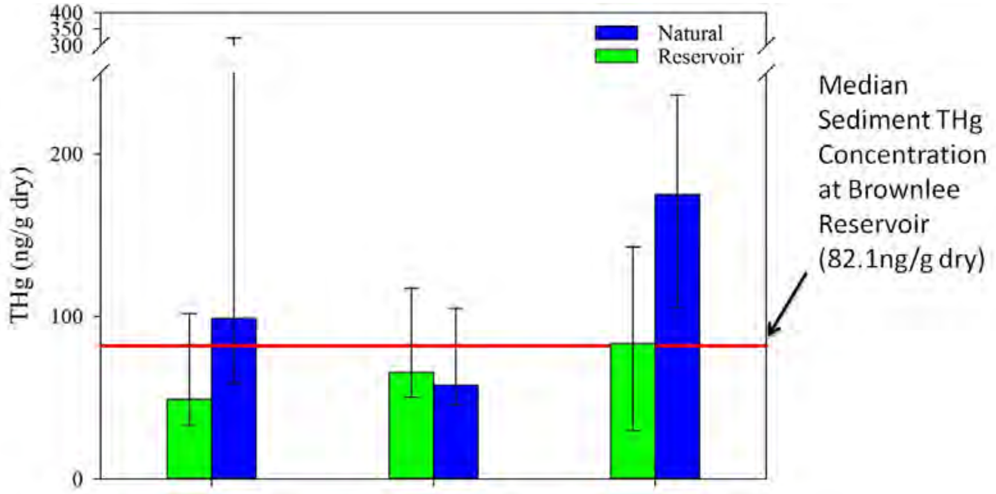

Figure 6.6-7
Total mercury in sediments in natural lakes and reservoirs. Data are from a 2007 regional EPA national lakes assessment. Values in red are the number of samples. The red line shows the median sediment total mercury concentration at Brownlee Reservoir of 82.1 ng/L dry. Adapted from Krabbenhoft 2012.

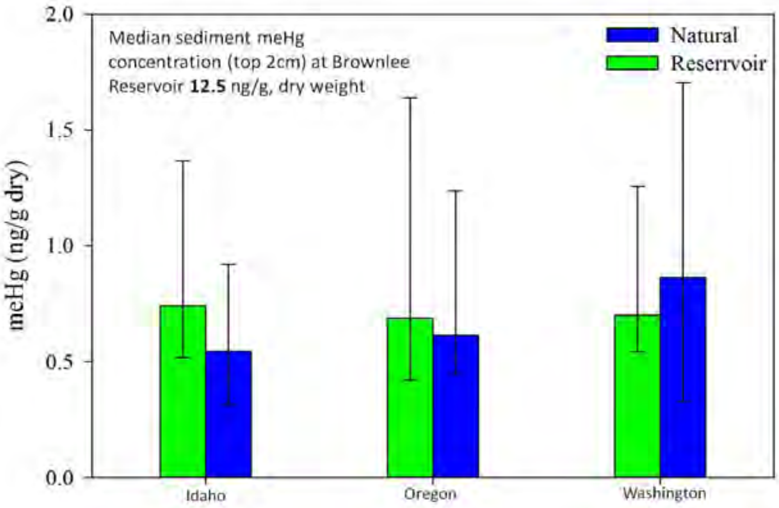

Figure 6.6-8
Methylmercury in the top 2 cm of sediments in natural lakes and reservoirs. Data are from a 2007 regional EPA national lakes assessment. Values in red are the number of samples. The median sediment methylmercury concentration (top 2 cm) at Brownlee Reservoir is 12.5 ng/g dry, which is too high to be shown on the chart. Adapted from Krabbenhoft 2012.

6.6.2.3.2. Pesticides, Organic Compounds, and Emerging Contaminants

In 2012, IPC and the USGS conducted sediment testing in Brownlee Reservoir for 526 toxics based on a list compiled in collaboration with the FWS, IDEQ, ODEQ, and others. Of those

526 toxics, 6 pesticides and organic compounds were detected: 1) propoxur (Baygon), 2) 2-4 dichlorobenzoic acid (2-4 D), 3) DDE, 4) promenton (TotalKill®), 5) glyphospate (Roundup®), and 6) pendimethalin (Fosness et al. 2013). Clark and Maret (1998) and CH2MHill (2000) also reported detectable concentrations of t-DDT and metabolites (i.e., DDE) in sediments. Similar to water-column organic toxics, most concentrations were less than reporting levels, which is useful to indicate the presence of the compound.

Fosness et al. (2013) also tested sediment for 57 wastewater compounds commonly known as emerging contaminates. Of the 57 compounds, 11 were present in Brownlee sediments, including 2,6,-dimethylnaphthalene (PAH), 3 beta coprostanol (fecal indicator), and 3 forms of plant steroid.

6.6.3. HCC Contribution to Toxics

Peterson et al. (2007) collected and analyzed over 2,700 large fish from more than 600 stream and river sites throughout 12 western states to assess regional distribution of mercury concentrations and correlate tissue concentrations with data on known point-source discharges of mercury. Finding no correlation with distribution, the authors concluded atmospheric transport is a key factor relative to mercury levels in fish across the western U.S. These findings suggested large-scale atmospheric transport, not local anthropogenic effects, was the key factor relative to mercury levels in fish across the western states. This conclusion is supported in Idaho by Essig and Kosterman (2008) and Essig (2010). They sampled mercury levels in fish throughout Idaho and concluded concentrations above the human-health criterion were widespread and common. They further reported that while providing a direct measure of human-health risk from the consumption of contaminated fish, looking at fish tissue provides no information on the origin of the mercury. Even in Salmon Falls Creek Reservoir, located in south-central Idaho where the IDEQ conducted an intensive study of mercury sources, definitive quantification and identification of discrete sources have remained elusive (Lay 2007). Identifying sources of mercury is difficult and involves intensive study, such as using isotopes to determine distinct methylmercury sources.

Brandt and Bridges (2007) evaluated water-column mercury concentrations flowing into and out of Brownlee Reservoir. They reported that most of the mercury entering Brownlee Reservoir was retained and noted that atmospheric deposition was not measured. They concluded the highest water-column mercury concentrations and loadings occurred during high-flow conditions, indicating a significant load to the HCC may be in particulate form. Clark and Maret (1998) and CH2MHill (2000) reported data indicating the retention of mercury in Brownlee Reservoir, likely a result of suspended sediment settling as velocity decreases. This corroborated with the interpretation of transport forwarded in the SR–HC TMDL (IDEQ and ODEQ 2004) that heavier sediments delivered to Brownlee Reservoir are contained in the reservoir and most of the mercury adsorbed or contained in those sediments is retained in Brownlee Reservoir. Harris and Beals (2013) further suggested that anoxic conditions that develop during late summer and fall in the hypolimnion of Brownlee Reservoir foster the highly efficient conversion of the inorganic mercury into methylmercury, with a possible accumulation of methylmercury in the hypolimnion during summer stratification.

6.6.3.1. Mercury TMDL

The SR–HC TMDL identified a need for a mercury TMDL (IDEQ and ODEQ 2004). To date, a mercury TMDL has not been developed. CH2MHill (2000) and Brandt and Bridges (2007) reported data useful to determine likely sources of mercury in the HCC and inflow tributaries.

6.7. Turbidity

Turbidity is an expression of the optical property of water that causes light to be scattered and absorbed rather than transmitted in straight lines (APHA 1999). Turbidity is frequently used as a surrogate measure of suspended inorganic particles; however, turbidity can be affected by organic particles, such as detritus and tannins. Neither Oregon nor Idaho has listed Snake River waters as being limited by turbidity (ODEQ 2014; IDEQ 2014) (tables 5.1-1 and 5.1-2).

6.7.1. Turbidity Standards

Oregon has a turbidity standard measured in nephelometric turbidity units (NTU). No more than a 10% cumulative increase in natural stream turbidities may be allowed, as measured relative to a control point immediately upstream of the turbidity causing activity (OAR 340 041 0036). Idaho similarly identifies turbidity criteria relative to a background: “Turbidity, below any applicable mixing zone set by the Department, shall not exceed background turbidity by more than fifty (50) NTU instantaneously or more than twenty-five (25) NTU for more than ten (10) consecutive days” (IDAPA 58.01.02.250.02.e.).

6.7.2. Conditions Relative to Turbidity

IPC has routinely measured turbidities in the Snake River and throughout the HCC in association with other water-quality monitoring efforts. The maximum turbidities, as measured between 1992 and 1997, were less than each immediately-preceding upstream reach of the Snake River (Table 6.7-1). A more representative measure is mean turbidity. Mean turbidities between 1992 and 1997 decreased from 39 NTU inflow to Brownlee Reservoir to 13.5 NTU in the reservoir, a 65% reduction. A similar percent of reduction occurred in Oxbow Reservoir, resulting in a mean turbidity of 4.1 NTU. Turbidities remained low throughout the remainder of the HCC and in the Snake River downstream of HCD.

Table 6.7-1
Minimum, maximum, and mean turbidity measures in NTUs for various reaches of the Snake River from 1992 through 1997 and the 10% cumulative increase threshold (thres.) as allowed by Oregon statute (OAR 340-041-0036)

	Snake River Upstream (RM 409–343.1)		**Brownlee Reservoir (RM 343–284.6)**		**Oxbow Reservoir (RM 284.5–272.5)**		**Hells Canyon Reservoir (RM 272.4–247.6)**		**Snake River Downstream (RM 247.5–247)**	
	NTU	**Thres.**	**NTU**	**Thres.**	**NTU**	**Thres.**	**NTU**	**Thres.**	**NTU**	**Thres.**
Count	213.0	–	978.0	–	265.0	–	434.0	–	174.0	–
Minimum	0.9	1.0	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.6
Maximum	291.0	320.1	213.0	234.3	50.2	55.2	48.9	53.8	41.7	45.9
Mean	39.0	42.9	13.5	14.8	4.1	4.5	5.4	6.0	5.0	5.5

6.7.3. HCC Contribution to Turbidity

IPC does not contribute to turbidity in the Snake River. The HCC actually reduces turbidity through settling suspended inorganic and organic solids.

6.8. TDS

TDS is a measure of dissolved ions in water that includes the major inorganic ions (e.g., calcium, magnesium, sodium, potassium, chloride, sulfate, carbon, and bicarbonate) and other trace soluble organic and inorganic materials. Neither Oregon nor Idaho has listed the Snake River or the HCC as limited (ODEQ 2014; IDEQ 2014) (tables 5.1-1 and 5.1-2). TDS data were not frequently available; however, limited analysis indicated the TDS criterion was exceeded both in the Snake River immediately upstream of the HCC as well as below.

6.8.1. TDS Standards and SR–HC TMDL Targets

Oregon has a TDS criterion not to exceed 100 mg/L unless otherwise authorized by the ODEQ (OAR 340-041-0032). Idaho does not have a criterion specific to dissolved ions, nor did the SR–HC TMDL identify a TDS target (IDEQ and ODEQ 2004).

6.8.2. Conditions Relative to TDS

IPC has periodically measured TDS in the Snake River and throughout the HCC in association with other water-quality monitoring. TDS concentrations measured in 1992 and 1995 exceeded the Oregon criterion both above and below the HCC. In 1992, levels inflowing to the HCC averaged 321 mg/L, while the levels in the Hells Canyon Reservoir outflow averaged 301 mg/L (Table 6.8-1). In 1995, levels inflowing to the HCC averaged 335 mg/L, while levels in the Brownlee Reservoir outflow averaged 285 mg/L. Outflow average and maximum TDS levels were lower than inflow levels.

Table 6.8-1
Minimum, maximum, and mean TDS concentrations in mg/L for inflow, Brownlee Reservoir outflow, and Hells Canyon Reservoir outflow in 1992 and 1995

	1992			1995		
TDS Concentrations	**Inflow (RM 330) (mg/L)**	**Brownlee Reservoir Outflow (RM 284.4) (mg/L)**	**Hells Canyon Reservoir Outflow (RM 247) (mg/L)**	**Inflow (RM 340) (mg/L)**	**Brownlee Reservoir Outflow (RM 284.4) (mg/L)**	**Hells Canyon Reservoir Outflow (RM 247) (mg/L)**
Count	9	7	7	10	11	NA
Minimum	240	265	274	173	138	NA
Maximum	375	340	325	450	413	NA
Mean	321	309	301	335	283	NA

Note: NA = Data not available.

6.8.3. HCC Contribution to TDS

TDS levels in the HCC are affected by sources to, and losses from, the reservoir complex, as well as the abiotic process within the reservoirs. The inputs include TDS inflowing the HCC, wet and dry precipitation (i.e., rainfall and wind-blown dust), and the weathering of soils and rock. While precipitation has not been assessed, it is expected to be relatively low. Weathering would be expected to exceed precipitation but still be much less than inflowing loads. A likely primary source contributing to the high inflow loads is runoff from surface irrigation. Losses from the HCC would include an outflow of surface water and a much smaller loss related to groundwater discharge.

Besides the abiotic processes discussed previously, biotic uptake and release can also affect TDS levels. Biological processing of organic matter releases TDS, while primary and secondary production uptakes constituents included in TDS.

TDS levels in the HCC are likely primarily related to levels in the Snake River inflow to Brownlee Reservoir or sources not associated with the HCC. Therefore, as levels in the Snake River and other tributaries are reduced and attain the criterion, TDS levels in the HCC and Snake River downstream should be reduced similarly. As previously stated, TDS is a measure of dissolved ions in water. While TDS is not a measure of sediment or organic matter, it can be assumed that some portion of TDS is derived from these constituents. Therefore, as sediment and organic matter are reduced, TDS levels will be correspondingly reduced. TMDLs upstream of the HCC have an established sediment and nutrient load and waste load allocations. These allocations, in part, targeted the reduction of runoff from surface irrigation. Therefore, as these TMDLs are implemented, dissolved ions (i.e., TDS) will be reduced.

6.9. Bacteria

Neither Oregon nor Idaho has listed Snake River waters as being limited by bacteria (ODEQ 2014; IDEQ 2014) (tables 5.1-1 and 5.1-2). A bacteria analysis has shown that available data do not exceed criteria, and designated recreational uses are not impaired (IDEQ and ODEQ 2004).

6.9.1. Bacteria Standards and SR–HC TMDL Targets

The SR–HC TMDL bacteria target is Oregon and Idaho's (except "specified public swimming beaches") criteria to protect recreational uses. Specifically, no single sample may exceed 406 E. coli organisms per 100 ml or a 30-day logarithmic mean of 126 E. coli organisms per 100 ml, based on a minimum of 5 samples.

6.9.2. Conditions Relative to Bacteria

The SR–HC TMDL evaluated bacteria data and reported no samples exceeded the criteria (IDEQ and ODEQ 2004). They concluded bacteria did not impair the recreational uses of the Snake River or the HCC.

6.9.3. *HCC Contribution to Bacteria*

IPC does not contribute to the bacteria of surface waters. The treated sanitary sewage disposal associated with the Brownlee Project was permanently eliminated on May 26, 2001. It was replaced with a new, upland on-site disposal (septic) system permitted through the IDHW SWDHD. The ODEQ has permitted (OR 002727-8) a sewage holding tank for the Hells Canyon Project. As such, no treated or untreated sewage is disposed directly to surface waters of Oregon or Idaho.

Associated with the HCC, IPC maintains several comfort stations that include showers, restrooms and vault toilets, and RV dump stations (Table 2.3-1). Similarly, there is no treated or untreated wastewater discharged directly to surface waters of Oregon or Idaho. The largest facility, Woodhead Park, which was developed in 1994, disposes effluent by a land-application treatment system meeting IDEQ standards.

6.10. Biocriteria

In addition to the specific numeric criteria addressed previously, Oregon has a general biological criteria (biocriteria) standard that provides that all waters are to be “of sufficient quality to support aquatic species without detrimental changes in the residential communities” (OAR 340-041-0011). Each of IPC’s past 401 applications have contained the general statement that this standard is addressed through each of the more-specific numeric criteria, targets, and allocations and that reasonable assurance that water quality is sufficient to support aquatic species without detrimental changes in the residential communities is inherent in the reasonable assurance that numeric criteria will be met. The biocriteria standard was not a specific topic of discussion prior to the release of the 2016 ODEQ draft 401 certification, which contained specific measures and conditions to address the standard. Notwithstanding, IPC continues to maintain that the general statement provided in past 401 applications applies and that the condition of key aquatic species and their habitat continue to provide evidence, and assurance, that the biocriteria standard is and will be met. IPC provides more specifics to support that position in this application.

Based on multiple evaluations of various aspects of key aquatic species and their habitats and aspects of the residential communities associated with the HCC, the waters associated with the HCC are of sufficient quality to support these uses. While not comprehensive, some significant examples of this function include strong populations of species of concern downstream of HCD. Significant increases in natural production of fall Chinook salmon have been observed since 1991. The area supports a strong population of migratory bull trout that use the mainstem Snake River. The Snake River below HCD supports a strong reproducing population of white sturgeon. Tributary habitats upstream of HCD, including Pine Creek, support several resident populations of bull trout and redband trout. Bull trout populations in these tributaries have not changed in abundance or distribution since some of the early surveys in the early 1990s, suggesting a long-term stability of these resident populations. The water-quality measures proposed in this application, along with other measures associated with other processes in this relicensing (e.g., ESA consultations), are expected to further enhance the status of these species and contribute to reasonable assurance that the biocriteria standard will be met.

6.11. Narrative Standards

The ODEQ has numerous narrative standards (i.e., descriptive standards for the protection of designated beneficial uses). In general, narrative standards strive to provide the best water quality given “the highest and best practicable treatment and/or control of wastes, activities, and flows” (OAR 340-041-0007(1)). Neither Oregon nor Idaho has identified Snake River waters as limited relative to narrative standards (ODEQ 2014; IDEQ 2014) (tables 5.1-1 and 5.1-2).

6.11.1. Narrative Standards and SR–HC TMDL Targets

Oregon narrative standards address many activities that do not directly apply to a § 401 application for the HCC (e.g., logging and forest-management activities). The following are narrative standards directly related to water-quality certification associated with the HCC:

- For any new waste sources, alternatives that utilize re-use or disposal with no discharge to public waters must be given the highest priority for use wherever practicable. New source discharges may be subject to the criteria in OAR 340-041-0004(9) and OAR 340-041-0007(4).

- No discharges of wastes to lakes or reservoirs may be allowed except as provided in OAR 340-041-0004(9) and OAR 340-041-0007(5).

- Road building and maintenance activities must be conducted in a manner to keep waste materials out of public waters and minimize the erosion of cut banks, fills, and road surfaces (OAR 340-041-0007(9)).

- The development of fungi or other growths having a deleterious effect on stream bottoms, fish, or other aquatic life, or that are injurious to health, recreation, or industry may not be allowed (OAR 340-041-0007(11)).

- The creation of tastes or odors or toxic or other conditions that are deleterious to fish or other aquatic life or affect the potability of drinking water or the palatability of fish or shellfish may not be allowed (OAR 340-041-0007(12)).

- The formation of appreciable bottom or sludge deposits or the formation of any organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry may not be allowed (OAR 340-041-0007(13)).

- Objectionable discoloration, scum, oily sheens, or floating solids or the coating of aquatic life with oil films may not be allowed (OAR 340-041-0007(14)).

- Aesthetic conditions offensive to the human senses of sight, taste, smell, or touch may not be allowed (OAR 340-041-0007(15)).

- Radioisotope concentrations may not exceed maximum permissible concentrations in drinking water, edible fish or shellfish, wildlife, irrigated crops, and livestock and dairy products or pose an external radiation hazard (OAR 340-041-0007(16)).

6.11.2. Conditions Relative to Narrative Standards

As stated in OAR 340-041-0007(1), the intent of narrative standards, notwithstanding numeric criteria, is to “maintain dissolved oxygen and overall water quality at the highest possible levels and water temperatures, coliform bacteria concentrations, dissolved chemical substances, toxic materials, radioactivity, turbidities, color, odor, and other deleterious factors at the lowest possible levels.” As such, conditions relative to narrative standards have been addressed in preceding discussions of conditions relative to numeric criteria.

6.11.3. HCC Contribution to Narrative Standards

Narrative standards relevant to the HCC relate to the discharge of wastes to public waters; nuisance growths and the formation of organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry; oily sheens or the coating of aquatic life with oil films; the creation of tastes, odors, or other toxic conditions; and land-management activities.

Narrative standards have been addressed in previous sections of this application or point-source permits specific to point-source discharge activities. The discharge of wastes to public waters is addressed by specific point-source discharge permits for appropriate HCC-related activities that are issued by the EPA and ODEQ. IPC does not directly discharge treated or untreated sanitary wastes to surface waters (see Section 6.9.3. HCC Contribution to Bacteria). The SR–HC TMDL addressed narrative standards associated with nuisance growths and the formation of organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry. IPC has identified its contribution in Section 6.4.3. HCC Contribution to Nuisance Algae. The EPA and ODEQ point-source discharge permits address oily sheens or the coating of aquatic life with oil films. IPC must not exceed levels or requirements as stated in permits. The creation of tastes, odors, or other toxic conditions are discussed in Section 6.6. Toxics. IPC will cooperate in the development of the mercury TMDL and implement appropriate measures to address its allocations. The *Hells Canyon Resource Management Plan*, developed by IPC as part of the HCC license application to FERC, establishes guidelines for the management of its lands. Road building and maintenance activities and aesthetic-condition narrative standards are addressed directly in the *Hells Canyon Resource Management Plan*, while other narrative standards are indirectly addressed. Exhibit 4.3-2 discusses compatibility with local land-use plans.

7. PROPOSED PME MEASURES

7.1. Temperature Proposed Measures

7.1.1. The SR–HC TMDL and the HCC Temperature Load

The SR–HC TMDL assigned a load allocation to the HCC to address temperature conditions below HCD during the salmonid spawning period when flows into Brownlee meet the downstream salmonid spawning standard. While recognizing the HCC is not a heat source, the SR–HC TMDL determined the HCC delays fall cooling downstream of HCD to the extent that if water flowing into Brownlee Reservoir met the upstream cold-water biota standard, outflows from the HCC would still exceed the applicable standard by a "small margin." The SR–HC TMDL summarized the narrative temperature load allocation assigned to the HCC as follows:

> To address violations of the water quality criteria for salmonid spawning temperatures, a thermal site-potential for water downstream of Hells Canyon Dam was established as the water temperature at RM 345 (approximately 10 miles upstream of Farewell Bend) using data from 1991 to 2001. A temperature load allocation in the form of a required temperature change at Hells Canyon Dam was identified as a change in water temperature such that the temperature of water released from Hells Canyon Dam is less than or equal to the water temperature at RM 345, or the maximum weekly maximum temperature target of 13 °C for salmonid spawning, plus the allowable temperature change defined as no greater than 0.14° C. The entire load for the Downstream Snake River segment (RM 247 to 188) is allocated to the Hells Canyon Complex of dams owned and operated by IPCo. Specific compliance parameters for meeting this load allocation will be defined as part of the 401 Certification process.

Key objectives of the SR–HC TMDL include attainment of water-quality standards through the "fair and equitable distribution" of pollutant loads and the development of a phased and iterative implementation process that allows for the adjustment of water-quality targets and load allocations to better meet the needs of designated beneficial uses. The SR–HC TMDL explains that due to the sparseness of data and the size and complexity of the watershed, implementation of the SR–HC TMDL would necessarily be an iterative process with the attainment of water-quality standards occurring over a period of several decades, requiring significant, long-term and coordinated efforts from all pollutant sources in the watershed.

The purpose or designated beneficial use for the temperature standard below HCD is the protection of SRFC spawning. SRFC were listed as threatened under the ESA on April 22, 1992. The SR–HC TMDL found that data available at the time (2004) did not indicate SRFC spawning below HCD was impaired by water temperatures in excess of the spawning standard during the spawning period. More recent data, including the record before the IDEQ supporting the approval of Idaho's site specific criteria on March 29, 2012, confirms this earlier finding and that the current temperature regime below HCD does not present an identifiable or immediate risk to salmonid spawning.

NOAA Fisheries recently determined that “the current water temperature regime downstream from HCD is more beneficial to SRFC than the natural regime, primarily due to warmer fall and winter temperatures that accelerate fry emergence[33].” Recently, NOAA Fisheries has further concluded that “while the temperatures are not always optimum, and while some Upper Hells Canyon reach spawners may be negatively affected, existing studies specific to Snake River fall Chinook salmon do not point to temperature as a significant limiting factor” (NOAA 2017; page 179). The fact that this beneficial use is supported under current temperature conditions provides the opportunity to address the HCC temperature load allocation in an adaptive manner to ensure SRFC spawning remains protected and other aquatic resources are not adversely impacted by abrupt or unintended changes in water quality or habitat conditions below the HCC.

As such, a thermal load off-set program known as the Snake River Stewardship Program (SRSP) has been developed based on the cumulative thermal load exceedance (CTLE) of the discharge at the HCC relative to the salmonid spawning standard. Specifically, an underlying and supporting premise of the SRSP is the DEQ and NOAA conclusion that current thermal conditions are not having a detrimental effect on SRFC spawning. This conclusion supports the decision to adopt the SRSP and, the feasibility of implementing the program over a period of years, because the beneficial use is not being adversely affected during the implementation period.

However, recent monitoring, specifically 2014 and 2015, has demonstrated brief periods in a few years at the onset of the spawning period where temperatures exceeded 17°C. In its recent recovery plan for SRFC, NOAA recognized that Snake River temperatures could potentially increase in the future and the uncertainty as to how these potential changes may affect SRFC. NOAA also referenced that data indicates that temperatures above 17°C may have detrimental effects to newly fertilized and incubating SRFC embryos and stressed the importance of continuing the “monitoring programs that document passage timing, redd counts, and river temperatures in order to detect changes and assess their effects on” SRFC. (NOAA 2017). IPC has been an active participant in monitoring and mitigation programs for SRFC and expects that participation to continue under the new FERC license for the HCC. The potential, for warmer temperature conditions during the SRFC spawning period does, however, raise uncertainties as to whether the conclusions regarding the effect of temperature conditions on SRFC spawning will remain constant during the new license term.

To assist in addressing these uncertainties, IPC is supplementing its previous SRSP proposal by incorporating actions that more directly influence water temperature in the early portion of the SRFC spawning period. Specifically, IPC proposes a Brownlee operational component that, in conjunction with the SRSP, is expected to address water temperatures below the HCD in excess of 16.5°C. IPC has chosen 16.5°C as the operative “ceiling” temperature for two reasons. First, 16.5°C is below 17°C, the temperature identified by NOAA as having the potential for detrimental effects to newly fertilized and incubating SRFC salmon embryos. Additionally, past studies commissioned by IPC in connection with the site specific standard rule change, approved by Idaho in 2012, concluded that water temperatures of 16.5°C did not have a detrimental effect on spawning SRFC. Second, the temperature data upon which the SRSP was based (1991-2014) reflect that the 7DAM temperature during the spawning period, except for

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[33] See January 27, 2011, NOAA Fisheries letter to the IDEQ and ODEQ, p. 6.

2003, 2010, and 2014 was below 16.5°C (see Table 6.1-5). These temperature conditions are reflective of, and form the basis for, NOAA's, and the SR-HC TMDL, conclusions that the current water temperature regime below HCD is not having a detrimental effect on SRFC. Implementing the Brownlee operational component, in addition to the SRSP, in an effort to ensure that the outflows from HCD do not go above 16.5°C during the spawning period will maintain the basis for that conclusion.

For purposes of this application, "Brownlee operational component" is defined to include changes in water management through changing flow regimes that are expected to effect changes to downstream water temperatures. At this time, IPC's proposed Brownlee operational component is an enhanced fall drafting of Brownlee Reservoir in years when temperature at the beginning of the salmonid spawning period are forecast to have a high probability of exceeding 16.5 °C.

Addition of the Brownlee operational component also led to the need to incorporate the effect of fall drafting when calculating the cumulative thermal load exceedance (CTLE) target as the offset requirement for the SRSP. In order to estimate the effects of the proposed fall draft on CTLE target calculation, IPC partitioned the HCC temperature load into 2 parts, the portion of the load that would be addressed by the Brownlee operational component and the portion of the load that remains, to be offset by the SRSP. This section presents IPC's proposed Temperature Management Plan that details how the historic dataset (see Section 6.1.2.3.2.) was analyzed to partition these portions of the HCC temperature load and describes the details of the Brownlee operational component and SRSP offset programs.

7.1.2. The Temperature Management Plan

In this application, IPC proposes to address the HCC temperature obligation through a comprehensive and adaptive Temperature Management Plan (TMP) that will include as its centerpiece the development and implementation of upstream Snake River mainstem and tributary measures that provide temperature, water-quality, and habitat benefits to the Snake River above, within, and below the HCC (the SRSP). The TMP also includes the Brownlee operational component to manage Brownlee Reservoir to lower October pool elevations in years when outflow temperatures are expected to exceed 16.5°C. The TMP will include adaptive management, monitoring and reporting components, and, as needed, consideration of alternative or supplemental measures. The SRSP and periodic additional fall drafts provide reasonable assurance that the temperature load obligation assigned to the HCC will be addressed in both the short and long-term. IPC expects that the detailed monitoring and reporting components of this program would be developed in post-certification implementation planning with the DEQs. A final TMP for DEQ review and approval will be submitted to IDEQ and ODEQ within 120 days after FERC license issuance, and will be informed by ongoing monitoring of water temperatures downstream of HCD.

7.1.2.1 The Brownlee Operational Component and Partitioning the Load Allocation into Two Parts

IPC's Brownlee operational component of the TMP is to draft Brownlee Reservoir, beginning after Labor Day, to a lower elevation than would otherwise be required for the SRFC flow program (see Section 4.5.1.). IPC's current fall drafts of Brownlee Reservoir are set primarily to accommodate stable SRFC spawning flows. Specifically, the fall minimum elevation is reached around the second Monday in October (see Section 4.5) after which HCC outflows are held stable for the SRFC flow program (i.e., until the 2nd Friday in December). The targeted minimum Brownlee elevation is identified in early September, based primarily on forecasted inflow volumes, the level of HCC outflows planned during the stable flow period and the ability to refill Brownlee for winter power production. Other factors considered include system reliability, power markets, and recreational impacts.

IPC's proposal for the TMP is to include forecasted HCC outflow 7DAM temperature conditions into the decision matrix, as a priority, and draft Brownlee to a lower elevation than otherwise planned in years when there is a high probability that temperature will exceed 16.5°C. The goal of this operation will be to cool HCC outflows and remain below 16.5°C as a 7DAM temperature during the salmonid spawning period. For compliance purposes, IPC proposes that this component would be applied so that the 16.5°C target would not be exceeded in 3 consecutive years. The 3-consecutive year threshold is based on several factors. First, the 3-consecutive year threshold is intended to be consistent with the Nez Perce Tribe comments submitted on February 28, 2017 regarding Oregon and Idaho's draft 401 certifications. Second, potential future climate conditions and forecasting uncertainty precludes a realistic expectation that a 7DAM of 16.5°C can be ensured every year. In addition, the 3-consecutive year target is based on SRFC life history (see Section 6.1.3. Snake River Fall Chinook Life History and Status) and avoiding effects of high temperatures on the same cohort as eggs and on embryo production resulting from that cohorts potentially reduced adult return. If 16.5°C is exceeded in three consecutive years, the adaptive management and alternative measures provisions of the TMP (see Section 7.1.2.5 Adaptive Management and Program Review) would be implemented.

Drafting Brownlee to a lower elevation, as described above, is effective in cooling HCC outflow temperature due to decreasing the volume in the epilimnion. By decreasing the volume of the epilimnion the deeper draft reduces the residence time of the inflowing water, which is cooler during the fall, while at the same time reducing the volume of warm water within Brownlee Reservoir that needs to be cooled either from meteorological conditions or mixing with the inflow water. IPC has conducted modeling to simulate the effectiveness of a deeper fall draft of Brownlee in low water years when warmer fall outflow temperature conditions are typically seen. CE-QUAL-W2 modeling (See Exhibit 7.1-1 for more detail on the CE-QUAL-W2 modeling) was developed to compare an operational baseline model with multiple models of deeper fall drafts (Figure 7.1-1). The modeled results of the deeper fall draft showed that, compared to the operational baseline, HCC outflow temperature began cooling in late September or early October and the cooling gradually increased till the end of the temperature exceedance period (Figure 7.1-2). The results also showed there was not a period of increased temperature downstream of the HCC while the reservoir was being drafted (i.e., beginning after Labor Day, Figure 7.1-2). Summarizing the model results showed that deeper drafts in the fall could cool HCC outflow 7DAM temperature during the period of temperature exceedances by an average of 0.4 to 1.2°C depending on conditions in that year and the extent of the additional draft (Table 7.1-1, Figure 7.1-2).

While the proposed drafting of Brownlee Reservoir could be an effective way to cool temperatures when temperatures are a concern during the SRFC spawning period, IPC also evaluated the potential for downstream unintended consequences as a result of the operations.

While the operational drafting is expected to slightly cool temperatures immediately downstream of Hells Canyon Dam as early as September, there is a potential for the increased flows needed to accomplish the drafting of Brownlee Reservoir, to slightly increase temperatures downstream of the Salmon River (Exhibit 7.1-2). Further, there are potential downstream effects, related to cooler late fall and early winter temperatures, on SRFC emergence timing in the following spring. Potential effects on SRFC emergence timing stem from cooler temperatures resulting from the additional draft slowing thermal unit accumulation and delaying SRFC emergence (See Exhibit 7.1-3 for additional analysis and information on SRFC emergence timing).

Table 7.1-1
CE-QUAL-W2 modeled cooling effect of an additional deeper draft of Brownlee Reservoir in the fall.

Model year	Brownlee October minimum water surface elevation (ft)		Modeled average cooling during exceedance period(°C)	Modeled cooling effect (°C/ft additional draft)
	Baseline	Additional Draft		
2002	2,052	2,010	1.0	0.024
2015	2,052	2,025	0.4	0.015
2015	2,052	2,010	0.7	0.017
2015	2,052	1,990	1.2	0.019
Average			0.83	0.019

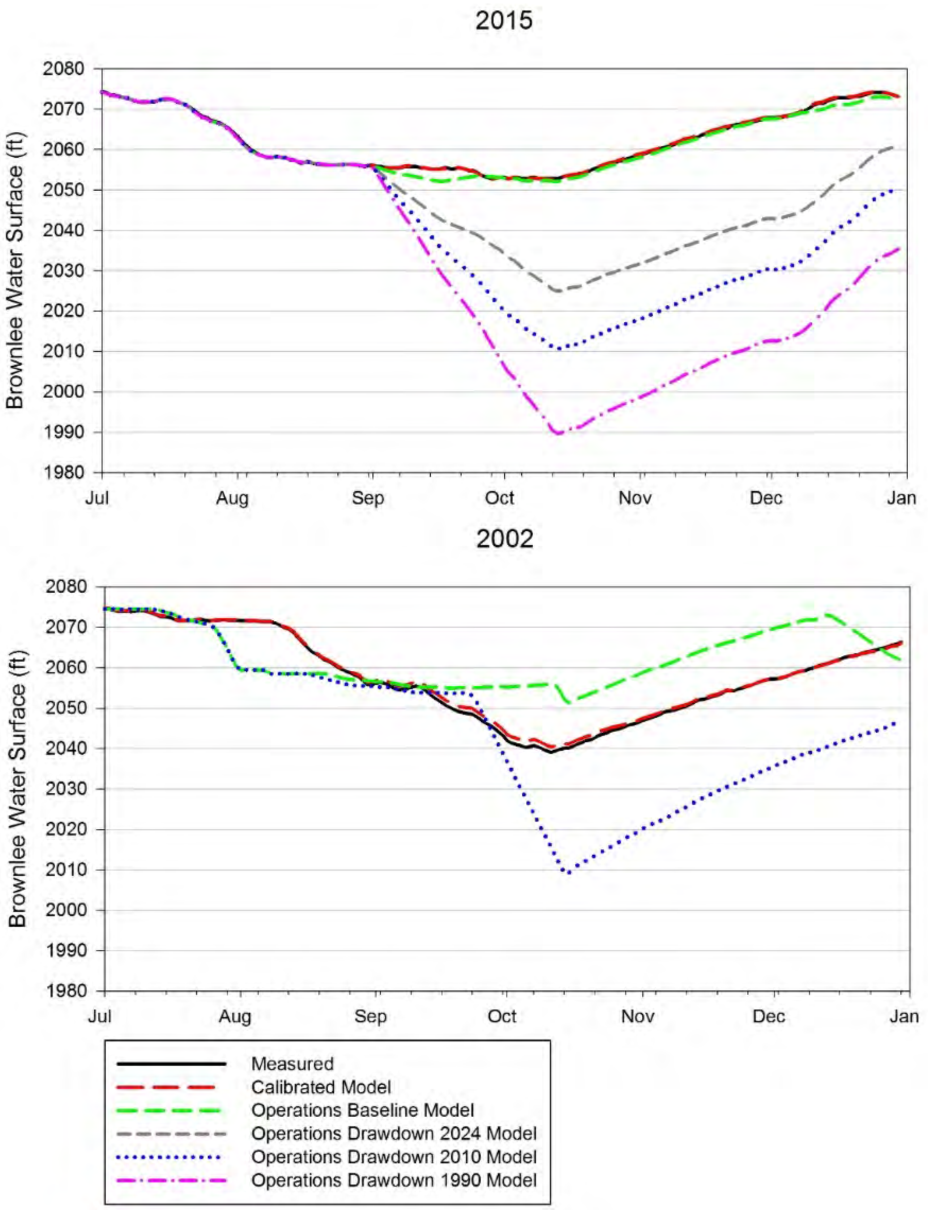

Figure 7.1-1
2002 and 2015 Brownlee water surface elevation compared between actual historic operations (measured) and multiple CE-QUAL-W2 modeled scenarios with additional fall drawdown for temperature improvement.

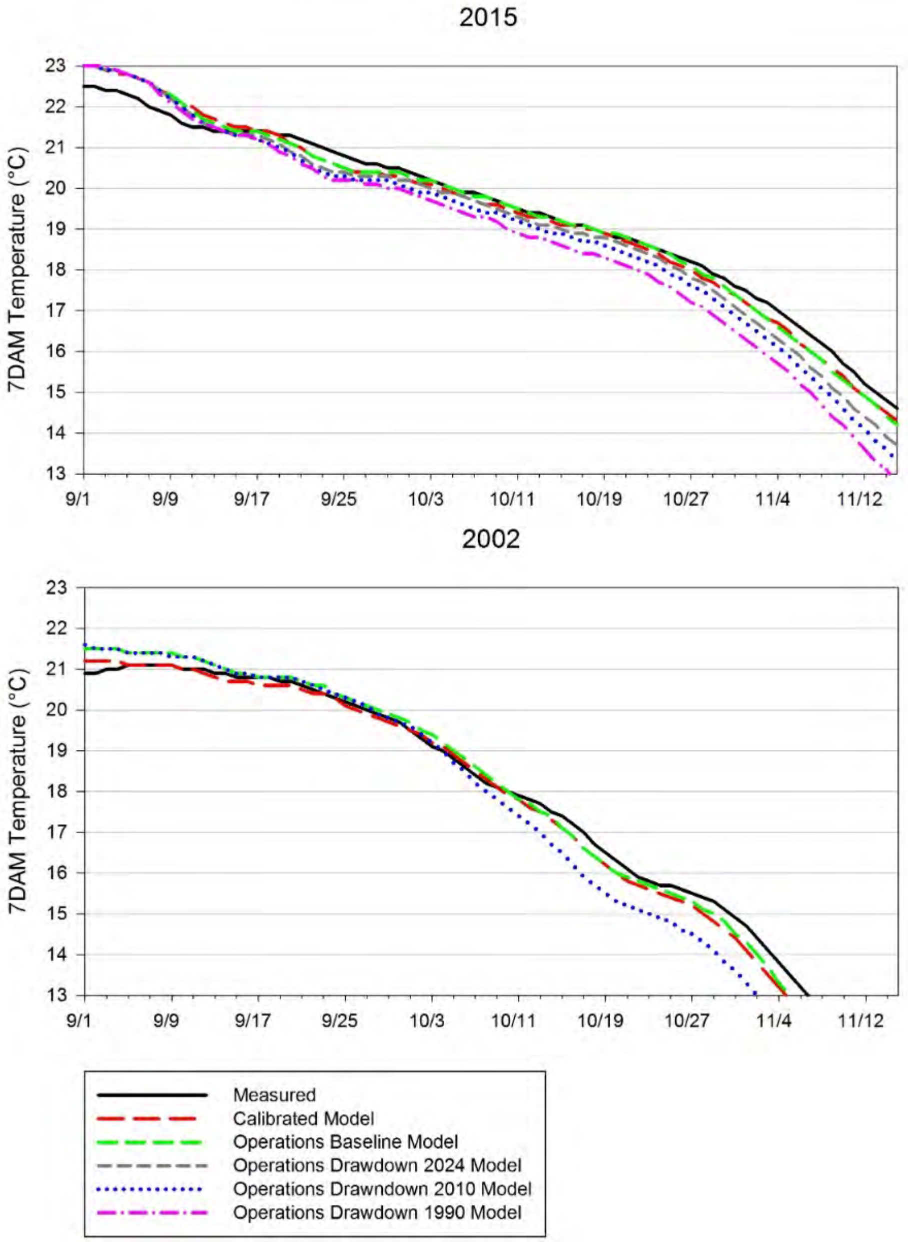

Figure 7.1-2
2002 and 2015 HCC outflow 7-day average maximum (7DAM) temperature comparing measured conditions with multiple CE-QUAL-W2 modeled scenarios with additional fall drawdown for temperature improvement.

Including the Brownlee operational component in the TMP, in effect, partitions the temperature load below HCD into two parts, the portion of the CTLEs (see Section 6.1.2.3.2.) that would be addressed by the Brownlee operational component and the portion of the CTLEs that remain, to be offset by the SRSP. To incorporate the effects of the operational component, the historic HCC outflow 7DAM temperature dataset was adjusted based on an assessment of which years in the dataset the operational component would have likely been implemented. The measured 7DAM temperature for those years were then replaced in the historic dataset with the adjusted 7DAM temperatures based on cooling from a deeper draft of Brownlee, and a revised CTLE target was then calculated to be offset by the SRSP.

Measured 7DAM temperature was adjusted for 7 years out of the 27-year dataset. Simply adjusting the 4 years in the dataset when measured HCC outflow 7DAM was above 16.5°C would not appropriately represent the effect of the proposed Brownlee operational component in the historic data because in the future, an additional draft of Brownlee Reservoir would occur when there is a high probability that temperature will exceed 16.5°C based on forecasted conditions. This means that the Brownlee operational component would have been implemented in forecasted warm years without knowledge of what actual measured temperatures would be. For these reasons, the 7 years were selected for adjustment based on when an example "reconstructed forecast" indicated a high probability that temperatures would exceed 16.5°C (Figure 7.1-4).

These reconstructed forecasts were developed using a multiple regression model that included Brownlee water surface elevation, inflow water temperature and air temperature to predict the outflow 7DAM temperature on October 29 (Figure 7.1-3, See Exhibit 7.1-1 for additional information on the multiple regression modeling). Input variables to the multiple regression and the uncertainty associated with these variables were based on estimates of what could be realistically forecast on September 1 of each year. Input variables were then permutated (81 individual outflow 7DAM predictions each year) to represent an example of the uncertainty with forecasting future conditions. The permutations resulted in a forecasted distribution of potential outflow 7DAM temperature on October 29 which indicated that years 2003, 2004, 2010, 2014, 2015 and 2016 would have shown a high probability of exceeding 16.5°C (Figure 7.1-4). In this analysis, exceeding 16.5°C in approximately 25% or more of the predictions was considered a high probability. Inflow temperature data was not available to predict a distribution for 1991 through 1995, and 2001, however, based on the measured 7DAM of 16.4°C in 1991 it was assumed that 1991 conditions were similar to 2004 and 1991 was included in the adjusted years.

After the years were identified, the magnitude of the additional fall Brownlee draft estimated to provide the necessary cooling was determined for each of the 7 years. To do this the average cooling effect from the CE-QUAL-W2 modeling (i.e., °C/ft, Table 7.1-1) was applied to lower the distribution of forecasted 7DAM temperatures to a point where less than 25% of the predictions exceeded 16.5°C. For example, in 2010 the approximate 75th percentile in Figure 7.1-4 was 17.0°C meaning 0.5°C of cooling from a draft would be needed to shift the distribution down to where only 25% of the predictions exceeded 16.5°C. Dividing the cooling needed in 2010 (0.5°C) by the average modeled cooling effect (0.019°C/ft additional draft) results in the additional draft needed (26 ft in 2010). The forecasted additional Brownlee drafts for the 7 adjusted years ranged from 16 to 63 ft and included a minimum elevation limit of 1,990 ft to remain within the bounds of the CE-QUAL-W2 modeling and operational considerations. The forecasted additional Brownlee draft, considering the 1990 limit, multiplied by the average CE-QUAL-W2 modeled cooling effect to calculate the temperature change that was used to adjust the measured 7DAM temperature on each day for the 7 years (Table 7.1-2).

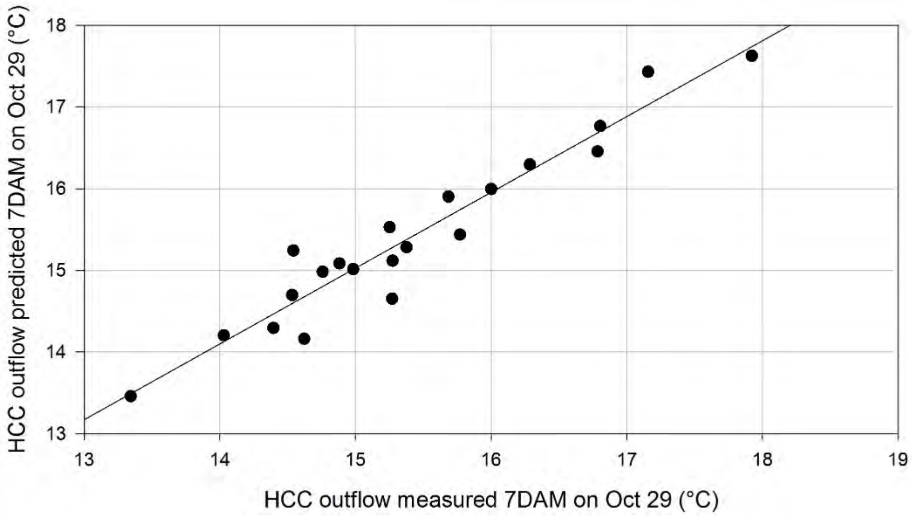

Figure 7.1-3
Measured HCC outflow 7DAM temperature on October 29 compared with predicted values from a multiple regression model (Adjusted R2=0.915, p<0.001) that incorporates Brownlee water surface elevation, inflow temperature and air temperature as inputs.

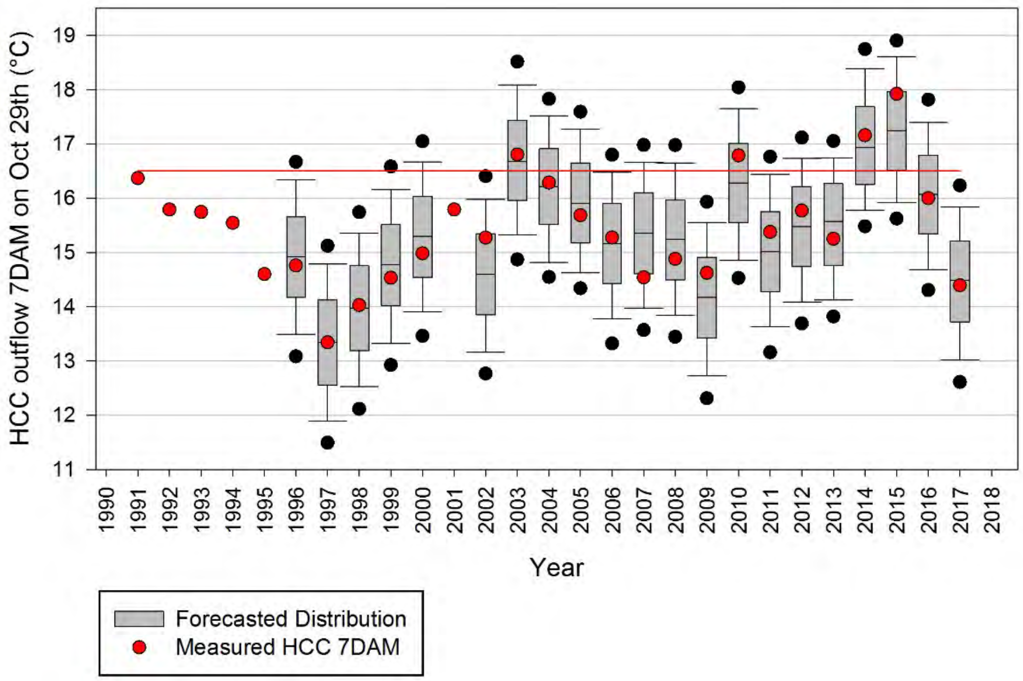

Figure 7.1-4
Measured HCC outflow 7DAM temperature on October 29 compared with a distribution of predicted temperatures from a multiple regression model with 81 permutations of forecasted input conditions for years when data were available. The boxes show the 25th and 75th percentile while the whiskers and dots show the 10th and 90th and 5th and 95th percentiles of the 81 predictions, respectively.

Table 7.1-2
Summarized information describing how a 7DAM temperature adjustment based on the Brownlee operational component was determined. Both the historical measured Brownlee water surface elevation (WSEL) and a calculated forecasted WSEL are show. The 7 years included are the 7 years identified from the historical dataset when reconstructed forecast information indicated a high probability of exceeding 16.5°C.

Year	Measured October minimum WSEL (ft)	Measured 7DAM temperature on October 29 (°C)	"Reconstructed forecast" 7DAM (°C)[1]	Forecasted temperature decrease needed (°C)	Forecasted WSEL target needed (ft)[2]	Cooling from drawdown (°C)[3]
1991	2,056	16.4	16.9	0.4	2,035	0.4
2003	2,039	16.8	17.4	0.9	1,992	0.9
2004	2,053	16.3	16.9	0.4	2,032	0.4
2010	2,045	16.8	17.0	0.5	2,019	0.5
2014	2,059	17.2	17.7	1.2	1,996	1.2
2015[4]	2,053	17.9	17.9	1.4	1,990	1.2
2016	2,046	16.0	16.8	0.3	2,030	0.3

Notes:

1 This predicted temperature is based on the approximate 75th percentile of the distribution of temperature predictions from an example "reconstructed forecast" in Figure 7.1-4.

2 This is the WSEL calculated to bring the "reconstructed forecast" 7DAM below 16.5.

3 This is the calculated additional fall draft (i.e., measured minus forecasted WSEL) multiplied by the average modeled cooling effect of 0.019°C/ft.

4 The actual modeled cooling effect from the 2015 CE-QUAL-W2 modeling was used for this year as opposed to the average modeled cooling effect used in the other years.

The adjusted data for the 7 years based on the Brownlee operational component was substituted into the historic dataset (Table 6.1 5, see Section 6.1.2.3.2) and revised CTLE estimates were recalculated for the 7 years. The resulting dataset represents the remaining CTLEs attributable to the HCC after incorporating the effects of the Brownlee operational component. CTLE values ranged from 0.0 to 728.3 bkcal and were used to develop the CTLE target to be offset by the SRSP component of the TMP (Table 7.1-3).

The variability exhibited by the CTLE dataset is not unique to environmental data, but it does pose challenges from a regulatory perspective in defining a target load for the SRSP program. Frequently in the regulatory arena, statistics are used to define an appropriate target based on a range of collected environmental data. Specifically, in a number of analogous regulatory contexts, regulators have used a 90% statistic to set appropriate compliance targets from a range of environmental data (Exhibit 7.1-4).

Therefore, in calculating the size of its CTLE to be offset by the SRSP, IPC used the 90th percentile statistic. The =PERCENTILE function in Microsoft Excel was used to calculate the 90th percentile value of the CTLEs for all years (1991-2017), using the adjusted CTLE from the operational component in 7 (Table 7.1-3) of the 27 years. This results in a calculated CTLE at the HCC outflow of 541.6 bkcal. IPC proposes that 541.6 bkcal represent the thermal load to be offset by SRSP. This CTLE quantifies the remaining thermal effects of the HCC relative to the salmonid spawning criterion, after incorporating the effect of the operational component and defines the compliance target for mitigating the effects within the framework described in Section 7.1.2.2. below.

While the water temperature and the flow discharges can vary on a given day, the one constant in the calculation of a daily thermal load exceedance is the applicable water-quality standard. Despite the fact that Idaho adopted and submitted a site-specific criterion of 14.5°C in 2012 the EPA has not yet acted on Idaho's criteria change. Therefore, the applicable standard for 401 certification at this time is the Oregon standard, which is 13°C. As explained in Section 6.1.1.4. Salmonid Spawning, IPC is proposing to use 13.3°C as the applicable standard.

Table 7.1-3
Cumulative thermal load exceedance (CTLE) over the duration of time when the HCC outflow temperature was greater than 13.3°C (1991-2017) calculated from the measured 7DAM temperatures (see Section 6.1) compared with adjusted CTLE based on the operational component. Also shown for reference is the annual average Snake River flow in cfs measured at Weiser, Idaho, and water-year category.

Year	CTLE Based on Measured Temperature (bkcal)	Adjusted CTLE Based on Operational Component (bkcal)	Water-Year Category
1991	453.2	349.4	Low
1992	551.0	Na	Low
1993	366.5	Na	Medium
1994	353.0	Na	Low
1995	114.8	Na	Medium
1996	150.2	Na	High
1997	0.0	Na	High
1998	58.7	Na	High
1999	181.4	Na	High
2000	192.9	Na	Medium
2001	422.2	Na	Low
2002	210.3	Na	Low
2003	547.7	326.8	Low
2004	500.4	383.0	Low
2005	456.0	Na	Low
2006	184.9	Na	Medium–high
2007	116.3	Na	Low
2008	175.1	Na	Low
2009	95.2	Na	Medium–low
2010	809.9	603.7	Medium–low
2011	428.0	Na	High
2012	438.1	Na	Medium

Year	CTLE Based on Measured Temperature (bkcal)	Adjusted CTLE Based on Operational Component (bkcal)	Water-Year Category
2013	277.4	Na	Low
2014	1,044.9	535.3	Low
2015	1,256.4	728.3	Low
2016	686.5	535.1	Low
2017	105.9	Na	High

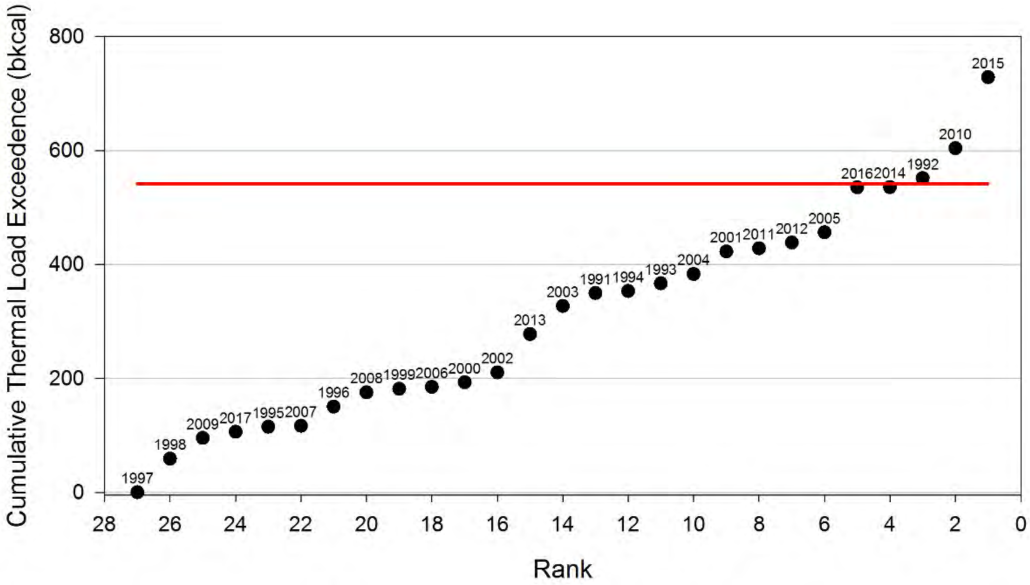

Figure 7.1-5
Plot ranking the cumulative thermal load exceedances remaining after incorporating the operational component for the 27 years available during the 1991 through 2017 period. The 90th percentile of the dataset, 541.6 bkcal, is shown as the solid red line.

The DEQs (in the SR HC TMDL) and NOAA have concluded that the past temperature conditions below HCD, which generally have been between the current 13°C salmonid spawning standard and 16.5°C over the past 27 years have not been a limiting factor in salmonid spawning success. The results of laboratory studies commissioned by IPC in connection with the Idaho approved site specific standard change is consistent with that conclusion. The continued maintenance of such temperature conditions below HCD with the Brownlee operational component allow the SRSP to be implemented and address the TMDL temperature load through the CTLE, while also addressing potential temperatures that could exceed 16.5°C without the Brownlee operational component.

7.1.2.2. Addressing the SRSP Cumulative Thermal Load Exceedance through a Thermal Load Offset Framework

IPC is proposing to address the CTLE remaining after incorporating the effect of the Brownlee operational component (i.e., 541.6 bkcal), referred to hereafter as the remaining CTLE, through implementation of the SRSP. The SRSP is a landscape scale watershed program with the primary objective of implementing measures upstream of the HCC (in-river and within tributaries) that will provide aggregate thermal benefits. The level of aggregate thermal benefits would be commensurate with the thermal load necessary to offset the remaining CTLE

The opportunity to address the remaining CTLE through a watershed approach is consistent with the SR-HC TMDL and NOAA conclusions, supported by scientific information that the water temperatures associated with the remaining CTLE are not likely to be having a detrimental effect on SRFC spawning success. Water temperatures below 16.5°C have been shown through both laboratory studies, and site-specific studies within Hells Canyon to be benign relative to negative effects on spawning success.

As described above, the remaining CTLE to be offset by the SRSP is 541.6 bkcal. The narrative description of the HCC temperature load in the SR–HC TMDL includes a 10% margin of safety (54.2 bkcal), increasing the remaining CTLE to 595.8 bkcal when added to this calculation. Following this determination of the HCC outflow remaining CTLE to offset by the SRSP, 3 steps remain in the offset framework.

1. Determine and apply a reservoir attenuation factor (i.e., the proportion of upstream thermal benefits that are reasonably expected to travel from the HCC inflow to the HCC outflow).
2. Determine and apply river attenuation factors. (i.e., what proportion of thermal benefits generated by in-river and tributary measures can reasonably be expected to travel from project sites to the HCC inflow).
3. Determine and apply a thermal benefit aggregation, and aggregation time.

After applying step 1 above, in this framework, the required HCC outflow CTLE can be expressed as an aggregate thermal load target needed at the HCC inflow. The term “aggregate” is used at this point in the framework because offsetting this load will be accomplished through the aggregation of project-specific thermal benefits from multiple upstream SRSP projects after considering both the spatial (step 2 above) and temporal (step 3 above) relationship of those benefits to the HCC inflow. Each of the steps in this framework are explained in more detail below.

7.1.2.2.1. Step One—Reservoir Attenuation

Because IPC’s proposal to offset the remaining CTLEs uses upstream watershed based projects, attenuation of the upstream thermal benefits that occurs in the HCC reservoirs must be taken into account. Attenuation here is defined as a decrease in thermal benefits that occurs as water moves through the reservoirs due to reservoir processes such as mixing, storage timing, and warming. To account for reservoir attenuation, IPC has employed the best available data, including water-quality modeling specific to the HCC, to estimate an appropriate attenuation factor. After analysis (see Section 7.1.2.2.4. Technical Information Relative to Attenuation and Thermal Benefit Aggregation Period) and in consultation with the DEQs, IPC concludes that using an attenuation factor of 50% (half of the thermal benefits provided at the inflow to the HCC will not be expressed at the HCC outflow during the salmonid spawning period) reasonably accounts for the attenuation of upstream thermal benefits caused by the HCC reservoirs. Applying this HCC reservoir attenuation factor to the CTLE to be offset by the SRSP (595.8 bkcal with the margin of safety included) results in an aggregate thermal load reduction target of 1191.6 bkcal at the HCC inflow. This is the aggregate thermal load reduction the SRSP must provide in the inflow to the HCC.

7.1.2.2.2. Step Two—River Attenuation of Upstream SRSP Thermal Benefits

Similar to the need to address attenuation through the HCC reservoirs, there is also a need to address attenuation of thermal benefits from each project to the inflow to the HCC. This task, however, is complicated by the fact that SRSP measures would be implemented throughout the watershed upstream of the HCC, and as a result, decreases in thermal loading from specific projects will vary depending on the distance of the project from the HCC inflow. As with the HCC reservoir attenuation analysis, IPC used the best available data in determining an appropriate attenuation factor for the upstream SRSP thermal benefits. Because of the complexity of tracking individual parcels of water through the riverine reaches between project areas and the HCC and the diversity of project locations within the watershed, IPC is proposing to use 1 attenuation factor for tributary projects, and 1 for in-river projects. To determine these 2 attenuation factors, IPC, along with the DEQs, examined CE QUAL W2 modeling conducted by Portland State University (Berger et al. 2009) and by IPC. Based on this examination (see Section 7.1.2.2.4.) a reasonable attenuation factor 1) for thermal load reductions realized from projects within the Snake River from Swan Falls Dam downstream to Homedale, Idaho, is 22%, and 2) for tributary projects is 25%. In other words, in-river and tributary project thermal benefits will be reduced by 22% and 25%, respectively, before being applied or credited toward the aggregate thermal load target of 1191.6 bkcal at the HCC inflow.

7.1.2.2.3. Step Three—Thermal Benefit Aggregation and Aggregation Time Period

The SRSP projects are intended to offset the remaining CTLE by producing thermal benefits at many individual projects upstream. Therefore, the thermal benefits from all upstream SRSP projects will be added together (i.e., aggregated), attenuated to reflect Steps 1 and 2, then compared against the remaining CTLE at the outflow.

The last step in determining how to apply the thermal benefits of SRSP projects toward the remaining HCC outflow CTLE is to determine the temporal duration of the SRSP thermal benefits. In other words, for what period of time will the SRSP measures provide thermal benefits that can reasonably be expected to influence the HCC outflow CTLE during the fall spawning period? While the measures to be implemented under the SRSP will provide thermal benefits year-round, IPC is proposing that only the thermal benefits that have a sufficient effect, or nexus, to the salmonid spawning period at the HCD outflow be aggregated and applied toward the offset.

In an effort to determine this aggregation time period, IPC, in consultation with the DEQs, used CE-QUAL-W2 modeling of inflow thermal load reductions during September and October and incrementally simulated additional thermal benefits through the prior months back to April. The results (described in detail in Section 7.1.2.2.4. Technical Information Relative to Attenuation and Thermal Benefit Aggregation Period) of this modeling indicate that thermal load benefits entering the HCC from April through October result in quantifiable benefits realized at

HCD outflow during the salmonid spawning period. While the thermal benefits from water entering the HCC from April through June do produce a benefit at the outflow from the HCD during the salmonid spawning period, the magnitude of that benefit at the HCD outflow is smaller than the benefits realized from the later months. These model runs show that July through October inflow best represents the make-up of thermal benefits realized at the HCD outflow during the salmonid spawning period. As a result, IPC is proposing that the thermal benefits provided by the SRSP measures during the period from July 1 through October 29 be summed and credited toward the offset of the remaining HCC outflow CTLE.

The selection of July 1 through October 29 as the aggregate thermal benefit period is also consistent with the HCC system dynamics and conclusions relative to those system dynamics in the SR–HC TMDL. Many thermal benefits generated upstream of the HCC may not translate immediately through to the HCC outfall on a daily basis. Rather, because of this complicated and delayed storage, retention, and release dynamic, the thermal benefits associated with water that has entered the HCC between the beginning of July and the end of October have a reasonable nexus to the thermal loading downstream of the HCC during SRFC spawning. The TMDL notes that water may reside in the HCC for over four months, or just a number of days, and water that enters the HCC may stratify over time. As such, the thermal benefits associated with the July, August, September, and October water that enters the HCC has an effect on the discharges occurring in late October and early November during the period of concern for spawning.
The summer period, including July when upstream water temperatures typically peak, was also identified in the SR–HC TMDL as a critical period for temperature loading upstream of the HCC (TMDL at 367–369). Therefore, it is reasonable to include the thermal benefits associated with SRSP measures during this period of greatest heat loading to the system.

7.1.2.2.4. Technical Information Relative to Attenuation and Thermal Benefit Aggregation Period

As mentioned in the previous sections, a collection of results from CE-QUAL-W2 temperature modeling were considered to inform the selection of attenuation factors and the aggregation time frame. The recent modeling of 2015, that was conducted to evaluate the potential effects of the Brownlee operational component, was not included in the assessment of potential attenuation and thermal benefit aggregation. While the modeling of 2015 was not specifically incorporated into the analysis, model scenarios of the Brownlee operational component could be expected to demonstrate less attenuation (Exhibit 7.1-1). The following information provides detail on attenuation and benefit aggregation modeling and analyses.

7.1.2.2.4.1. Model Background

To support the FERC license application process, IPC developed CE-QUAL-W2 models for Brownlee, Oxbow, and Hells Canyon reservoirs (Harrison et al. 1999; Zimmerman et al. 2002). Models were initially developed for 1992, 1995, 1994, 1997, and 1999. These years were selected based on water-year conditions combined with data availability for set-up and calibration. The initial calibration effort was focused on 1992, 1995, and 1997 for low, medium, and high water years, respectively. The 1994 and 1999 models represent medium-low and medium-high water years, respectively. The 1994 and 1999 models were developed as verification years (e.g., the model settings developed through calibration of the other years were applied to these years). The general calibration process for the HCC models is described in

Harrison et al. (1999) and Zimmerman et al. (2002). The majority of the calibration effort was focused on conditions in Brownlee Reservoir where physical and biological processes are more complex. Also, field studies consistently show that conditions in Oxbow and Hells Canyon Reservoirs are driven by Brownlee outflow conditions.

In 2002, a large data collection effort by IPC and others provided additional information relative to inflowing Snake River organic matter, including algae (Harrison 2005). Also studied were Brownlee hydrodynamics, temperature stratification, DO dynamics, meteorological conditions, and intake channel configuration (Botelho et al. 2003, Botelho and Imberger 2007). A 2002 CE QUAL-W2 model was developed using this additional information, which reduced uncertainty relative to boundary conditions for the existing low-water year model (i.e., 1992). After the 2002 model was developed, many of the updates and improvements were then applied to the other model years, and calibration for all the years was re-evaluated. IPC used several methods to analyze model output and improve the calibration, including animations of the water quality constituents over time, time-series plots of the outflow constituents and isopleths and profile plots at various locations and times in the reservoir. IPC also used absolute mean error analysis as a quantitative means of assessing in-reservoir calibration. Measured temperature collected at multiple depths and locations in the reservoir were compared with modeled values and summarized to show the overall error over the year.

The HCC models have been recently upgraded to CE-QUAL-W2 Version 3.7. As part of this upgrade process, the settings for all the models were reviewed, and changes were made where applicable. Specific to temperature settings, 2 changes were made to the Hells Canyon model, including resetting evaporation coefficients to default values and updating the bathymetry to include the old coffer dam that remains in place upstream of HCD. The resulting temperature calibration for the Hells Canyon outflow temperature is shown in Figure 7.1-6 and Figure 7.1-7.

For the HCC reservoir modeling analysis presented in the following sections, 2 of the 6 years (1992 and 2002) are used. Both of these years represent low water conditions. Using low-water year models allows the evaluation of conditions when the largest exceedances of the salmonid spawning criterion are typically seen in historical data.

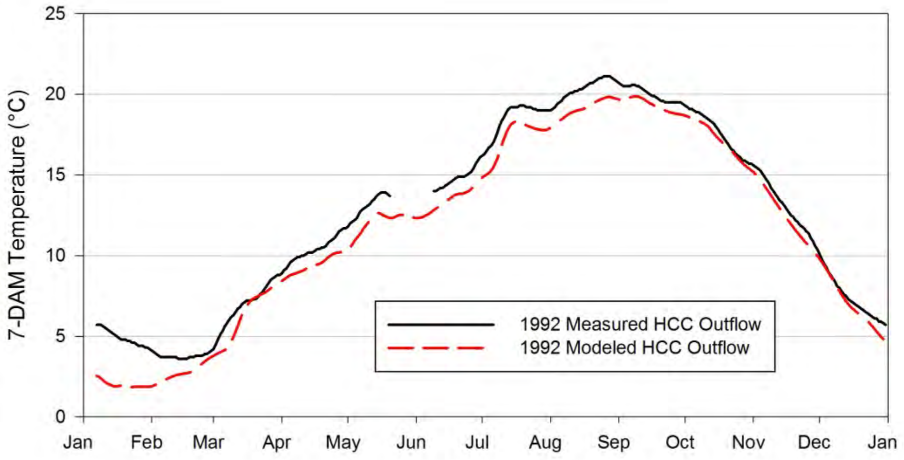

Figure 7.1-6
Modeled Hells Canyon outflow 7DAM compared with measured 7DAM for the 1992 CE QUAL W2 model

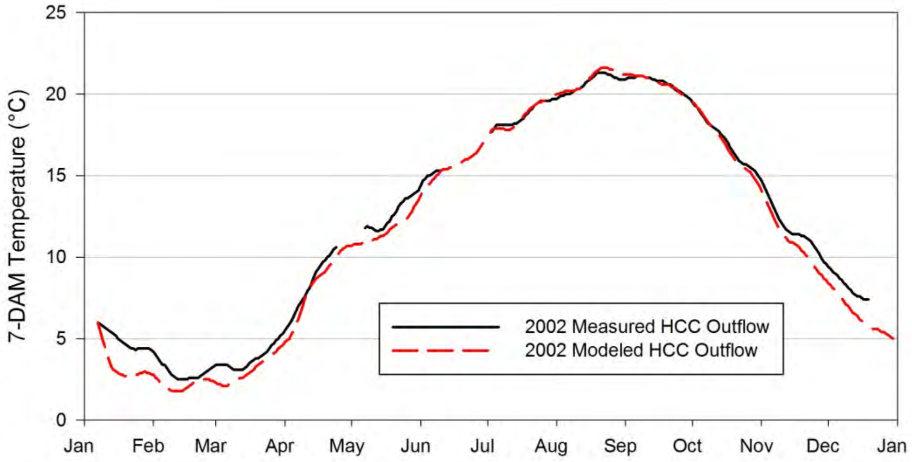

Figure 7.1-7
Modeled Hells Canyon outflow 7DAM compared with measured 7DAM for the 2002 CE QUAL W2 model

IPC used a Snake River CE-QUAL-W2 model, developed for 1995 by IPC and used in the SR–HC TMDL development process (Harrison et al. 2000), along with modeling conducted by Portland State University (Berger et al. 2009), to inform the decision relative to thermal load attenuation through the free-flowing mainstem Snake River and tributaries. The 1995 Snake River model includes an approximately 150-mile stretch of the Snake River from C. J. Strike Dam (RM 494) to Brownlee Reservoir inflow (RM 340). The model was specifically developed to support the analysis and development of Snake River TP targets and a Brownlee Reservoir DO allocation. The model was developed for 1995 because substantial data were available to support model development in that year and because 1995 represented “average” flow conditions, which is consistent with the SR–HC TMDL focus on average water conditions.

The calibration process for the 1995 Snake River model is described in Harrison et al. (2000). The model simulated temperature conditions reasonably well throughout the year (Figure 7.1-8). The most accurate simulated temperature appears to occur at the Brownlee inflow (i.e., Porters RM 340) and near the downstream end of the Marsing reach (i.e., Adrian RM 403). At other locations, the model values appeared warmer than measured values, especially during spring months.

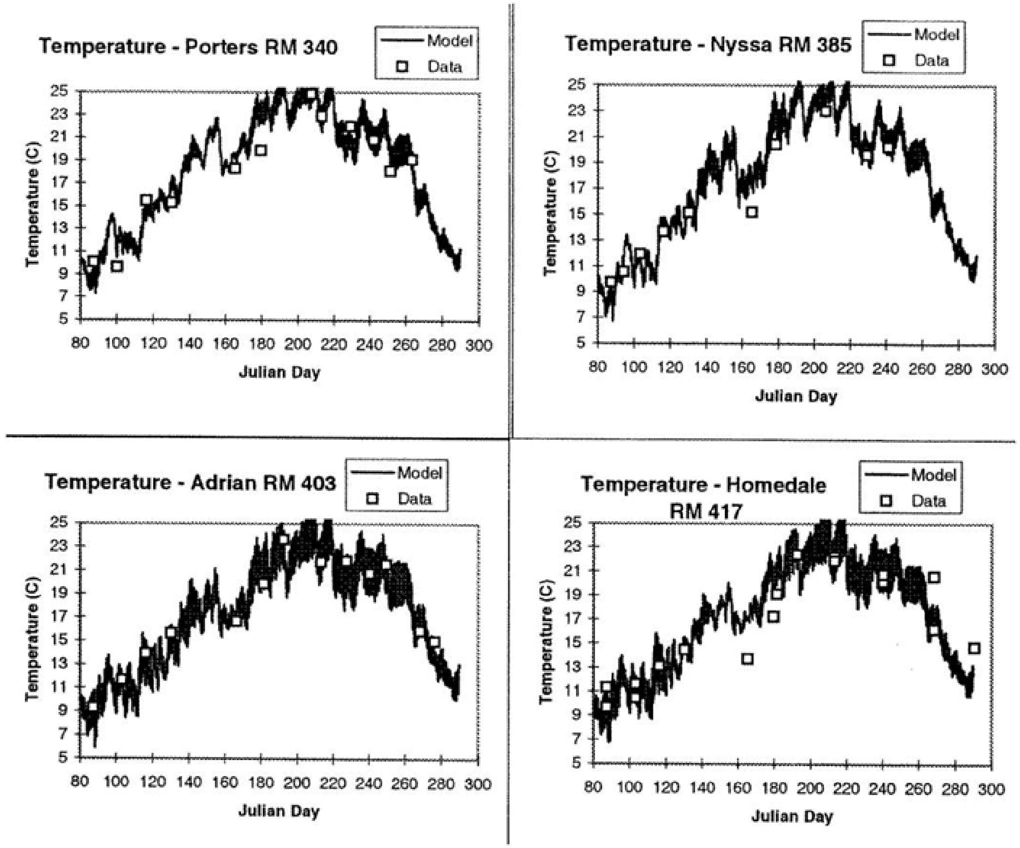

Figure 7.1-8
1995 Snake River modeled temperature compared with measured at 4 locations in the Snake River. Figure from Harrison et al. (2000).

7.1.2.2.4.2. Reservoir Attenuation and Time Period

The 1992 and 2002 CE-QUAL-W2 reservoir models were used in a sensitivity analysis to help evaluate both the effect of time frame and attenuation of inflowing thermal load reductions on outflow thermal load reductions during the salmonid spawning period. A series of four model runs were developed starting with an equal per day inflow temperature reduction during September through October, then increasing the time frame by month back to July and then to April (Figure 7.1-9). This resulted in 4 model runs with inflow temperature reductions for each of the 2 model years (1992 and 2002): 1) September through October 2) August through October 3) July through October, and 4) April through October. The objective of modeling a 2°C equal per day temperature reduction over these 4 time periods was to explore which of the 4 inflow time frames best represented the make-up of thermal benefits realized at the HCD outflow during the salmonid spawning period. These modeling results also assist in identifying the proportion of the inflowing thermal load reductions that are translated to the outflow (i.e., reservoir attenuation). As noted above, the results of these model runs informed the selection of attenuation factors and aggregation time frame.

7.1.2.2.4.2.1. Time Period

The selection of an aggregate thermal benefit time period is based on the results of the 1992 and 2002 CE-QUAL-W2 reservoir models, as well as other qualitative information relevant to the dynamics of the HCC.

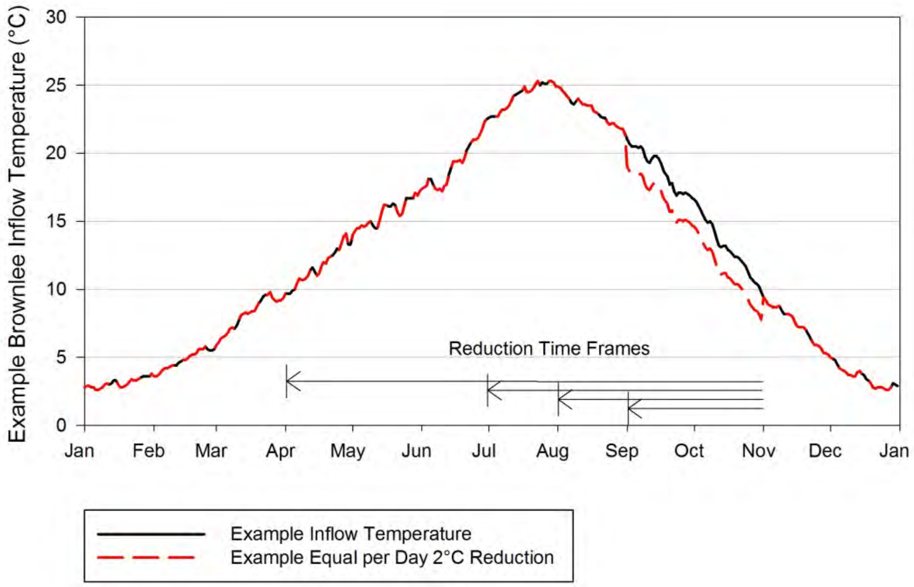

Figure 7.1-9
Example inflow temperature series showing an example 2°C equal per-day temperature reduction over the September 1 through October 29 time frame and arrows indicating the other time frames that were modeled.

In these 4 model runs, the Brownlee inflow thermal load reduction was calculated based on an assumed example temperature reduction (i.e., 2°C per day) and the historical measured average flow over the time frame for each year. An equal per day approach was selected as the most straightforward method to apply the temperature reduction for modeling sensitivity purposes. While the temperature reduction was equal across the different time frames, the thermal load reductions vary over the different modeled periods because flow entering the HCC is variable throughout the year. For example, doubling the inflow while applying a constant temperature reduction results in a doubling of the thermal load reduction. The inflow thermal load reduction was summarized as an average per day over the various time frames by:

$$Thermal\ Load\ (\frac{bkcal}{day}) = \left(Q\frac{cf}{sec} * \Delta T(°\mathrm{C}) * \frac{28.317kg}{cf} * \frac{86400sec}{day} * \frac{1kcal}{\frac{kg}{1}°\mathrm{C}} \right) /1{,}000{,}000{,}000$$

Where:

- Thermal load = The average daily thermal load in bkcal/day over the time frame
- Q = The average of measured Snake River at Weiser flow (cfs) over the time frame
- ΔT = The temperature reduction (i.e., 2°C) per day over the time frame

In both the 1992 and 2002 model results, inflow water from the September through October and August through October time periods had a significant impact on the inflow thermal load reduction realized at the outflow before those impacts leveled off. In the 1992 model results (Table 7.1-4), 39% of the September through October inflow thermal load reductions were realized at the outflow, 47% of the August through October inflow thermal load reductions were realized at the outflow (an additional 8%), 52% of the July through October inflow thermal load reductions were realized at the outflow (an additional 5%), and 53% of the April through October inflow thermal load reductions were realized at the outflow—meaning that those 3 additional months combined (April, May, June) only resulted in an additional 1% of thermal benefit realization at the outflow. Similarly, in the 2002 model results (Table 7.1-5), 37% of the September through October inflow thermal load reductions were realized at the outflow, 43% of the August through October inflow thermal load reductions were realized at the outflow (an additional 6%), and 44% of the July through October inflow thermal load reductions were realized at the outflow—meaning that the magnitude of adding the thermal benefit from July was relatively smaller than the magnitude from August, September, and October.

Table 7.1-4
1992 CE-QUAL-W2 modeled reductions in the HCC outflow 7DAM from a series of HCC inflow thermal load reductions over 4 time frames

Inflow reduction time frame	Inflow thermal load reduction[1] (bkcal/day)	Outflow 7DAM temperature reduction on Oct. 29 (°C)	Outflow thermal load reduction on Oct. 29[2] (bkcal)	% inflow thermal load reduction realized at the outflow
Sept. 1–Oct. 29	38	0.66	15	39
Aug. 1–Oct. 29	34	0.71	16	47
July 1–Oct. 29	33	0.75	17	52
April 1–Oct. 29	34	0.79	18	53

1 Based on a 2°C equal per-day reduction and average flow over the time frame

2 Based on daily average outflow cfs on Oct. 29

Table 7.1-5
2002 CE-QUAL-W2 modeled reductions in the HCC outflow 7DAM from a series of HCC inflow thermal load reductions over 4 time frames

Inflow reduction time frame[1]	Inflow thermal load reduction[1] (bkcal/day)	Outflow 7DAM temperature reduction on Oct 29 (°C)	Outflow thermal load reduction on Oct 29[2] (bkcal)	% inflow thermal load reduction realized at the outflow
Sept. 1–Oct. 29	51	0.86	19	37
Aug. 1–Oct. 29	47	0.90	20	43
July 1–Oct. 29	45	0.91	20	44
April 1–Oct. 29	53	0.96	22	42

1 Based on a 2°C equal per-day reduction and average flow over the time frame
2 Based on daily average outflow cfs on Oct. 29

Both 1992 and 2002 showed a similar pattern: the results from the series of different time periods showed that each additional month with a reduced inflow thermal load, from the summer months through October, resulted in additional thermal load reductions realized at the outflow of HCD during the salmonid spawning period. In the 1992 model, this trend continued through the July through October time period before leveling off. In the 2002 model, this trend continued through the August through October time period before leveling off. While both model years clearly indicate the potential for April, May, and June inflow thermal load reductions to result in reductions of outflow thermal load during the salmonid spawning period, the magnitude of the thermal benefits realized from these months is comparatively small. Therefore, in the interest of conservatism, IPC proposes to exclude this April through June time period from the thermal benefit aggregation time period.

Because the 1992 and 2002 CE-QUAL-W2 reservoir model results identified different points at which this trend showed a plateau—July versus August—additional qualitative information was also used in the selection of the July through October 29 aggregate thermal benefit time period (as discussed in Section 7.1.2.2.3. Step Three—Thermal Benefit Aggregation and Aggregation Time Period). This information includes: 1) CE QUAL W2 modeled age of water within the HCC, 2) SR–HC TMDL discussion of retention time through the HCC, and 3) retention and release dynamics of water that entered the HCC during various times of the year.

First, the CE QUAL W2 modeled age of water within the HCC aligns with a July through October time period. Modeled water age within the HCC, represented as the month of the year when the water entered the model grid, shows that as the salmonid spawning period approaches, there are layers of water stored that entered the HCC from February through October. During the beginning of the salmonid spawning period, the mixing and release dynamics of theses layers of water will be variable each year depending primarily on flow, meteorological conditions, and operational conditions. In a low water year, water representing July through October is present and being mixed within and out of the reservoir (Figure 7.1-10). Qualitatively, water that entered the reservoirs during July through October is present in the reservoirs and has an influence on the release temperature during the salmonid spawning period.

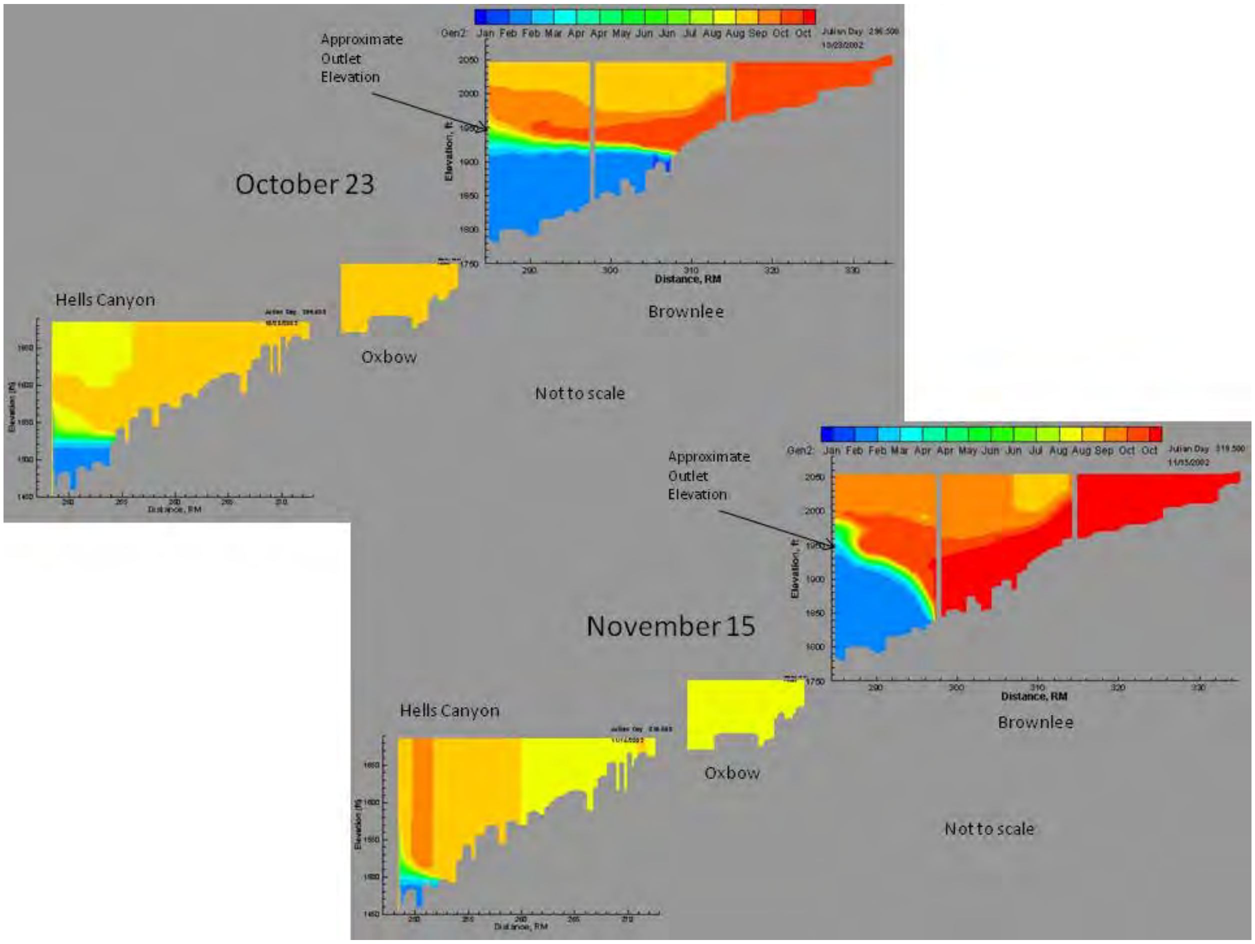

Figure 7.1-10
2002 CE QUAL W2 modeled water age within Brownlee, Oxbow, and Hells Canyon reservoirs represented as the month when water entered the model grid. Top panel shows conditions on October 23, and the bottom panel shows November 15.

Second, as discussed in Section 7.1.2.2.3. Step Three—Thermal Benefit Aggregation and Aggregation Time Period, the SR–HC TMDL notes that water may reside in the HCC for over 4 months, or just a number of days, and water that enters the HCC may stratify over time. The summer period, including July, was also identified in the SR–HC TMDL as a critical period for temperature loading upstream of the HCC. Third, as discussed in Section 7.1.2.2.3, the selection of July 1 through October 29 as the aggregate thermal benefit period is consistent with the complicated and delayed storage, retention, and release dynamic in the HCC.

7.1.2.2.4.2.2. Reservoir Attenuation

The same results from the 1992 and 2002 CE-QUAL-W2 reservoir model runs informed the selection of 50% as a HCC reservoir attenuation factor. This factor must be set so as to account for the loss of thermal benefits from upstream projects due to attenuation through the HCC reservoirs. Focusing on the July through October time period selected for thermal benefit aggregation shows that in the 1992 model, 52% of the average daily inflow thermal load reduction was realized at the HCC outflow during the beginning of the salmonid spawning period, while 44% was realized in the 2002 model (tables 7.1-4 and 5). In other words, these model runs demonstrate that approximately half (48–56%) of thermal benefits associated with the July through October inflows are not expressed at the outflow. Variability among model run results between years makes it problematic to definitively identify one single, precise attenuation factor for the HCC. Selecting a single number that implies precision to a level greater than 40% or 50% would misrepresent the inherent variability of the reservoir attenuation. Given these factors and the complex nature of the HCC, a 50% in-reservoir attenuation rate was selected to capture the thermal benefit attenuation through the system.

When selecting this rate, the presence of a margin of safety factor is relevant. The SR-HC includes a 10% margin of safety factor to be used in calculating IPC's thermal load exceedance (TMDL at 469–470). Because this margin of safety has already been accounted for in calculating the size of IPC's cumulative thermal load exceedance, selection of a reservoir attenuation rate on the lower end of this range is appropriate. A 50% in-reservoir attenuation factor is reasonably within the range identified by the 1992 and 2002 CE-QUAL-W2 reservoir model runs and captures the loss of thermal benefits through the HCC.

7.1.2.2.4.3. In-River Attenuation Factors

In addition to thermal benefit attenuation through the HCC reservoirs, attenuation of thermal benefits will also occur as water travels from SRSP project locations in the mainstem Snake River and tributaries to the HCC inflow. As discussed in Section 7.1.2.2.2. Step Two—River Attenuation of Upstream SRSP Thermal Benefits, due to the diversity of project locations and the complexity and variability involved in tracking individual quantities of water through riverine reaches between project locations and the HCC, IPC is proposing to use one attenuation factor for tributary projects (i.e., 25%) and a separate factor for in-river projects (i.e., 22%). IPC reviewed a collection of relevant existing modeling to inform the selection of these 2 attenuation factors. The primary piece of information utilized was Berger et al. (2009), which was developed as an evaluation of a previous (2009) IPC watershed program concept.

Berger et al. (2009) presented 4 scenarios where thermal load reductions from example projects were determined at the project site, then tracked through a Boise River model and a Snake River model from the Boise River confluence to Brownlee inflow. The loss or reduction of the project site thermal load reduction was determined and referred to as attenuation. Two of the Boise River scenarios were run with a 2001 model representing low water conditions and 2 with a 1999 model representing higher water conditions. The models were developed for the summer period, generally July through September. Based on these 4 scenarios, the range of thermal benefit attenuation through the Boise River (i.e., tributary attenuation) was 19 to 33%. In addition to these scenarios, project benefits from 2 scenarios were applied to the mainstem Snake River model, resulting in a range of 22 to 25% attenuation (Table 7.1-6). Considering the range of tributary attenuation results presented in Berger et al. (2009), the selection and proposal of 25% for the offset framework tributary attenuation factor is reasonable and within range.

Table 7.1-6
Summary of model results presented in Berger et al. (2009) relative to attenuation of watershed project thermal benefit as water flows through the lower Boise River and mainstem Snake River from the mouth of the Boise River to Brownlee Inflow. Scenarios in 2001 represent low water conditions, while 1999 represents higher water conditions.

Model Year	Watershed Project Cooling Scenario	Boise River Thermal Benefit Attenuation (%)	Snake River Thermal Benefit Attenuation (%)
1999	1°C cooling from restoration near Middleton	23	25
2001	1°C cooling from restoration near Middleton	33	22
1999	0.5°C cooling of flow through Willow Creek Wetland	19	NA
2001	0.5°C cooling of flow through Willow Creek Wetland	27	NA

Note: NA indicates the modeling was not presented in Berger et al. (2009)

IPC's 1995 Snake River CE-QUAL-W2 model was also considered in the selection of the mainstem Snake River attenuation factor. A thermal load reduction was applied to the model near the Owyhee River confluence (RM 393) and tracked downstream to Brownlee Reservoir inflow (RM 340). This modeling was conducted over the August through October time period, which was the focus of the analysis at that time. The results showed that thermal processes and influences from tributaries as water moved downstream resulted in 22% of this thermal benefit being lost, or attenuated, by the time it reached Brownlee inflow. This result agrees well with the range of 22 to 25% presented by Berger et al. (2009). Therefore, considering both the mainstem Snake River results from Berger et al. (2009) and previously developed IPC modeling, the selection of 22% for the offset framework mainstem Snake River attenuation factor is also appropriate and within range.

7.1.2.3. The SRSP

A large collection of data and information has been developed and analyzed through the course of IPC's work with TFT. The following discussion in this section summarizes the key details of this work, including the program area; eligible restoration actions for thermal benefits; methods for quantification of thermal benefits from those actions; total estimated supply of thermal benefits in the project area; implementation considerations; ongoing milestones, actions, tracking, and monitoring; and adaptive management and reporting. This section outlines IPC's proposal for the SRSP and is intended to be a summary of Exhibit 7.1-5, where substantially more detail on the SRSP is provided by TFT.

7.1.2.3.1. SRSP Program Area

Thermal benefits will be generated from SRSP projects located on the mainstem Snake River and its tributaries from HCD upstream to Swan Falls Dam. The eligible tributaries include but are not limited to, the following: Boise River, Burnt River, Malheur River, Payette River, Owyhee River, Payette River, Pine Creek, Powder River, Eagle Creek, Succor Creek, and Weiser River. The thermal benefit modeling and area eligible for projects does not extend upstream beyond any reservoir or substantial impoundment.

7.1.2.3.2. Proposed Restoration Actions for Thermal Benefits

There are 3 actions currently prioritized for generating thermal benefits. These actions are listed below along with a description of how thermal benefits can currently be quantified.
The currently quantifiable thermal benefits represent only a portion of the overall anticipated thermal and ecological benefits from these projects.

- In-stream habitat restoration projects in the mainstem Snake River that would reduce surface-area exposure to thermal loading from the sun and may provide additional shade from plantings:
    - Floodplain enhancement projects
    - Island creation projects
    - Inset floodplain creation
    - Emergent wetland creation
- Riparian revegetation projects in tributaries of the Snake River that would produce shade and reduce thermal loading from the sun.

The above 3 actions are the primary categories of measures that the SRSP will focus on for thermal benefits. However, as lessons are learned through implementation, or thermal benefit quantification methods improve or change, it may be appropriate to include additional or substitute restoration actions in the SRSP portfolio. For example, instream flow augmentation activities in tributaries of the Snake River could increase depths and velocities and reduce water temperature. While literature and studies indicate increased flow in the tributaries will result in improved temperature conditions, the methods to calculate and include the thermal benefits are still under development. If new or additional restoration actions are identified that provide quantifiable thermal benefits, IPC may incorporate these actions into the SRSP after appropriate review and approval from the DEQs, and as required by FERC.

7.1.2.3.3. Thermal Benefit Quantification Methods

There are 3 models or methods available for quantifying thermal benefits from the various project types: 1) Shade-A-Lator for riparian revegetation and revegetation components of the in stream projects, 2) wetland energy budget models for emergent wetlands, and 3) a suite of currently available models for surface-area changes associated with island projects. The models are limited to the quantification of potential reduced thermal loading from the sun. Many other benefits, such as increased thermal buffering and cold-water refugia and increased floodwater storage (i.e., bank storage), are not captured by the current models (Exhibit 7.1-5). Because of these limitations, the thermal benefits of the restoration actions planned for the SRSP implementation calculated with these methods are currently undervalued. In other words, the modeled thermal benefit assigned to each project derived from these methods likely does not represent the full thermal benefit of the project. IPC's proposal relies on the currently available methods but allows for improvements and the quantification of additional thermal benefits in the future as appropriate methods are developed and approved by the DEQs, and as required, by FERC.

The modeled thermal benefits for each project will be determined and documented in the project planning and design phase. Once the project is completed, the modeled thermal benefits of the project will be aggregated for the July through October 29 period, then will be counted in conjunction with other projects to offset the HCC outflow cumulative thermal load exceedance. As long as the project continues to be maintained and functions in accordance with the project specifications, as confirmed by the monitoring and tracking components of the SRSP and independent performance audits, the initially determined thermal benefits will remain applicable towards the offset. This proposed procedure is described in more detail in Section 7.1.2.3.5.

7.1.2.3.4. SRSP Implementation Considerations

IPC and TFT have conducted an in-depth analysis relative to the implementation of the SRSP to ensure the SRSP is achievable and feasible from a thermal benefit supply (i.e., project availability), project design and implementation (e.g., permitting, quality standards, construction, and supply chain), and regulatory standpoint. Moreover, IPC's Bayha Island Research Project and tributary projects on the Powder River (Exhibit 7.1-6) have demonstrated that projects can be designed, permitted, and implemented consistent with the proposed standards and guidelines. IPC is proposing to implement the SRSP consistent with the framework and guidelines presented in Exhibit 7.1-5, and IPC expects to refine and further develop this information in the future with TFT and the DEQs.

7.1.2.3.4.1. Thermal Benefit Supply and Feasibility

TFT evaluated the total thermal benefit supply through a comprehensive landscape assessment to determine what areas have the potential for project implementation based on current conditions and the potential thermal benefits from individual projects. TFT found that approximately 15.216 bkcal/day (averaged from July–October) would be available from 55 potential in-stream projects, and about 14.939 bkcal/day (averaged from July–October) would be available from riparian revegetation projects. In total, TFT identified approximately 30.155 bkcal/day (averaged from July–October). TFT then applied ownership boundaries to the thermal benefits to better assess recruitment realities. The methodologies and assumptions used to develop supply estimates are described in Exhibit 7.1-5. Even after reducing the aggregate amounts for tributary and in-river attenuation, 22 or 25%, respectively, and accounting for reasonable recruitment percentages, TFT determined there are sufficient potential projects and thermal benefits to reach the amount needed in the offset framework. The TFT recruitment feasibility analysis is based on prior experience implementing these types of watershed restoration actions in other basins in the Northwest. IPC and TFT expect that a sufficient number (see Section 2.4. of Exhibit 7.1-5 for more details) of the potential projects will be feasible to implement depending on the willingness of landowners to participate in the program (i.e., recruitment). TFT also analyzed the timing of thermal-benefit implementation, concluding it will be necessary to build up supply chain and labor capacity for this geographically dispersed program. As a result, TFT identified suggested thermal benefit milestones over a 30-year implementation timeframe. IPC is proposing that the actual mix of project types for the SRSP will be based on project availability, feasibility, and thermal benefit to-cost ratio, which will be adaptive over the life of the implementation period.

7.1.2.3.4.2. Project Design and Implementation

TFT, in consultation with IPC, developed draft restoration quality standards for each SRSP project type. Draft restoration quality standards are based on relevant literature, TFT experience, interviews with local professionals, and NRCS Conservation Practice Standards (see Attachment 1 of Exhibit 7.1-5). Draft restoration quality standards are specific to project type and will guide the selection, design, implementation, monitoring, and maintenance of SRSP projects over time. They will also help ensure quality, integrity, and consistency over the term of the program. The draft restoration quality standards will be refined after 401 certification and before full program implementation begins.

7.1.2.3.4.3. Regulatory Considerations

The thermal benefits generated from SRSP project actions can be counted toward the remaining CTLE so long as those thermal benefits are “additional.” A thermal benefit is considered additional when the thermal benefit or the restoration action from which the thermal benefit is realized is not already required by federal, state, tribal, or local law or regulation, and the restoration action would not have been generated without funds or resources provided by IPC. Additionality[34] and related regulatory considerations are addressed in greater detail in Section 2.5.2 of Exhibit 7.1-5. As more specifically described in that Exhibit, no existing affirmative land-management obligations have been identified for SRSP project sites on private and non-federal public property in the SRSP program area that would require implementation of SRSP project actions, or reduce or otherwise affect the total thermal benefit calculated from potential SRSP project sites. As such, all of the thermal benefits generated from SRSP restoration actions should be credited toward IPC’s cumulative thermal load exceedance. This conclusion is an integral component of the SRSP, and approval and incorporation of the SRSP in the 401 certification constitutes acceptance of the conclusion. As described in Section 2.5.2 of Exhibit 7.1-5, periodic verification of this conclusion, and adaptation if needed based on new laws and regulations, will occur at regular SRSP adaptive management intervals over the term of the SRSP. Beyond additionality considerations, IPC will receive confirmation from participating landowners that land-use operations at the property follow applicable laws and regulations (see Attachment 1 of Exhibit 7.1-5).

A further regulatory consideration involves the consistency of the SRSP with ODEQ and IDEQ regulatory approaches to water quality trading. On June 29 2016, ODEQ submitted an additional information request to the IPC requesting that IPC submit additional information demonstrating whether and how the SRSP is consistent with Oregon’s water quality trading rules (OAR 340-039). While the Idaho Department of Environmental Quality (IDEQ) rule IDAPA 51.01.02.055.06 authorizes pollutant trading, and IDEQ is currently updating its trading guidelines, IDEQ has advised that the SRSP will be treated as offsets under Idaho’s rules and guidelines, and not as trades. Exhibit 7.1-7 shows that the SRSP is fully consistent with the Oregon and Idaho water quality standards, the SR-HC TMDL, and any applicable Oregon or

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[34] Additionality means a thermal benefit is considered additional (and therefore eligible to count toward achievement of IPC’s cumulative thermal load exceedance) when the thermal benefit or restoration action from which the thermal benefit is realized is not already required by federal, state, tribal or local law or regulation, and the restoration action would not have been generated without funds or resources provided by IPC.

Idaho water quality trading and offset rules and guidelines. IPC has not characterized either program as a trade under Oregon or Idaho rules or guidelines. Nevertheless, ODEQ and IDEQ have advised IPC that classifying and analyzing the SRSP as a trade or as an offset does not have material regulatory consequences to the SRSP, nor will doing so result in the alteration of any of the compliance, monitoring, or enforcement obligations associated with the 401 certification for the HCC FERC license.

7.1.2.3.5. Ongoing Milestones, Project Tracking, Monitoring, and Reporting

IPC's proposal for the SRSP includes an interrelated system of thermal benefit milestones, project stewardship (e.g., maintenance, discussed in Section 7.1.2.3.6. Project Stewardship), project monitoring, and project tracking. IPC is proposing that the portion of the thermal load responsibility to be addressed by the SRSP is the remaining CTLE calculated in Section 7.1.2.1 The Brownlee Operational Component and Partitioning the Load Allocation into two Parts. The remaining CTLE target is 541.6 bkcals per year. This target is based on the 90th percentile of 27 years of temperature data after incorporation of the Brownlee operational component of the TMP. This target would be addressed in full by SRSP projects. Thermal offsets associated with the SRSP would be calculated based on methodology described in this section below and in Exhibit 7.2-5. This target is supported by the historic data as long as IPC implements the Brownlee operational component intended to cool temperature during the SRFC spawning period to below 16.5°C.

IPC's SRSP proposal specifically includes the following monitoring components (see Section 2.6.2 of Exhibit 7.1-5) to be developed in detail post certification in consultation with the DEQs as part of the TMP:

- Project monitoring will follow a 3-tiered approach:

    1. Qualitative (i.e., project) monitoring at all sites

    - Goal is to ensure projects remain in place and are continuing to demonstrate progress toward forecasted conditions.
    - Repeat photo points and standardized site assessment checklist to allow for consistent data collection and assessment.
    - Conducted annually from implementation through "establishment," which is expected to be 5 to 10 years following implementation.
    - After establishment, qualitative monitoring will continue until the end of the license term at a gradually reduced frequency.

    2. Remote effectiveness monitoring at all sites

    - Goal of efficient tracking of thermal benefit progress of projects over a broad geographic area; provides continued backup that projects remain in place and are continuing to demonstrate progress toward forecasted conditions as qualitative monitoring frequency decreases at sites over time.
    - LIDAR or other applicable remote sensing technologies repeated every 5 years over the life of the FERC license.

        3. Quantitative (i.e., effectiveness) monitoring on a selected sample of projects representative of the in-stream habitat and riparian revegetation project types

            - Generate confidence that projects are tracking toward performance objectives and modeled conditions (e.g., % canopy cover for riparian projects.
            - Confirm modeling assumptions used in thermal benefit calculations are valid.
            - Use results to improve and adaptively manage the effectiveness of site implementation and maintenance for future projects.
            - Inform qualitative checklist questions so the checklist helps track projects consistently with trends observed at quantitative monitoring sites.

- The SRSP monitoring plan and approach will be adaptive and managed over the life of the FERC license.

- Independent verification and third-party auditing program.

    - Confirmation that every project has been implemented consistent with project design and implementation quality standards

    - Audit a selected subset of sites

        - Auditor will review monitoring results and records for the selected sites and perform site visits as necessary to determine if the sites are materially consistent with the records and the projects are in place and functioning/progressing as designed/anticipated.

Results of the above monitoring components will provide feedback to the modeling, generation, accounting, tracking, and reporting of the thermal benefits applicable to the offset.
IPC’s proposal for this process is captured by the following outline:

- Thermal benefits of projects are estimated during the project design phase.

- Projects are implemented according to design.

- Thermal benefits of projects are modeled after implementation has been completed.

- Implementation is verified to be consistent with project design and implementation quality standards. Once verified, project details will be made available through a tracking system (e.g., program website).

- Project thermal benefits are counted toward the overall offset.

- Projects are monitored and audited.

    - So long as projects are implemented and maintained in accordance with quality standards and pass program audits, the thermal benefits of these projects will count toward the offset.

  - If projects are not implemented or maintained in accordance with quality standards (in a way that materially affects the thermal benefits produced by the project) or fail program audits, the thermal benefits of these projects cannot be counted toward the offset until subsequent maintenance and monitoring show the project has returned to specifications[35], at which time thermal benefits will be reapplied to the offset.
  - Information obtained from the quantitative monitoring will be used to inform the thermal benefit calculation, implementation, and maintenance of future projects but will not be used to adjust thermal benefits already modeled and counted toward the offset.
- Thermal benefit milestones.
  - Within 15 years of FERC license issuance, IPC proposes to have projects implemented and maintained according to project specifications equal to 50% of the applicable CTLE target.
  - Within 30 years of FERC license issuance, IPC proposes to have projects implemented and maintained according to project specifications equal to 100% of the applicable CTLE target.
  - These milestones will be reviewed during program adaptive management and agency review cycles and may be modified based on monitoring and implementation information.
- Life of thermal benefits.
  - IPC proposes to sign renewable land access and protection agreements with participating landowners to protect the longevity of thermal benefits.
- Annual reporting will include the following:
  - The results of the quantitative and qualitative monitoring, including a map showing the location of all projects implemented to date together with the thermal load reduction credits assigned to each project and the site-level monitoring reports.
  - A description of the proposed projects scheduled for implementation in the next year or future years, including IPC's estimate of the projects' aggregate thermal load to be applied toward the offset.
  - A description of the projects implemented in that year, including the status of implementation, expected completion date, and any modeled or expected thermal benefits associated with the projects.

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[35] This process will include appropriate provisions for force majeure.

  - Audit review report, including a summary of whether the sites surveyed comported with the acceptance threshold for the audit and any remediation activities, if necessary.
  - A summary of the progress made toward achieving the offset amount, including IPC's assessment of whether the program is on track to achieve compliance with the 15- and 30-year compliance targets established by the 401 certifications.
  - A summary of any adaptive management measures, amendments, or modifications to the TMP or SRSP being considered or recommended. The summary shall include a discussion of any alternative or supplemental measures being considered, and the status of any mercury or other water-quality studies or analysis related to the alternative or supplemental measure being considered.
- Five-year review statement, agency review cycle, and adaptive management steps. In addition to the annual reporting, a 5-year review statement will be submitted every fifth year following issuance of the FERC license. This will include all the elements of the annual report plus the following:
  - Evaluation of observed changes occurring relative to pre-project conditions in monitored implemented projects (including vegetation, hydrology, morphology).
  - A summary and evaluation of changes in applicable laws or regulations related to the regulatory baseline in the SRSP program area that may affect the crediting of project thermal benefits.
  - Changes to quality standards and implementation guidance and modeling of thermal benefits. This includes whether revision to thermal benefit modeling or accounting procedure for future projects are recommended.
  - Summary of thermal benefits associated with previously implemented projects that were not previously quantified, including any benefits unquantified due to a lack of data or recognized methodology.
  - Summary of new SRSP restoration actions and quantification methodologies proposed for the next cycle of the SRSP.
  - A report and consolidation of the previous annual summaries of the progress toward achieving the offset amount, including an analysis and updated assessment of whether the program is on track to achieve compliance with the 15- and 30-year compliance targets established by the 401 certifications. The report shall include a discussion of any alternative or supplemental measures (see Section 7.1.2.5. Adaptive Management and Program Review) being considered together with the status of any mercury or other water-quality studies or analysis related to alternative measures.

7.1.2.3.6. Project Stewardship

IPC will actively maintain SRSP project sites to ensure the thermal benefit generating measures remain in place and functioning for the term of the renewed FERC license. These actions will be conducted in accord with quality standards for stewardship of the thermal benefit projects (Exhibit 7.1-5).

7.1.2.4 Compliance with Salmon and Steelhead Migration and Cold-water Aquatic Life Standards

The Idaho temperature criteria for the protection of cold-water aquatic life are a daily maximum temperature not to exceed 22°C, with a maximum daily average temperature of no greater than 19°C (IDAPA 58.01.02.250.02.b). The Oregon migration corridor requirement for salmon and steelhead includes a numeric 20°C 7DAM criterion that applies to the river downstream of HCD (OAR 340-041-0028(4)(d)). In addition to the numeric component, this OAR provision establishes narrative requirements that cold-water refugia are sufficiently distributed throughout a river to allow for salmon and steelhead migration without significant adverse effects from higher water temperatures in the river, and a seasonal thermal pattern in the Snake and Columbia rivers that reflects the NSTP.

The SR–HC TMDL did not give HCC a load allocation for the salmonid rearing/cold-water aquatic life standard based on available data and modeling work completed by IPC that showed if the water flowing into Brownlee Reservoir was at or below numeric temperature targets for salmonid rearing/cold-water aquatic life, water leaving the HCC at HCD would also be below the numeric temperature targets. The DEQs found the HCC is not the source of the heat load in the reservoirs and that if upstream conditions were cooler, the water exiting the HCC would also be cooler. Based on those findings, the DEQs concluded that the HCC is not "contributing to temperature exceedances specific to the salmonid rearing/cold-water aquatic life designated use and no requirement for temperature adjustment, specific to salmonid rearing/cold-water aquatic life use" was assigned to the HCC" (SR HC TMDL, at 404–405, 465). Since the SR–HC TMDL analysis was conducted using Oregon's previous 17.8°C criterion, IPC presents a similar analysis here relative to the current criteria (i.e., the Idaho 19°C daily average and Oregon 20°C 7DAM) that supports the conclusion in the SR–HC TMDL that continued operations of the HCC following relicensing will not cause or contribute to a violation of either the 19°C Idaho or the 20°C Oregon numeric criteria (see Section 7.1.2.4.1. Compliance with Numeric Criteria).

The purpose of each of the narrative criteria, sufficiently distributed cold-water refugia, and reflection of the NSTP is to protect fish from excessive temperatures during the migration period. For the reasons set forth below (and discussed in Section 6.1.2.3.1. Salmon and Steelhead Migration and Cold-Water Aquatic Life), IPC submits that the HCC currently complies with each of these narrative criteria and that the implementation of fall Brownlee Reservoir drawdowns along with the SRSP, a large-scale upstream watershed restoration program, will only further protect fish from excessive temperatures, thus providing further assurances of that compliance.

7.1.2.4.1. Compliance with Numeric Criteria

As discussed in Section 6.1.2.3.1. Salmon and Steelhead Migration and Cold-Water Aquatic Life, the DEQs concluded in the SR–HC TMDL that the HCC is not responsible for elevated

Hells Canyon temperatures in the summer months relative to the numeric criteria at the time, 17.8°C. That conclusion was supported at the time with an analysis of measured temperature data and the results of IPC temperature modeling that demonstrated that if inflows were at or below the numeric temperature criteria, the outflow at HCD would also be at or below the numeric temperature criteria for cold-water aquatic life and salmonid migration. (SR–HC TMDL at 381; 402–04). The following analysis and information uses HCC CE QUAL models to model the resulting outflow temperature conditions if inflow temperature met numeric criteria to re-evaluate the SR–HC TMDL conclusions relative to current criteria.

To be consistent with the approach in the SR–HC TMDL, the first step in the analysis is to determine which of numeric criteria are the most stringent (i.e., would result in a lower temperature). The SR–HC TMDL evaluation of Oregon and Idaho water-quality standards, as first published in 2003, identified the then-existing Oregon numeric temperature criterion for salmonid rearing as the most stringent criterion. That criterion provided for a 7DAM temperature of 17.8°C (IDEQ and ODEQ 2004). Therefore, the SR–HC TMDL applied this criterion for the year-round inflows to the HCC reservoirs and the outflows from HCD from June to September. Oregon has since revised its water-quality standards, including temperature standards. The EPA has approved these revisions. For aquatic life and salmonid rearing, Oregon currently has 2 temperature criteria applicable to waters of the HCC and Snake River:

- The 7DAM temperature of a stream identified as having Lahontan cutthroat trout or redband trout use may not exceed 20°C (OAR 340 041-0028(4)(e)). This criterion is applicable to the HCC reservoirs and Snake River from RM 247.5 to RM 409 (i.e., HCC inflows).
- The 7DAM temperature of a stream identified as having a migration corridor use for salmon and steelhead may not exceed 20°C (OAR 340-041 -028(4)(d)). This criterion is applicable to the Snake River from RM 169 to RM 247.5 (i.e., HCC outflow).

Idaho temperature criteria for the protection of cold-water aquatic life are a daily maximum temperature not to exceed 22°C, with a maximum daily average temperature of no greater than 19°C (IDAPA 58.01.02.250.02.b).

Daily average, daily maximum, and 7DAM statistics were calculated from temperature measurements made every 10 minutes during 2002, along with the reduction needed to lower the peak 7DAM value to the revised Oregon criteria (i.e., 20°C). The needed reduction to meet the 7DAM was then subtracted from the daily average, daily maximum, and 7DAM to calculate reduced temperature statistics (Table 7.1-7). Comparing the reduced temperature to the various criteria showed that if the temperature was reduced sufficiently to meet Oregon's revised 7DAM criteria, Idaho's daily maximum (i.e., 22°C) would also be met; however, Idaho's daily average criteria of 19°C would still be exceeded (Table 7.1-7, Figure 7.1-11). Based on this analysis, the conclusion is that Idaho's 19°C daily average criteria is the most stringent of the current applicable criteria for the Snake River at the inflow to Brownlee Reservoir and HCD outflow during the aquatic life and salmonid rearing period.

Table 7.1-7
Snake River Brownlee Reservoir inflow and HCD outflow daily temperature statistics in 2002 (baseline) and reduced by the amount needed to meet Oregon's 7DAM criteria (reduced)

	Baseline				Reduced		
Location	Maximum Daily Average (°C)	Maximum Daily Max (°C)	Maximum 7DAM (°C)	Reduction needed (°C)	Maximum Daily Average (°C)	Maximum Daily Max (°C)	Maximum 7DAM (°C)
Inflow	28.1	28.8	28.1	8.1	20.0	20.7	20.0
Outflow	21.3	21.5	21.3	1.3	20.0	20.2	20.0

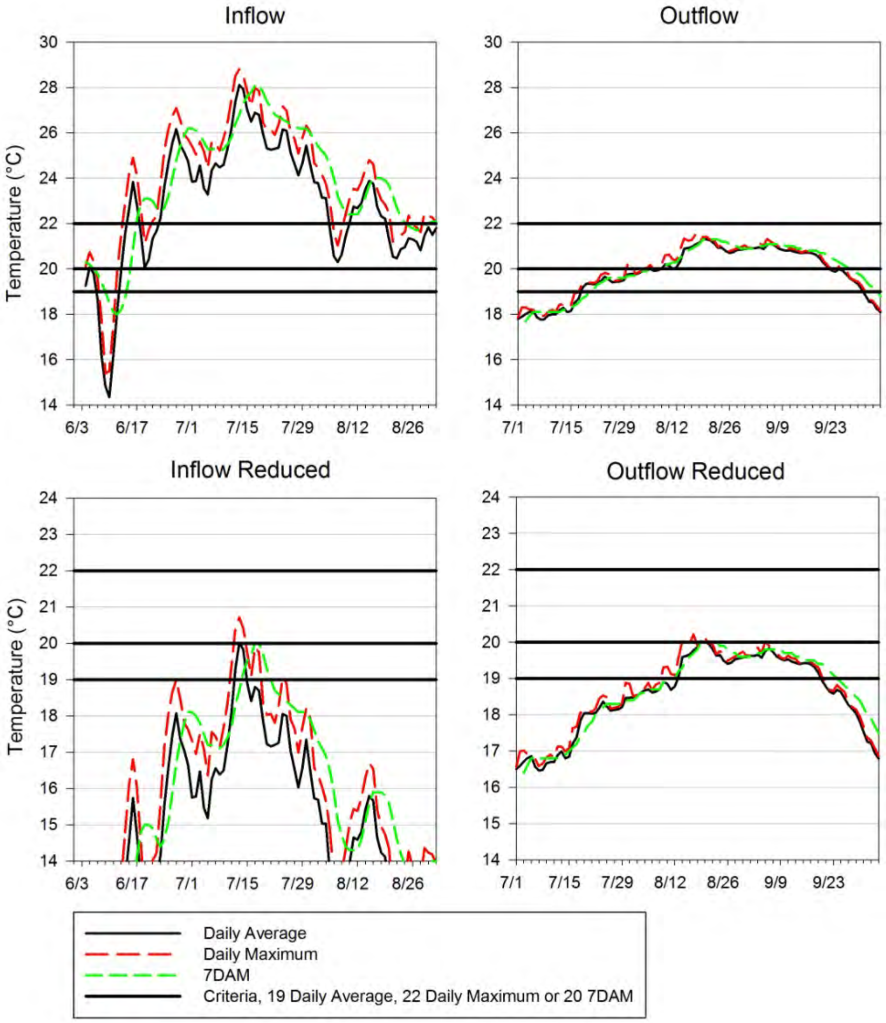

Figure 7.1-11
Snake River Brownlee Reservoir inflow and HCD outflow daily temperature statistics in 2002 compared with applicable Oregon (i.e., 20°C 7DAM) and Idaho (i.e., not to exceed 22°C daily maximum and 19°C daily average) temperature criteria. Figures with reduced temperatures show all the daily statistics reduced by the amount needed to meet the 20°C 7DAM criteria.

The next step in the analysis is to reduce Brownlee inflow temperature so that the Idaho 19°C daily average criterion is met. The SR–HC TMDL did not describe specifically how the inflow temperature was reduced or what the "shape" of the inflow thermal regime was after the reductions. The analysis presented here uses 3 assumptions to develop 3 separate inflow temperature conditions that all meet the numeric criteria. While there are potentially limitless assumptions and iterations that can be used in the development of these temperature conditions, the objective of this analysis is to develop 3 conditions that cover a wide range of assumptions and results. Below, the 3 assumptions and resulting conditions are compared and contrasted with measured temperatures to illustrate the technical defensibility of each.

Of the 3 temperature conditions, the first temperature condition is the most basic and simply caps the daily average inflow temperature at 19°C (Capped, Figure 7.1-12). This temperature condition is not reflective of a natural river condition but it is a straightforward way to represent an inflow condition that meets the numeric criteria. The second temperature condition is developed by calculating the percent reduction needed at the summer peak to meet the numeric criteria. This percentage reduction is then applied year-round. Since it is a percent reduction, it results in relatively large degree reductions when temperature is warm and small degree reductions during cold times of the year (% Year-Round, Figure 7.1-12). This temperature condition is reflective of a natural river condition as it essentially shifts the baseline condition down proportionally. The third temperature condition applies the same percent reduction in tapered fashion. That is, the entire percent reduction is applied at the peak; however, the percent reduction is tapered off to zero at the beginning and end of the year. This condition also reflects a natural river condition since it also shifts the baseline condition down proportionally while recognizing the potential for less temperature sensitivity in the winter, spring, and fall seasons (% Tapered, Figure 7.1-12). Of the 3 temperature conditions, both the % Year-Round and % Tapered conditions are reflective of a natural river condition and, more specifically, the % Tapered condition is comparable with measured temperature in the Snake River upstream of the HCC (i.e., below Bliss Dam and upstream of American Falls Reservoir at Blackfoot, Figure 7.1-13).

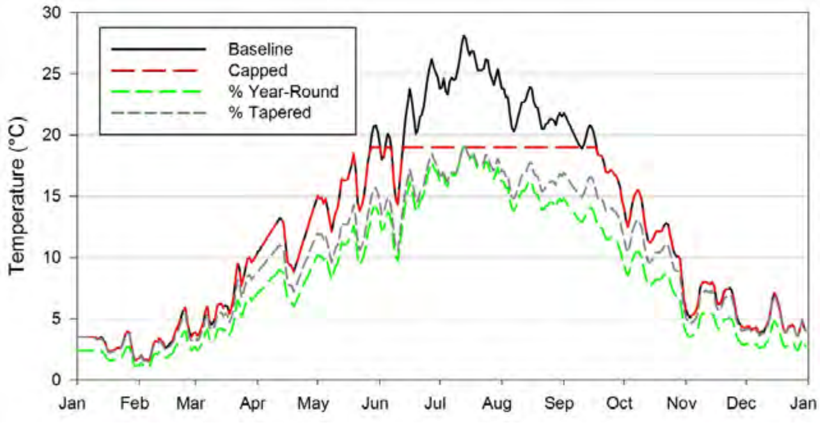

Figure 7.1-12
2002 Baseline CE-QUAL-W2 daily average temperature inflow conditions compared with 3 separate inflow conditions that meet the numeric criteria of a daily average not to exceed 19°C

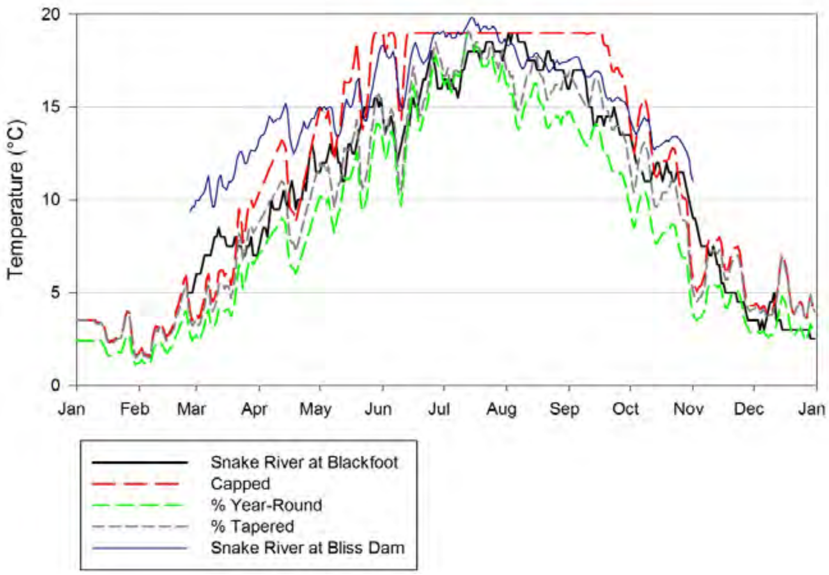

Figure 7.1-13
2002 inflow conditions that meet the numeric criteria of a daily average not to exceed 19°C compared with temperature measured at 2 locations in the Snake River, at Bliss Dam (RM 560) in 2002, and near Blackfoot, Idaho, above American Falls Reservoir in 2005 (another low-water year).

The Capped, % Year-Round, and % Tapered inflow temperature conditions were modeled through the 2002 HCC CE QUAL W2 model applications (see Section 7.1.2.2.4.1. Model Background for model background information) and resulting summer outflow temperature compared with criteria. The % Year-Round inflow condition meeting the Idaho 19°C daily average criterion resulted in HCC outflow also meeting the same temperature criterion (Figure 7.1-14). The HCC outflow results from the % Tapered condition also met the Idaho 19°C criteria on all days but one where modeled temperature deviated by only 0.2°C. Both the % Year-Round and % Tapered inflow condition meeting the Idaho 19°C daily average criterion resulted in HCC outflow meeting Oregon's 20°C 7DAM criterion (Figure 7.1-15). These model results reevaluate the modeling analysis referred to in the SR–HC TMDL and support the conclusion that if inflow temperature conditions met the current most stringent numeric criteria, the HCC outflow temperature would also meet all applicable numeric criteria. To expand on that conclusion, the general type of inflow temperature condition that resulted in outflow meeting numeric criteria represented a natural river condition and not an artificial "capped" regime.

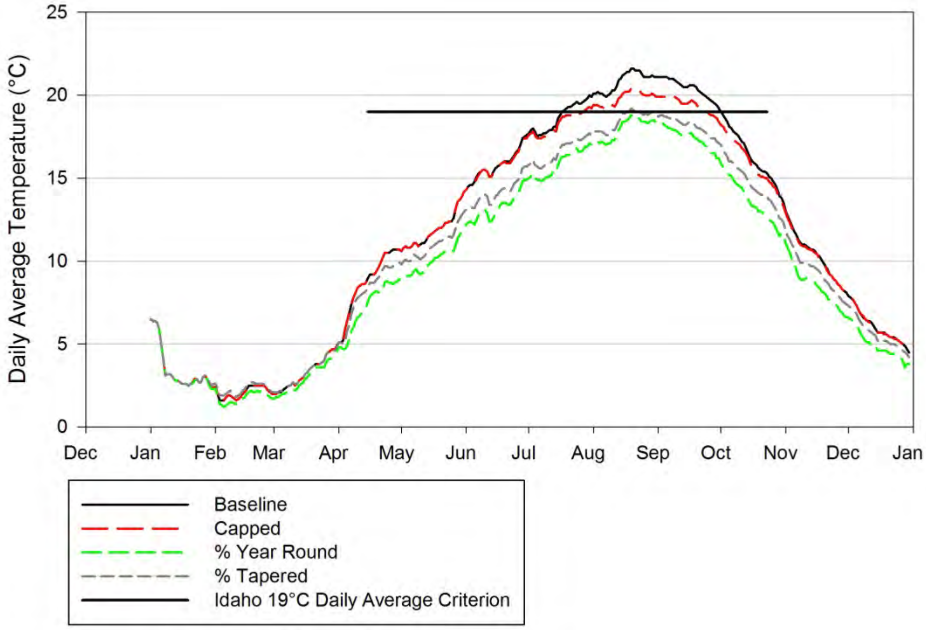

Figure 7.1-14
Modeled daily average 2002 CE-QUAL-W2 HCC outflow temperature under baseline (i.e., calibrated) and 3 inflow temperature conditions that all met the Idaho 19°C daily average criterion (Capped, % Year Round, and % Tapered).

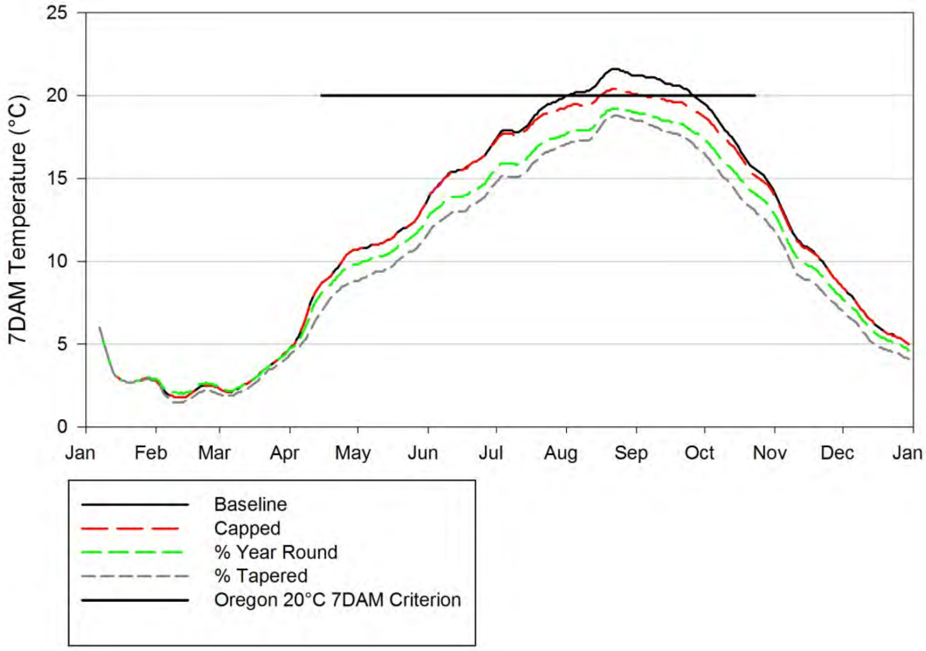

Figure 7.1-15
Modeled 7DAM 2002 CE-QUAL-W2 HCC outflow temperature under baseline (i.e., calibrated) and 3 inflow temperature conditions that all met the most stringent Idaho 19°C daily average criterion (Capped, % Year Round, and % Tapered).

7.1.2.4.2. Compliance with Cold-water Refugia

The first of the 2 narrative criteria provides that the water bodies “must have coldwater refugia that are sufficiently distributed so as to allow salmon and steelhead migration without significant adverse effects from higher water temperatures elsewhere in the water body.” As referenced in Section 6.1.2.3.1.1 of this application, the DEQs concluded in the SR–HC TMDL that, both within and downstream of the HCC, the designated beneficial uses, which include salmon and steelhead migration, are being supported through availability of cold-water refugia” (SR–HC TMDL, at 422). This conclusion was supported by the referenced population study (Chandler et al. 2003). The potential ecological benefit of tributaries providing thermal habitats for organisms in downstream waters is also documented in the scientific literature and bolstered by a recent scientific study finding of the importance of perennial and ephemeral streams in providing cold-water refugia (Ebersole et al. 2015; Fullerton et al. 2015). The river downstream of HCD has 132 perennial streams and 813 intermittent streams distributed throughout its length that provide cold-water thermal refuge to varying extents (See Exhibit 6.1-1). Ebersole et al. (2015) conservatively defined cold-water patches as discrete areas of relatively cold-water that were ≥3°C colder than the ambient stream temperature. While not a complete data set of all perennial streams, temperature data of surface flows collected by IPC during 2003 and 2004 show that during the critical summer months of July through September, the majority of the perennial streams measured would provide refugia (Exhibit 6.1-1). These measurements do not include the potential additional benefit of subsurface flow upwelling into the Snake River at these stream mouths. In addition, the free-flowing river retains natural processes that create areas of downwelling and upwelling of surface flows into the hyporheic zone of the riverbed, which can also create thermal refugia in areas of upwelling. Based on the current presence of thermal refugia, along with the expected thermal benefits of the proposed SRSP, compliance with the cold-water thermal refugia requirements is assured.

7.1.2.4.3. Compliance with NSTP

The second narrative criterion associated with the migration corridor provides that “the seasonal thermal pattern in Columbia and Snake Rivers must reflect the natural seasonal thermal pattern.” The concept of preserving or restoring natural temperature patterns was first addressed in the EPA Region 10 2003 guidance for state water-temperature standards. In waters with a designated use of salmon and trout migration corridors, the guidance called for a standard of 20°C and a requirement to “protect and, *where feasible* restore the natural thermal regime” (emphasis added), and indicated the objective of thermal regime restoration is some approximation of the natural watershed as it existed before human alteration of the landscape.

Neither Oregon water-quality standards nor internal management directives define NSTP. ODEQ has interpreted the intent of NSTP standard to be “to protect migrating fish from temperatures routinely exceeding the 20°C criterion. Attainment of NSTP would allow the migrating fish to experience varying temperatures, not constant warm temperature.” (ODEQ Memo 2011). In IPC’s view, the NSTP criterion is intended to work in conjunction with the cold-water refugia criterion to “allow salmon and steelhead migration without significant adverse effects” from peak 20° C or greater temperatures during migration. (OAR 340-041-0028(4)(d)). The presence of cold-water thermal refugia downstream of HCD reduces the potential for adverse effects on migrating fish. As detailed and shown in Section 6.1.2.3. Outflow Temperature, the HCC is not creating conditions whereby migrating fish are being exposed to "constant warm temperature," nor substantially extended periods of temperatures in excess of 20°C.

The EPA temperature guidance indicates it may be necessary to supplement the numeric criterion with a narrative provision like NSTP to address the concern "that rivers with significant hydrologic alterations (e.g., rivers with dams and reservoirs, water withdrawals, and/or significant river channelization) may experience a loss of temperature diversity in the river, such that maximum temperatures occur for an extended period of time and there is little cold-water refugia available for fish to escape maximum temperatures." The HCC does not cause a condition where "maximum temperatures occur for an extended period of time." In fact, the potentially harmful maximum temperatures measured in the inflowing water to Brownlee Reservoir are not found in water flowing from HCD because of the cooling effect of the HCC when inflows exceed 20°C.

In the SR–HC TMDL, based on modeling reviewed at the time the DEQs concluded that if upstream conditions were cooler, the water exiting the HCC would also be cooler (SR–HC TMDL, at 405). Figure 7.1-15 further illustrates how outflow temperatures could be expected to change under modeled reduced inflow temperature scenarios. Section 7.1.2.4.1. Compliance with Numeric Criteria describes how IPC modified inflowing temperatures to a maximum summer temperature of 19°C using 3 alternative thermal regime shapes. The SRSP will likely not result in thermal regimes represented by the modeled hypothetical regimes (e.g., temperature reduction to 19°C). Rather, the modeling is presented to illustrate that as upstream thermal loads are reduced, this reduction is translated through the HCC and outflow temperatures are reduced.

Qualitatively, Figure 7.1-15 shows that inflowing water temperature reductions can be expected to result in accelerated late summer and fall cooling compared to what is currently occurring in the HCC outflows, which supports the conclusion on the SR–HC TMDL that if upstream temperatures are cooler, the water exiting the HCC will also be cooler.

7.1.2.5. Adaptive Management and Program Review

Consistent with the phased and iterative implementation theme of the SR–HC TMDL, the TMP will include an active adaptive management component designed and intended to instruct decision making, resolve uncertainty, and result in the improvement and potential modification of the SRSP, and the associated operational component temperature measures. The adaptive approach will be supported by monitoring and reporting on a scheduled basis both at the project and program level. Based on the information developed by IPC, with the assistance of the TFT, IPC believes the implementation of the TMP, as proposed in this application, will be sufficient to address the thermal benefit milestones of the SRSP and the 16.5°C target of the Brownlee operational component. However, as implementation of the TMP proceeds, IPC will review and assess the progress of the program and identify and consider alternative or supplemental measures that may provide, or assist in providing, reasonable assurance that the temperature goals and thermal benefit milestones will be achieved. "Alternative or supplemental measures," as used herein, means an alternative method, approach, or amendment to the TMP that will provide, or assist in providing, reasonable assurance that the thermal benefit milestones, and/or the 16.5°C target of the operational component will be achieved or that addresses, or assists in addressing, other issues associated with the implementation of the TMP. The following describes programmatic monitoring, reporting, and mechanisms for program adjustments and modifications as necessary.

7.1.2.5.1 TMP Monitoring

Within 90 days of the date of FERC's issuance of a new license for the Project, IPC will submit to the DEQs for approval a TMP Temperature Monitoring Plan. Once approved by the DEQs, IPC shall implement the Temperature Monitoring Plan. At a minimum, the TMP monitoring plan will include monitoring requirements as proposed in the SRSP program (Section 7.1.2.3.5.) and the following components:

1. Proposed temperature monitoring locations to provide data collection. Collection and reporting of these temperature data is for compliance purposes related solely to the attainment of temperatures that will not exceed 16.5°C, for 3 consecutive years, during the salmonid spawning period, and does not impose additional compliance obligations. Locations shall be proposed that are representative of the Snake River flows entering Brownlee Reservoir and Snake River flows being released from HCD.
2. Proposed data collection equipment and procedures;
3. Proposed frequency of monitoring;
4. A project-specific *Quality Assurance Project Plan* ("QAPP"); and
5. A proposal for data analysis and reporting.

7.1.2.5.2. TMP Reporting

IPC will provide the following reports to the DEQs:

1. **Annual Temperature Reports.** Within 90 days of the end of each calendar year following the issuance of the new license for the Project, IPC shall provide an Annual Report that includes but is not limited to the following:
   a. A description of the operational component conducted in that calendar year.
   b. A description of the effects of the operational component on downstream water temperatures within the SRFC spawning period. The description will specifically address the success of the measures in maintaining spawning temperatures below 16.5°C by reporting of 7DAM temperatures measured at the approved monitoring station downstream of HCD.
   c. If the data show that the measures have not been successful in maintaining spawning temperatures below 16.5°C, the report will explicitly address the reasons and IPC's proposed actions to address this issue in subsequent years.
   d. A description of the SRSP projects implemented in that calendar year. The SRSP project description will include the status of implementation of projects, expected completion date, and any other information necessary to determine if the

project has been implemented and maintained in accordance with Restoration Standards. IPC shall include a map showing the location of all SRSP projects implemented to date.

e. The thermal benefits IPC attributes to SRSP projects implemented in that year. For projects implemented in prior years, a statement as to whether the project is being maintained in accordance with Restoration Standards and if so, the thermal benefits IPC claims from those projects.

f. The results of the required monitoring of SRSP projects.

g. A description of the proposed projects scheduled for implementation in the next year or future years, including IPC's estimate of the projects' aggregate thermal benefits.

h. An audit review report, including a summary of whether the sites surveyed complied with the acceptance threshold for the audit and any remediation activities if necessary.

i. The cumulative thermal benefits from that year and past years, and IPC's assessment of whether implementation of the TMP, including the SRSP, is reasonably likely to achieve the 15 and 30 year required thermal benefits.

j. IPC may include a request for the DEQs to consider approval of alternative or additional measures "Alternative Measures" are methods or approaches that may or may not be currently explicitly included in the TMP that would provide, or assist in providing, reasonable assurance that the temperature goal of outflow temperatures not exceeding a 7DAM of 16.5°C during the salmonid spawning period and that if 16.5°C is exceeded it is for less than 3 consecutive years, or in the case of the SRSP, that the CTLE offset will be achieved.

2. **DEQs Response to Annual Temperature Reports.**

a. IPC expects the DEQs will review Annual Reports to confirm that SRSP audits show projects were implemented and maintained in compliance with Restoration Standards. If audit results show a sufficient number of sites were not implemented and maintained in compliance with Restoration Quality Standards & Guidelines, the DEQs shall notify IPC the deficiencies and provide a schedule for corrective action. During the corrective action period, credits may be suspended. If remedied, credits will be reactivated. If not remedied on time, the DEQs shall notify IPC of the amount of thermal benefits in that year that cannot continue to be counted as thermal benefits.

b. IPC expects the DEQs will notify IPC whether they approve of or reject any amendment to the TMP to address issues associated with implementation.

c. IPC expects the DEQs will respond to any alternate measures request.

3. **Five Year Temperature Reports.** At the end of every fifth calendar year following the issuance of a new license for the Project, IPC shall provide a Five-Year Temperature Report that includes the following:

    a. All the required elements of the Annual Temperature Report for that year.

    b. Summary of data analysis, progress on implementation of the TMP, and program effectiveness during the five-year review period.

    c. Identification of any data gaps, program inefficiencies or challenges.

    d. An evaluation of observed changes occurring relative to pre-SRSP project conditions in monitored implemented projects (including vegetation, hydrology, morphology).

    e. A summary and evaluation of changes in applicable laws or regulations related to the regulatory baseline in the SRSP program area that may affect the thermal benefits assigned to projects.

    f. Any proposed changes to Restoration Standards, including changes to modeling of thermal benefits. Any such changes must be approved by the DEQs before implemented by IPC.

    g. Summary of thermal benefits associated with previously implemented projects that were not previously quantified, including any benefits unquantified due to a lack of data or recognized methodology. New benefits not previously quantified can only be counted towards meeting the required thermal benefits if the DEQs, approve of the data and methodology for determining such benefits.

    h. Non-temperature benefits calculated, projected or observed specific to projects that have been implemented. This includes a discussion of progress towards meeting the non-temperature related goals of the in-stream work in the mainstem Snake river, as well as non-temperature benefits of the tributary restoration work. Reporting of these non-temperature benefits goals and calculations is for informational purposes and would not impose additional compliance obligations.

    i. Summary of any new SRSP restoration actions and quantification methodologies proposed.

    j. Estimates of current trajectory of thermal benefits to achieve modeled conditions. A report and consolidation of the previous annual summaries of the progress toward achieving the required thermal benefits, including an analysis and updated assessment of whether the program is reasonably likely to achieve compliance with the 15 and 30 year required thermal benefits.

4. **DEQs Response to Five Year Reports.** The DEQs will respond to a Five-Year Temperature Report as follows:

a. With respect to information that must or may also be included in the Annual Temperature Reports, IPC expects the DEQs will respond as set forth above in this section 2.a above.

b. IPC expects the DEQs will notify IPC whether it approves of or rejects any changes to the Restoration Standards proposed by IPC.

7.1.2.5.3. Alternative or Supplemental Measures to the TMP

The adaptive management approach will include consideration of alternative or supplemental measures and, as appropriate, inclusion of those measures as a component part of the TMP. Based on the information developed by IPC, with the assistance of the TFT, IPC believes the implementation of the TMP, as proposed in this application, will be sufficient to address the SRSP thermal benefit milestones and the goal of the Brownlee operational component. However, as implementation of the TMP proceeds, IPC will review and assess the progress of the program and identify and consider alternative or supplemental measures that may provide, or assist in providing, reasonable assurance that the milestones and goals will be achieved. “Alternative or supplemental measures,” as used herein, means an alternative method, approach or amendment to the TMP that will provide, or assist in providing, reasonable assurance that the thermal benefit milestones milestones of the SRSP and/or goals of the Brownlee operational component will be achieved or that addresses, or assists in addressing, other issues associated with the implementation of the TMP.

The DEQs have indicated that a “Plan B” is a requirement in this 401 process. Plan B identifies a specific measure that would be implemented should the proposed SRSP component of the TMP not be sufficient to address the thermal benefit milestones. The DEQs have expressly communicated the expectation that this Plan B should include an engineered measure, such as a hypolimnetic pumping system (HPS). Therefore, IPC includes a Plan B below.

Separate from Plan B, if during the term of the license, water temperature data collected downstream of HCD shows that temperatures during the SRFC spawning period have exceeded 16.5°C, for three consecutive years, the DEQs may require IPC to implement an alternative or supplemental measure that may provide, or assist in providing, reasonable assurance that the goals of the Brownlee operational component will be achieved. IPC reserves the right to consider augmenting the Brownlee operational component with a modified, smaller, HPS to maintain the 7DAM spawning temperature below 16.5°C if the Brownlee operational component proves to be ineffective in the future. An appropriately sized smaller HPS should be capable of addressing temperature above 16.5°C since, as discussed below, the capacity of the larger HPS system (Plan B) should be sufficient to meet the salmonid spawning temperature criterion. A smaller system would also reduce the potential for coincidental negative effects, (see Section 7.1.2.5.3.3), from operation of a HPS. Alternative or supplemental measures to the Brownlee operational component could also include modification by adjusting the aggressiveness of the additional fall Brownlee draft. Final design and installation of an alternative measure would be completed within a timeframe to ensure that temperatures do not exceed 16.5°C for more than 3 consecutive years.

7.1.2.5.3.1. Plan B

For over a decade, IPC has been analyzing and considering options or measures to address issues associated with water-temperature conditions downstream of HCD. In this application, IPC proposes a watershed-based approach, together with a Brownlee operational component, to address the HCC temperature load allocation. As a corallory benefit, this approach is expected to also imporove water-quality and habitat conditions above, within and below the HCC.

Over the course of the 401 certification process, IPC has also considered engineered approaches to address the HCC temperature load allocation, generically referred to as Temperature Control Structures (TCSs). A summary review of the consideration of various TCS options is included below. While IPC's review of these TCS options indicates that temperature conditions downstream of the HCC can be influenced by the installation and operation of a TCS within the HCC, serious questions remain relating to the effect of operating a TCS on downstream and in-reservoir water-quality conditions, aquatic species, and their habitat. IPC is currently involved in a collaborative study in cooperation with the USGS to answer these questions, particularly those related to the fate and transport of methylmercury within and below the HCC. This study and analysis effort will take multiple years (estimated approximately 10 years) to explore the many issues associated with the fate and transport of methylmercury and the effect of those issues on the potential for installing an HPS or other TCS that relies on the release of cool water from the hypolimnion of HCC reservoirs (see Section 6.6.2.2. Water Column for more information on the goals and schedule of the USGS study). As part of the SRSP reporting protocols, IPC will annually update the DEQs on the progress of this study effort.

Notwithstanding those serious unanswered questions, the DEQs have requested this application include an analysis of one type of TCS, the HPS, for reducing HCC outflow temperatures, should the proposed TMP not be sufficient to address the SRSP thermal benefit milestones. Therefore, as a Plan B, IPC proposes the installation of an HPS in Brownlee Reservoir, designed to blend cooler water from the lower strata of the reservoir with warmer upper-strata waters. This HPS was included as a proposed temperature measure in IPC's September 24, 2010, 401 application. In that application, IPC concluded there was a sufficient volume of cold water in Brownlee Reservoir in October to cool historical conditions at the HCC outflow to meet the salmonid spawning temperature criterion and that in 95% of years analyzed, there was a sufficient volume of cold water in Brownlee to also provide a margin of safety relative to the availability of cold water (Exhibit 7.1-8).

Excerpts from the 2010 Application are included below together with additional information relative to IPC's consideration of a HPS. The HPS proposed in 2010 consisted of a system of high-flow, low-head pumps designed to move cold water from the hypolimnion of Brownlee Reservoir to discharge into the intake channel in front of the turbine penstocks. An initial engineering assessment indicated this system was feasible to construct and operate (Exhibit 7.1-8). Subsequent engineering assessments (Exhibit 7.1-9) also indicate the construction is feasible and could consist of a floating platform that supports 20 axial flow pumps, each capable of pumping 250 cfs (maximum flow rate of 5,000 cfs) by suctioning cold water up through telescoping vertical fiberglass-reinforced pipes and transmitting the cold water horizontally through twenty 9-foot diameter delivery pipes to within about 200 feet of the Brownlee power intake structure. The 2,000-foot long delivery pipes are held together in 3 rows by 19 structural steel bands that are each connected to a float that keeps the pipes just under the reservoir water surface (Figure 7.1-16). The cold water discharged into the intake channel in front of the turbines would mix with warmer water being drawn through the powerhouse to cool Brownlee Project outflow during the period of operation. Cooler Brownlee Project outflows would then propagate through Oxbow and Hells Canyon reservoirs, resulting in cooler outflows from the HCD.

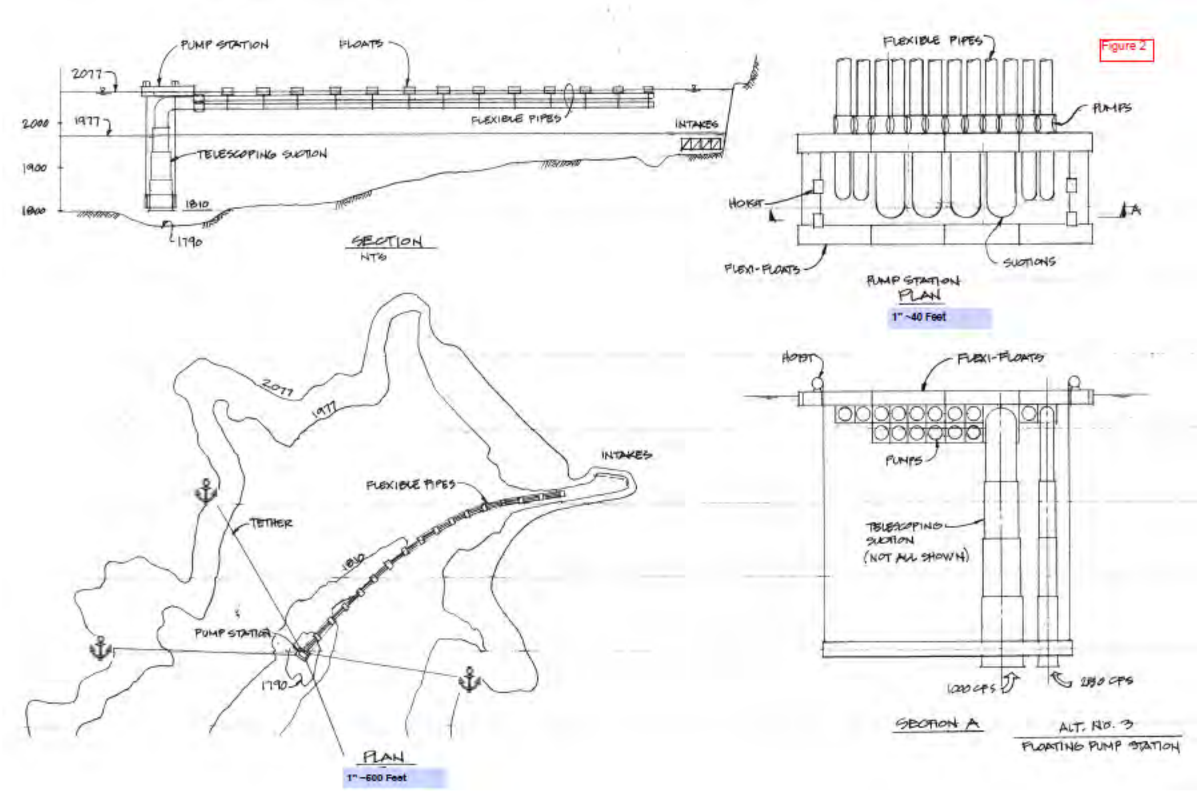

Figure 7.1-16
Brownlee cold-water pumping plan concept design sketch (Exhibit 7.1-9)

The September 2010 analysis relative to the ability for a conceptual HPS to meet temperature objectives was based on a flow-weighting analysis. The calculation used measured conditions in Brownlee Reservoir (i.e., temperature of the hypolimnion water) and temperature and flow rate at the outflow from HCD from 1991–2009 (i.e., the temperature exceedance of the salmonid spawning criterion and duration of the exceedance).

Excerpts from the 2010 application, Section 7.1.1:

> *The cold water temperature in Brownlee Reservoir, along with outflow temperature and flow from Hells Canyon Dam, were used in the flow weighting analysis. The basic equation shown below was used in this analysis and the cold water flow rate iteratively adjusted to meet 13.3 °C. This cold water flow rate was then used with the measured duration of the criteria exceedence for that year to estimate the cold water volume needed.*
>
> $$TempHC_{predicted} =(((FlowHC_{out}-Flow_{pump})*TempHC_{out})+(Flow_{pump}*Temp_{Hypo}))/FlowHC_{out}$$

Where:

- *$TempHC_{predicted}$ is calculated flow weighted HCC outflow temperature including cool water from Brownlee Project.*
- *$FlowHC_{out}$ is average HCC outflow from 10/23 to 10/29 for that year. This is representative of fall Chinook flows that are typically held flat through the period.*
- *$Flow_{pump}$ is flow of cool water from Brownlee Reservoir.*
- *$TempHC_{out}$ is measured 7-day average maximum HCC outflow temperature on October 29. This does not account for the "tapering" of the temperature exceedence over the duration of flows.*
- *$Temp_{Hypo}$ is volume weighted average hypolimnetic temperature below 1,920 ft msl in Brownlee Reservoir based on measured conditions for that year.*

Assumptions in this analysis include:

- *No tapering as exceedence declines, i.e., HCC outflow temperatures are assumed to be constant at the measured value for the duration of exceedence. Actual conditions are cooling (i.e., tapering) to 13 °C over the duration. This is a conservative assumption because a tapering, not constant, cold water flow rate would be sufficient to remain below criteria and would use less cold water volume.*
- *Future HCC outflows are similar to measured flows for specific years.*
- *Regionally managed flood control operations for Brownlee Reservoir will remain as they were historically. The hypolimnion temperatures in Brownlee are related to mandated flood control drawdowns of Brownlee Reservoir.*

Based on this flow weighting analysis there was sufficient volume of cold water in Brownlee Reservoir in October to cool historical conditions at the HCC outflow to meet the SR–HC TMDL load allocation (Table 7.1-2). In 95 percent of years analyzed, there was sufficient volume of cold water in Brownlee to also provide a margin of safety relative to the availability of cold water. With the exception of 1999, pumping rates from 1,000 to 4,200 cfs would be adequate for cooling the outflows.

In December 2010, in response to IPC's September 2010 401 application, the ODEQ submitted AIRs to IPC. As part of these AIRs, the ODEQ noted that the flow weighting analysis "does not address the possible attenuation of cold water as it moves through the Hells Canyon complex" and requested modeling of representative flow years to "simulate the flow of water as it moves through the three dam complex and address the possible attenuation of the cold water as it moves through the complex." To model the HPS and respond to the ODEQ AIRs, IPC's existing CE-QUAL W2 models were upgraded and customized by Scott Wells (Environmental Engineering). The custom coding allowed water to be withdrawn at a point in the hypolimnion of Brownlee and placed in the turbine intake channel. The coding also allowed the simulation of a variable pump flow rate, meaning the pump rate was calculated by the custom CE-QUAL-W2 coding based on a temperature target for the modeled Brownlee outflow and the turbine outflow rate. The results of the HPS modeling showed very similar results as the flow-weighting analysis in the September 2010 application and are detailed below in an excerpt from IPC's response to the ODEQ AIR. IPC's entire response is included as Exhibit 7.1-10.

Excerpt from IPC's March 2011 response to the ODEQ AIR on IPC's 2010 401 application:

> *Results of the HPS modeling indicate that the criterion can likely be achieved with the proposed HPS (Table 3 and Figures 1-5). Calculated 7-day average maximums on October 29 using hourly Hells Canyon modeled outflow temperature were at or below 13.3 °C for all years except 1999 which was at 13.6 °C (Table 3). Results for 1999 (and all years) should be evaluated in the context of model uncertainty and specific conditions (e.g. meteorological and hydrological) unique to that year. In both 2002 and 1995 a Brownlee outflow temperature target of 12.8 °C resulted in output that was cooler than the 13.3 °C criterion at Hells Canyon outflow. In 1992, the translation was not as direct and water did appear to warm and/or attenuate slightly as it moved through Oxbow and Hells Canyon Reservoirs. Overall, the modeling confirms the capacity of the proposed HPS in Brownlee Reservoir to achieve the necessary cooling to meet the criterion at Hells Canyon outflow in a broad range of water years (Figure 2, 3, 4 and 5). These results are similar to the results of mass balance analyses provided in Table7.1-2 of the 401 application.*

Table 3. Modeled Hells Canyon outflow temperature results as 7-day average maximum on October 29 for the 4 model years.

Model Year	*Baseline, no HPS (7-day average maximum °C)*	*HPS, variable flow (7-day average maximum °C)*	*Average pump flow rate for HPS variable (cfs)*
1992	*15.5*	*13.3*	*3395*
1995	*14.0*	*12.8*	*1865*
1999	*14.5*	*13.6*	*4292*
2002	*14.2*	*12.9*	*1476*

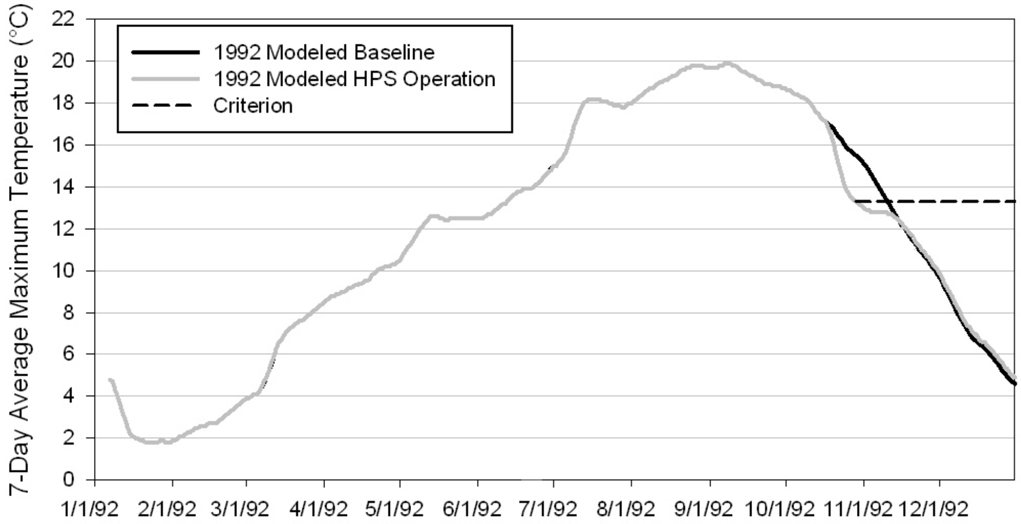

Figure 2. Modeled 1992 Hells Canyon outflow 7-day average maximum temperature for Baseline (no HPS) and HPS operation with CE-QUAL-W2 calculated pump flow rate.

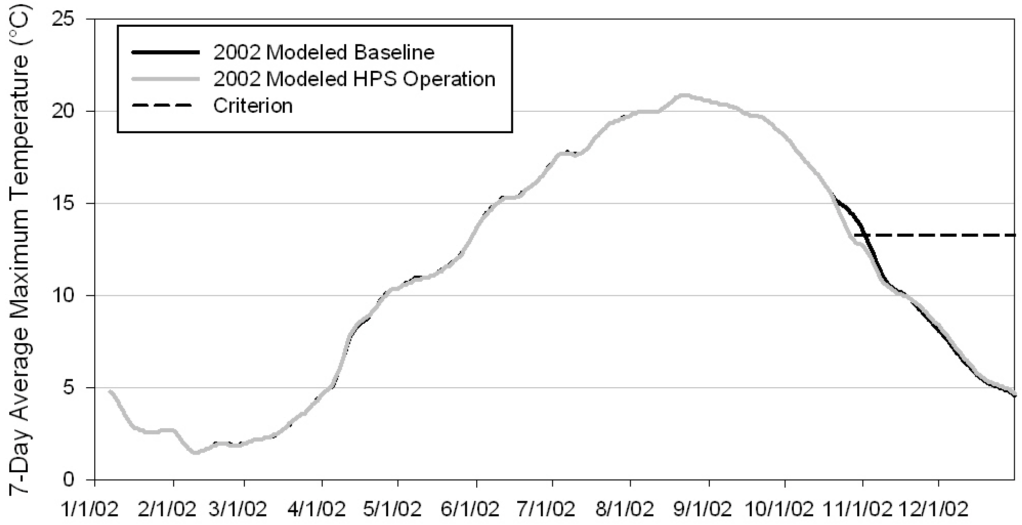

Figure 3. Modeled 2002 Hells Canyon outflow 7-day average maximum temperature for Baseline (no HPS) and HPS operation with CE-QUAL-W2 calculated pump flow rate.

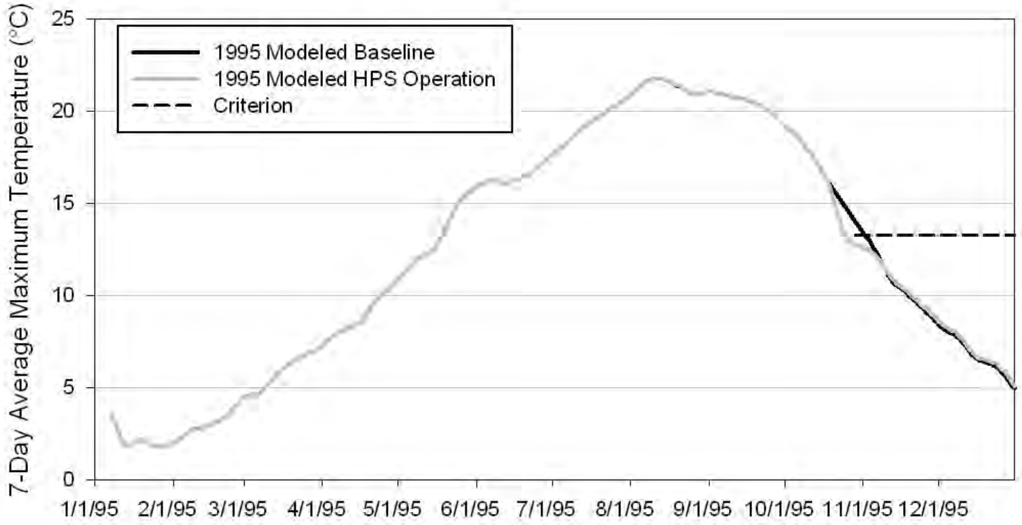

Figure 4. Modeled 1995 Hells Canyon outflow 7-day average maximum temperature for Baseline (no HPS) and HPS operation with CE-QUAL-W2 calculated pump flow rate.

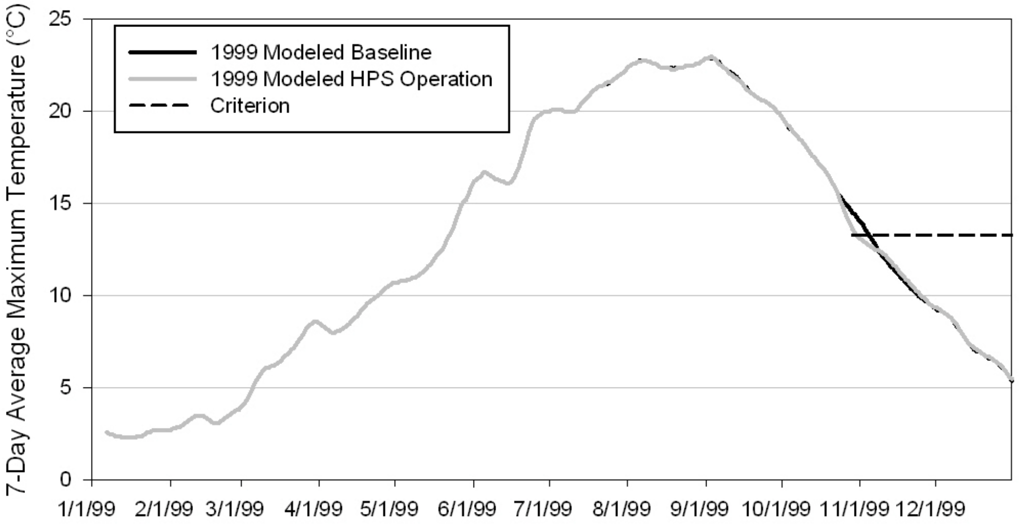

Figure 5. Modeled 1999 Hells Canyon outflow 7-day average maximum temperature for Baseline (no HPS) and HPS operation with CE-QUAL-W2 calculated pump flow rate.

Subsequent to IPC's March 2011 response to the 2010 ODEQ AIR, additional modeling was conducted by the University of Iowa to further evaluate the capability of an HPS (Exhibit 7.1-11). The specific objective was to evaluate the stability of the thermocline during the operation of a HPS and the ability of the HPS to draw cold hypolimnetic water without disturbing the thermocline and accessing warmer layers of the reservoir. Two stratification conditions (i.e., strong, 2002, and relatively weaker, 1999) were simulated to bracket the range of historical conditions seen in Brownlee Reservoir. During strong stratification conditions, the thermocline remained stable throughout the HPS operation, although the temperature of the pumped water increased slightly. During weaker stratification conditions (i.e., 1999), water was drawn from the hypolimnion and warmer layers of the metalimnion due to the elevation of the pump intakes and stratification in conditions in 1999. However, the pumped water was cooler than the baseline and resulted in cooling up to 1.2°C, tapering off to zero in about 12 days, which was similar to the results seen with the CE-QUAL-W2 modeling discussed previously (Exhibit 7.1-10).

The information summarized above and in exhibits 7.1-8, 7.1-9, 7.1-10, and 7.1-10 represent a detailed evaluation of the feasibility and efficacy of the HPS currently proposed as Plan B. Based on this collection of information, the HPS is feasible to construct and could be operated to meet the salmonid spawning criteria.

Consideration of an HPS or other TCS, as an acceptable Plan B alternative measure is contingent on a finding by the DEQs and IPC that the operation of an HPS complies with all applicable water quality standards, including toxics and antidegradation, and has no adverse effect on in-reservoir or downstream aquatic species, their habitat, or on human consumers of such species (see Exhibit 7.1-8, Section 6.6 and Section 7.1.2.5.3.3 for more information on potential adverse effects). These considerations and findings are consistent with OAR 340-041-0028 (12)(g), which states, "Stored cold water may be released from reservoirs to cool downstream waters in order to achieve compliance with the applicable numeric criteria. However, there can be no significant adverse impact to downstream designated beneficial uses as a result of the releases of this cold water, and the release may not contribute to violations of other water quality criteria. Where the Department determines that the release of cold water is resulting in a significant adverse impact, the Department may require the elimination or mitigation of the adverse impact."

As indicated above, as part of the adaptive management component of the TMP, IPC will continue to identify and consider alternative or supplemental measures that may provide, or assist in providing, reasonable assurance that the thermal benefit milestones will be achieved and reserves the right to request amendment or modification of this proposed Plan B by including or substituting additional or alternative measures. Any amendment or modification would be contingent on approval by IDEQ and ODEQ. Such a progressive review process would allow for potential benefits from new and advancing technologies while still ensuring that lacking other acceptable options, Plan B will be implemented as described in this application.

7.1.2.5.3.2 Consideration of Alternative or Supplemental Measures

At any time during the term of the TMP, IPC may present to the DEQs for consideration an alternative or supplemental measure that may provide, or assist in providing, reasonable assurance that the SRSP thermal benefit milestones and/or the goals of the Brownlee operational component will be achieved, or that addresses, or assists in addressing, other issues associated with the implementation of the TMP. In connection with the second 5-year review, the DEQs may also consider whether implementation of Plan B is necessary to achieve compliance targets, given the lack of performance of existing measures, as defined in the SRSP and established by the 401 certification.

Consideration of alternative or supplemental measures relative to Brownlee operational component would occur on a schedule dependant on the performance of that component in meeting the 16.5°C salmonid spawning period temperature goals.

Any proposal by IPC to the DEQs that alternative or supplemental measures to the TMP should be considered shall be in writing and, at a minimum, include the following:

1. The basis or reason why IPC considers alternative or supplemental measures to the TMP to be necessary or appropriate
2. A detailed description of the proposed alternative or supplemental measure
3. An analysis of the how the alternative or supplemental measure will provide, or assist in providing, reasonable assurance that the goals of the SRSP and/or the Brownlee operational component will be met.
4. A statement of whether the proposed alternative or supplemental measure will comply with applicable water-quality standards, including antidegradation, or otherwise adversely affect in-reservoir or downstream aquatic species or their habitat.

Within 60 days of receipt of the written proposal by IPC for alternative or supplemental measures to the TMP, IPC requests the DEQs meet with IPC and discuss the proposal and any additional information that may be required by the DEQs for its consideration. Thereafter, within 60 days of the meeting with the DEQs and the submission of any necessary additional information, IPC requests DEQs notify IPC in writing of its approval or rejection of the proposed alternative or supplemental measures. If rejected, IPC requests DEQs identify the basis for the rejection. Within 120 days of a DEQ approval, IPC shall submit to the DEQs an Alternative or Supplemental Measures Plan with details relating to the implementation of the approved measure.

Consideration by the DEQs of whether a Plan B, or another alternative or supplemental measure, is necessary to achieve compliance with the 15- and 30-year thermal benefit milestones identified in the SRSP proposal, and established by the 401 certification would occur in connection with the second 5-year review in year 10 following license issuance. Within 60 days of the submission to the DEQs of the second 5-year review statement, IPC would meet with the DEQs to review the statement and discuss, among other relevant issues, whether any data provided or issues raised by the statement indicate that the TMP, as implemented to date, is not reasonably expected to achieve compliance with the 15- and 30-year SRSP compliance targets established by the 401 certification and whether implementation of “Plan B”, or another alternative or supplemental measure, may be necessary to reasonably ensure compliance. In determining whether implementation of a Plan B or other measure may be necessary, IPC will present to the DEQs the following:

1. Any previously approved revisions to the SRSP, whether projects implemented and to be implemented under the SRSP appear reasonably likely to achieve the year 15 and 30 thermal benefit milestones.

2. Whether Plan B or the alternative measure being considered, operated alone or in combination with other alternative measures, after consideration of any mercury or other water quality studies undertaken, and any other information the DEQs deem relevant, may cause or contribute to a violation of applicable water quality standards, including antidegradation, or otherwise adversely affect in-reservoir or downstream aquatic species or their habitat.

3. Other issues relevant to the consideration of Plan B or an alternative measure, including whether the construction or implementation of the measure may require any permitting or approval by any state or federal agency, including FERC.

Within 60 days of the meeting with IPC to review the second 5-year review statement, the DEQs shall notify IPC, in writing, of a determination that the implementation of Plan B, or another measure is necessary to reasonably ensure compliance with the year 15 and 30 thermal benefit milestones. Within 120 days of the DEQ notification, IPC shall submit a Plan B or Alternative Measures Plan for DEQ review and approval that contains the following:

1. Details of the measure to be implemented, including a comparison of the proposed measure to the current SRSP, and the originally approved SRSP.

2. An evaluation of whether the measure may cause or contribute to a violation of applicable water-quality standards or otherwise adversely affect in-reservoir or downstream aquatic species or their habitat, and, if so, whether there are any actions that can be undertaken to ensure no such violations or adverse effects occur.

3. If the construction or implementation of the measure may require permitting or approval by any state or federal agency, a description of the process necessary and the estimated time period to acquire such permitting or approval.

4. A schedule for the implementation of the measure.

IPC will continue to implement the SRSP and the Brownlee operational component in a manner consistent with the approved 401 certification until a Plan B or an Alternative or Supplemental Measures Plan is approved by the DEQs. Either plan may include a reduction in the size or scope, or other modification of the SRSP and/or the Brownlee operational component Upon approval of a Plan B or an Alternative or Supplemental Measures Plan by the DEQs, IPC will implement the plan.

7.1.2.5.3.3 Summary Review of TCS Options

In the early years following the filing of IPC's draft license application in 2003, the primary focus of these efforts relating to changing temperature conditions below HCD was on a TCS of some kind. Analyses of TCS options, and the potential effects of those options, were prompted by a 2004 AIR by FERC asking IPC to prepare and file a "conceptual design report on alternative designs for TCSs that could be installed at Brownlee intake…to enhance conditions for SRFC spawning, incubation, rearing and migration in the Hells Canyon reach" [36] (Exhibit 7.1-12). In that AIR, FERC commented on the motivation for the request:

> Nearly all of the agencies, Tribes, and NGOs involved in this proceeding have requested that you [IPC] evaluate the potential benefits of modifying the Brownlee intake to allow the depth of withdrawal to be adjusted to provide some control over the temperature of water that is discharged from the project. Your application, however, provides little information about this potential enhancement measure. In our EIS on this licensing action, we will need to consider the costs and benefits of this and other measures that could protect and enhance aquatic resources. Therefore, you should evaluate this measure and provide the information that is listed below. We will use this information to examine the effects of variable level releases in terms of improving the reproductive success and growth of fall Chinook and effects on other aquatic resources downstream of the project. *Id*.

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[36] FERC AIR, May 4, 2004.

Footnotes continued on the next page.

With the receipt of this AIR, designated as WQ-2, IPC embarked on a multi-month process of study and analysis of the potential design and efficacy of 3 TCS options. [37]

During this same time period, IPC was engaged in discussions with FERC, NOAA Fisheries and the FWS with regard to the potential effect of the interim operation of the HCC in advance of relicensing on species listed under the ESA. In fall 2004, these discussions led to the establishment of a Settlement Working Group (SWG) comprised of various relicensing stakeholders and separate FERC staff. [38] The initial objective of the SWG was to address interim operations and the effect of those operations on aquatic species listed under the ESA. In late 2004, twelve (12) of the SWG participants[39] entered into an Interim Agreement to address issues relating to HCC operations and ESA-listed species in advance of relicensing (Exhibit 7.1-13). This Interim Agreement was filed with FERC on January 7, 2005. Subsequent to the filing of the Interim Agreement, the SWG continued with the discussion of broader relicensing issues with the intent of developing a comprehensive settlement for the relicensing of the HCC. Among other things considered by the SWG was the data and information that IPC was developing in response to FERC AIR WQ-2 relative to temperature and the potential installation of a TCS within Brownlee Reservoir.

FERC’s May 4, 2004, AIR requested IPC respond to the WQ-2 AIR within 9 months, or by February 2005. IPC requested extensions of time for the filing of those responses to allow for the SWG to consider the information being developed. Draft responses to the AIR were shared and discussed with the SWG. In an effort to determine whether the installation and operation of a TCS in Brownlee would benefit SRFC emergence and migration, in April of 2005 IPC entered into a contract with the USACE to model the impact of the installation of a TCS in Brownlee on water temperatures in the Snake River at the Lower Granite Dam tailwater. The results of this modeling were discussed with the SWG and included in IPC’s final response the WQ-2 AIR filed with FERC on September 30, 2005[40] (Exhibit 7.1-14), and also in IPC responses to FERC comments in October 2005 (Exhibit 7.1-15). In that response, IPC summarized the reports’ conclusions:

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[37] IPC evaluated 3 TCS alternatives: a stop-log weir, a gated weir and tunnel, and a 35-thousand cfs tower.

[38] Parties participating in the SWG included IPC, NOAA Fisheries, the FWS, BLM, USBR, USFS, USACE, EPA, State of Oregon, State of Idaho, Nez Perce Tribe, Shoshone–Bannock Tribes, Burns–Paiute Tribe, American Rivers, Confederated Tribes of the Umatilla Indian Reservation, Columbia River Inter-tribal Fish Commission, Idaho Rivers United, Idaho Water Users Association, Payette River Water Users Association, Pioneer, Settlers and Nampa Meridian irrigation districts, Committee of Nine, Idaho Farm Bureau, Idaho Council on Industry and Environment, J.R. Simplot Company, Malheur County (Oregon), Adams and Washington counties (Idaho), and the Idaho Association of Counties.

[39] The Interim Agreement was signed by IPC, NOAA Fisheries, the FWS, USFS, BLM, Idaho Rivers United, American Rivers, ODEQ, ODFW, Shoshone–Paiute Tribes, Nez Perce Tribes, and Shoshone–Bannock Tribes. The State of Idaho did not sign the Interim Agreement but submitted a letter (included in Exhibit 7.1-13) supporting the settlement process.

[40] Responses to FERC AIR WQ-2(c), Detailed Evaluation of Alternative Temperature Control Structures, September 2005.

> Using the Corps modeling results, IPC, in conjunction with NOAA Fisheries, subsequently completed an analysis of the effect of changing the outflow temperature from Hells Canyon Dam, by installing and operating a TCS in Brownlee, on the timing of emergence of juvenile fall Chinook below Hells Canyon dam and the survival of those juveniles at the Lower Granite tailwater. Generally, this analysis concluded that installing a TCS at Brownlee and operating the structure in low water years to cool outflows in an attempt to meet the salmonid spawning water quality standard of 13° C below Hells Canyon Dam offsets any benefit of attempting to influence earlier emergence of juvenile fall Chinook from operating the TCS for spring warming. This analysis, when considered with the other information developed with regard to the operation and effect of installing a TCS at the HCC, leads to the following conclusions: water temperatures cannot be warmed sufficiently in the spring to provide significant benefit to incubating fall Chinook salmon, e.g., the change in emergence timing is relatively modest; operating the TCS to cool outflows in the fall in an effort to meet the existing water quality standard for salmonid spawning actually results in a delay in spring emergence timing, thereby offsetting any benefit of the spring operation; and, finally, the installation and operation of a TCS at Brownlee Dam in an attempt to meet either of these objectives actually results in a lower survival of juvenile fall Chinook through Lower Granite Reservoir. *Id.*

Although the potential effect of operating a TCS on overall water quality within and below the HCC was not the primary focus of the FERC AIR, IPC also concluded that the operation of the type of TCS evaluated in the AIR would raise the elevation of the thermocline in Brownlee Reservoir, thereby changing the thermal structure of the reservoir and altering the physical, biological, and chemical processes occurring in Brownlee Reservoir. The operation of a TCS would therefore likely result in the release of increased anoxic and toxic laden (including mercury) water downstream. Based on the modeling results and these preliminary water quality findings, in the AIR response IPC advised FERC it was not advisable to install a TCS at the HCC. NOAA Fisheries, a member of the SWG and a collaborator on the USACE temperature modeling, reached a similar conclusion:

> Temperature Control: The temperature of the Project release water is an issue of concern to NMFS and we worked extensively with IPC to investigate several temperature control measures at the project and various strategies for using these structures during the relicensing study period. Based on this information, NMFS concluded that these structures would not provide the substantial benefits to incubating, rearing, migrating, or spawning fall Chinook that the agency had hoped would be attained with these structures. While we believe that this effort was thorough, we have no objection to further consideration or analysis of methods to improve discharge water temperatures, particularly if new or innovative approaches can be found[41] (Exhibit 7.1-16 and 7.1-17).

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[41] November 3, 2006, NMFS comments to FERC Draft Environmental Impact Statement for the HCC, p. 39 (Exhibit 7.1-16). Not everyone agreed with the IPC/NOAA conclusions; see EPA comments to Draft Environmental Impact Statement, November 3, 2006 (Exhibit 7.1-17).

The SWG settlement process concluded in fall 2005 without a comprehensive settlement. Thereafter, IPC continued to work with the ODEQ and IDEQ on 401 certification issues, including the fall temperature load allocation assigned to the HCC by the SR–HC TMDL. In light of the 2005 TCS analysis, which raised questions as to the benefits and potential adverse effects from operation of a TCS, from 2006 through 2009 the focus of IPC's efforts on temperature centered around an upstream watershed approach to address water-temperature conditions above and below the HCC. In 2009, IPC submitted a § 401 application to the DEQs proposing an upstream watershed improvement program, identified as the *Temperature Enhancement Management Plan* (TEMP), intended to address the HCC temperature load allocation and improve overall water quality and habitat conditions above and within the HCC. NOAA Fisheries and the FWS expressed support for the proposal, but the EPA, and other downstream interests, opposed it, in large part because of perceived issues concerning appropriateness of the modeling boundary conditions relied on by IPC in the development of the watershed program. This resulted in uncertainties in the size and feasibility of the TEMP watershed program and ultimately IPC's withdrawal of the application in December 2009.

After several months of discussions with the DEQs, in September 2010 IPC filed a new § 401 application. In Section 7.1. Temperature Proposed Measures of this application, IPC addressed the SR–HC TMDL load allocation by proposing the installation of a hypolimnetic pump system (HPS) in Brownlee Reservoir designed to meet the SR–HC TMDL load allocation assigned to IPC below HCD by blending cold water from the lower strata of Brownlee Reservoir with warmer upper-strata water. [42] (Exhibit 7.1-8). While IPC submitted that the proposed HPS would adequately address the HCC load allocation and applicable salmonid spawning temperature criteria, it cautioned, as it did in the 2005 response to the FERC AIR for WQ-2, that the operation of the HPS, or any other TCS that accesses and moves water from the hypolimnion of Brownlee Reservoir downstream, poses a level of risk for natural resources in the river and the 3 reservoirs within the HCC and that the precise nature and extent of these risks could not be determined until the HPS is constructed, operated, and the effects on in-reservoir and downstream resources analyzed:

> In October, the cold water in the hypolimnion of Brownlee Reservoir is anoxic and pumping this water to the intake channel to be drawn through the turbines will correspondingly result in reduced DO immediately downstream of Brownlee Reservoir and at the HCC outflow. Increased levels of methane, sulfides, dissolved nutrients, methylmercury and other dissolved inorganics associated with the anoxic conditions in the hypolimnion of Brownlee Reservoir may also be released downstream. Some of these products (e.g., methane, sulfides) are oxidized when oxygen is added to the water and can create additional oxygen demand. Others, such as methylmercury are a concern due to aquatic toxicity. *Id., pg. 154.*

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[42] Section 401 Water Quality Certification Application—Hells Canyon Complex, FERC No. 1971 (September 2010).§ 7.1 of that Application, Temperature Proposed Measures, is attached as Exhibit 7.1-8.

IPC's proposal to install and operate an HPS in Brownlee Reservoir to address the downstream temperature standard elicited negative reaction from the FWS and NOAA Fisheries:

> At this point, the effects of a deep water withdrawal system that may affect the dynamic processing balance in Brownlee Reservoir are little understood. Furthermore, potential oxygen reduction and contaminant transport to downstream species is a threat of unknown magnitude…Unfortunately, history has shown that engineered solutions to a perceived resource problem addressing one narrow issue, in this case temperature, may have multiple adverse resource effects that may not be evident until final construction and operation. In the case of the HPS, the Service is concerned that we may again be creating a narrow solution to a discreet aquatic habitat issue while ignoring, and possibly damaging, other resources within the HCC and the Snake River watershed. [43] (Exhibit 7.1-18)

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> NMFS does not support this application because it does not focus on the broader set of water quality issues at an ecosystem scale that affect anadromous fish in the Snake River…In other words, the abundance and productivity of naturally produced SR fall Chinook in this [HC] reach does not appear to be limited by water temperatures in the reach, but by the amount of quality juvenile rearing habitat (space) available in the reach…IPC's most recent 401 application proposes to meet ODEQ's numerical water temperature standard for spawning salmon by pumping cooler water from deep in Brownlee Reservoir into the intake channel for the Brownlee powerhouse, cooling the discharge to the Snake River at Hells Canyon Dam. This plan itself causes NMFS concern due to water quality issues associated with nutrients and toxics; however, it does not cause us concern with respect to temperature…The proposed TCS would not provide any additional spawning and rearing habitat, which is what is needed to benefit the species at this point. NMFS does not believe that meeting spawning water temperature standards would appreciably increase either the abundance or the productivity of spawning aggregate in the Hells Canyon reach of the Snake River. We are also concerned that by entraining water from depth in Brownlee Reservoir into the discharge stream from the project, additional risks to the existing SR fall Chinook population and its critical habitat would be incurred. These risks include low dissolved oxygen concentrations, high nutrient (nitrogen and phosphorus) concentrations resulting in high biological oxygen demand, and toxins (DDT, and other pesticides and herbicides and heavy metals, particularly methyl-mercury).[44] (Exhibit 7.1-19)

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[43] FWS comments on Idaho Power's water-quality application for the HCC, November 15, 2010.

[44] NOAA Fisheries comments on IPC's water-quality application for the HCC, January 27, 2011. NOAA's comments on the September 2010 HPS proposal reflect a consistency with its 2003 comments to the EPA on the *Region 10 Guidance for State and Tribal Temperature Water Quality Standards*, where it said large federally-licensed dams were already subject to extensive regulation under the ESA

Footnotes continued on the next page.

In December 2010, in response to IPC's September 2010 § 401 application, the ODEQ submitted AIRs to IPC. These AIRs included inquiries related to the potential risks of installing and operating an HPS. In this context, the ODEQ asked IPC to further describe "what water quality conditions, throughout the project, could be exacerbated by the discharge of water from Brownlee Reservoir's hypolimnion…discuss all available data indicating these risks and define data gaps." The ODEQ also advised that in considering the application, it must complete an antidegradation review and asked IPC to "describe specifically how water quality within Brownlee Reservoir and downstream water quality and beneficial uses will be affected by the blending of cooler water from Brownlee Reservoir (Exhibit 7.1-20). [45]

IPC responded to the ODEQ AIR on March 11, 2011, including in the response available data and information relating to toxic levels in Brownlee Reservoir, much of which was developed for the relicensing of the HCC (Exhibit 7.1-10).[46] IPC noted that the presence of toxic materials in the hypolimnetic waters of Brownlee had received only limited study during the relicensing process and that the potential risks and water-quality issues associated with the operation of the proposed HPS remained uncertain. The filing of this response fostered further discussion and ultimately a collaborative study effort by IPC, the FWS, and the DEQs to better assess toxic levels in Brownlee Reservoir (see Section 6.6. Toxics for more information on toxics). Over time, these efforts have increasingly focused on the level of mercury in Brownlee and the fate and transport of that constituent downstream (see Section 6.6. Toxics for more information on toxics in the HCC). This evolution resulted in IPC's participation in a large study effort headed by the USGS, which began in 2014, is ongoing, and is anticipated to extend for 7 to 10 years. IPC plans to continue participating in this effort for the duration of the study.

Due to the ongoing and uncertain risks associated with the operation of a HPS (or TCS) within Brownlee Reservoir on downstream resources, in July 2011 IPC withdrew the September 2010 § 401 application and submitted a new application without sections 6.1 and 7.1 relating to temperature. Subsequent to this submission, IPC continued to work with DEQ staff on alternatives for addressing the HCC temperature load allocation. These discussions continued through 2011, 2012, 2013, and 2014 with annual withdrawals of the pending § 401 applications and submissions of new applications. IPC retained TFT as a consultant to assist with the analysis and planning of an upstream watershed program to improve temperature conditions within, and downstream of, the HCC. In 2013, as consideration of an upstream watershed program continued, IPC explored the option of augmenting the temperature benefits realized from an upstream program with the installation of small HPS in Hells Canyon Reservoir (Exhibit 7.1-21). [47] Like Brownlee Reservoir, HCR accumulates cool water in its hypolimnion in lower water years, although the approximate potential volume of the HCR HPS design is significantly less (approximately 20,000 acre-feet in HCR as compared to approximately 150,000 acre-feet in

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and FERC licensing proceedings and that temperature effects should be considered in combination with other project effects as part of a comprehensive consultation.

[45] ODEQ AIR, HCC Application for Certification under CWA § 401, December 6, 2010.

[46] IPC responses to ODEQ AIR, March 11, 2011.

[47] *Hells Canyon Surface Collector with Temperature Management Component: Conceptual Design Report Executive Summary*.

Brownlee Reservoir), thereby providing the potential to supplement the upstream watershed temperature benefits and partially address the HCC temperature load allocation. IPC explored this option under the assumption that because HCR was smaller than, and downstream from, Brownlee, the mercury and toxic levels of the reservoir would be much less than in Brownlee Reservoir. Subsequent study and analysis, however, indicated that this does not appear to be the case, and IPC ultimately set this option aside until the studies referenced previously provide more information as to the presence, fate, and transport of mercury.

7.2. DO Proposed Measures

IPC is proposing three measures to fully mitigate the effects of the HCC on DO. First, the Riverside Operational Water-Quality Improvement Project (ROWQIP), along with the accompanying reasonable assurance measures, will fully address the 1,125 ton per year DO load allocation assigned to Brownlee Reservoir in the SR-HC TMDL through phosphorus reductions. Second, distributed aeration systems in 4 of the 5 units in the Brownlee Powerhouse will be operated to add as much additional DO as possible whenever incoming DO to Brownlee Powerhouse is less than applicable criteria below HCD. This will address IPC's proposed DO supplementation goal of 0.4 and 1.2 mg/L during the cool-water aquatic life and salmonid spawning periods, respectively. This annual average level of aeration offsets the current downstream DO deficits, incorporates reaeration that is occurring immediately downstream of HCD, addresses the uncertainty in the time frame for full upstream SR HC TMDL implementation and provides assurance that downstream standards will be met in the future (see Section 6.2.3. HCC Contribution to DO). Third, a destratification system will be installed in the deep pool in the Oxbow Bypass near Indian Creek to address thermal stratification and resulting anoxic conditions.

7.2.1. Proposed Upstream Phosphorus Reduction

7.2.1.1. Riverside Operational Water-Quality Improvement Project

IPC is proposing to address its DO load allocation assigned to the transition zone and metalimnion of Brownlee Reservoir in the SR–HC TMDL (IDEQ and ODEQ 2004) by implementing the ROWQIP. The SR–HC TMDL identified the HCC CWA § 401 certification as the process for detailing IPC's implementation plan for the required DO improvements. Following is a description of the proposed project and the supporting documentation to ensure the project is transparent, reliable, and verifiable. IPC is also providing documentation that DO improvements equal to, or greater than, its required DO responsibility identified in the SR–HC TMDL will be realized in Brownlee Reservoir. The proposal includes an adaptive management process if load reductions produced by the ROWQIP are reduced in the future.

The Riverside Irrigation District (Riverside) will operate its primary delivery facility (Riverside Canal) to reduce the loads of phosphorus and other pollutants discharged from the Riverside Canal to the Boise and Snake rivers. The studies and analyses discussed below show the ROWQIP as currently implemented by Riverside will meet IPC's DO requirements identified in the SR–HC TMDL (Exhibit 7.2-1).

IPC initiated research and development of this project in 2010. In 2014, IPC initiated implementation of the ROWQIP prior to acceptance of this program in the HCC CWA § 401 certification or FERC license. Early implementation of the ROWQIP, relative to IPC's regulatory requirements, allowed IPC to take advantage of a time-sensitive opportunity, increase certainty associated with phosphorus reductions expected from project implementation, and provide immediate water quality benefits. Constructing control systems, establishing flow monitoring stations, and testing operations (Exhibit 7.2-2), as part of early implementation of the program, has allowed IPC to collect and analyze data to ensure the ROWQIP reduces phosphorus and organic matter in sufficient quantities to meet IPC's SR–HC TMDL responsibility for DO in the transition zone and metalimnion of Brownlee Reservoir.
Data collected and analyzed since 2010 indicates that the expected benefits in phosphorus load reductions to the Snake and Boise rivers have occurred and will continue to occur in future years.

On June 29 2016, ODEQ submitted an additional information request to IPC requesting that IPC submit additional information demonstrating whether and how the ROWQIP is consistent with Oregon's water quality trading rules (OAR 340-039). While the IDEQ rule IDAPA 51.01.02.055.06 authorizes pollutant trading, and IDEQ is currently updating its trading guidelines, IDEQ has advised that the ROWQIP will be treated as offsets under Idaho's rules and guidelines, and not as trades.

Exhibit 7.2-3 demonstrates that the ROWQIP is fully consistent with the Oregon and Idaho water quality standards, the SR-HC TMDL, and any applicable Oregon or Idaho water quality trading and offset rules and guidelines. IPC is proposing to implement the ROWQIP for the purposes of the CWA section 401 certification for the licensing of the HCC FERC and has not characterized the program as a trade under Oregon or Idaho rules or guidelines. Nevertheless, ODEQ and IDEQ have advised IPC that classifying and analyzing the ROWQIP as a trade or as an offset does not have material regulatory consequences to the ROWQIP, nor will doing so result in the alteration of any of the compliance, monitoring or enforcement obligations associated with the 401 certification for the HCC FERC license.

7.2.1.1.1. Project Description

Riverside operates the Riverside Canal, located at the western end of the Boise River valley near the confluence of the Boise and Snake rivers, as its primary conveyance for the delivery of irrigation water (Figure 7.2-1). Riverside delivers water to about 230 water users for agricultural purposes, with principal crops of onions, sugar beets, wheat, potatoes, alfalfa, beans, and hops. According to IDWR records, Riverside has water rights authorizing the irrigation of 10,158 acres within the district boundary (IDWR 2013). The primary diversion to the Riverside Canal is from the south bank of the Boise River near Caldwell (Figure 7.2-1). Additionally, many tributaries and drains discharge into the canal along its length. Excess canal inflows are discharged (i.e., spilled) to the lower Boise and Snake rivers upstream of Brownlee Reservoir.

The ROWQIP was designed for automatic operation of the Riverside Canal in a manner that reduces phosphorus loading to the Boise and Snake rivers. The load reductions are accomplished by prioritizing the use of high-nutrient agricultural and municipal drainage water in the Riverside canal for delivery to irrigators. This automation allows Riverside to reduce water diverted from the Boise River, and at the same time, reduce agricultural return flows to the Boise and Snake rivers. Specific actions are described and defined in the canal operating guidelines

(Exhibit 7.2-2—Appendix 1). In addition, the project was designed to be consistent with generally accepted quality standards and guidelines.

Under historical operations, water in Indian Creek and the West End Drain and several other agricultural drains enter the Riverside Canal, along with Riverside's water-right diversion from the Boise River. Because of the configuration of the canal system, Riverside had no operational option other than to accept the water from Indian Creek and the West End Drain and these other drains. Flows entering the Riverside Canal from Indian Creek and the West End Drain and the other drains are variable and unreliable. Consequently, under baseline conditions, Riverside's necessary operation was to divert up to its water right from the Boise River. This ensured sufficient water for irrigation demand. If the total flow into the Riverside Canal exceeded irrigation demand, excess water was spilled back into the Boise and Snake through 4 spill gates along the canal and a spill at the end of the canal. The lack of system automation hampered operations capable of efficiently dealing with the variability of inflows from Indian Creek, the West End Drain, and other minor inflows. Consequently, more water was typically diverted from the Boise River than would be necessary under improved, more efficient operations proposed under the ROWQIP. Baseline diversion from the Boise River was consistent with the decreed water rights and was a practical necessity to meet irrigation demand because of the lack of operational flexibility and efficiency under the pre ROWQIP system design.

The current operations, made possible by the ROWQIP, allow Riverside to preferentially use water with relatively high phosphorus levels for irrigation purposes, rather than spilling it, or a portion of it, into the Boise or Snake rivers. The result is reductions in phosphorus loading to the Boise and Snake rivers. The reduced phosphorus loading to the rivers will result in corresponding reductions in phosphorus and organic matter loading to Brownlee Reservoir. IPC is proposing to use the reduction in oxygen demand in Brownlee Reservoir, resulting from the reduction of phosphorus and organic matter loading to Brownlee Reservoir, to meet its DO load allocation defined in the SR–HC TMDL.

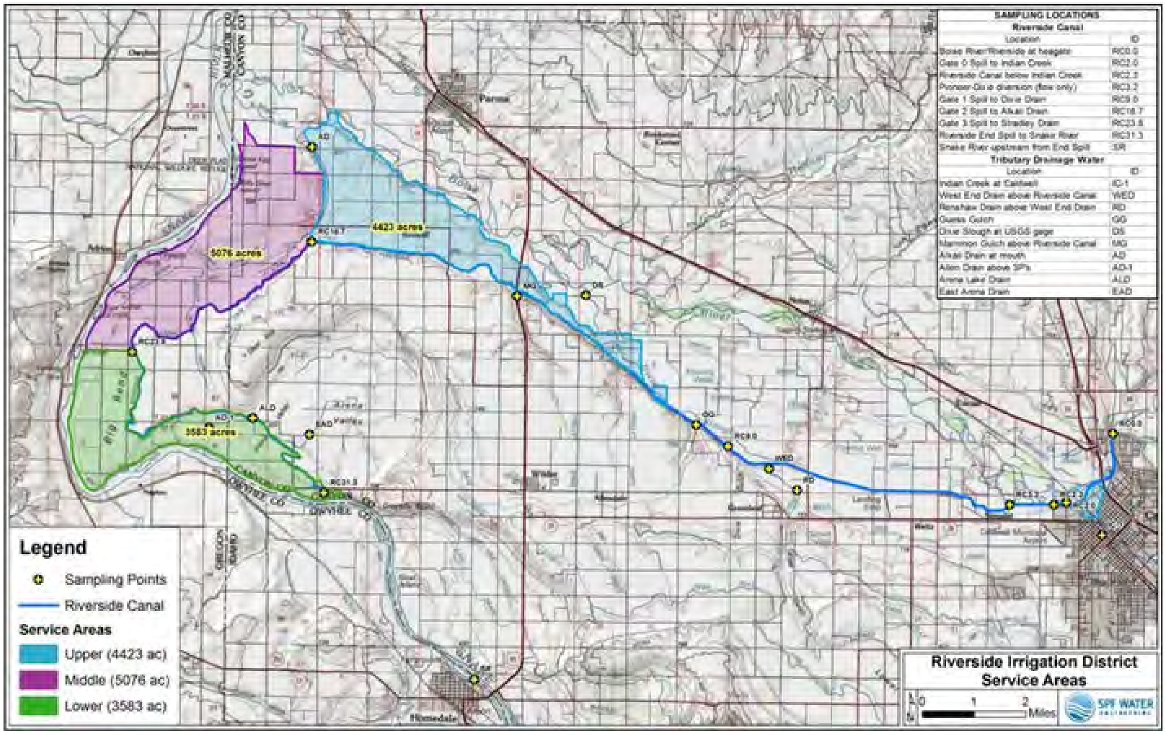

Figure 7.2-1
Riverside Irrigation District, approximate irrigated acreages, and sampling locations, including spill gates

7.2.1.1.2. Equivalent Phosphorus Load

To address DO concerns in Brownlee Reservoir, the SR–HC TMDL allocated an annual DO supplementation of 1,125 tons to IPC. The SR–HC TMDL (IDEQ and ODEQ 2004) specifically allows IPC to use upstream nutrient reduction to satisfy this requirement to improve DO levels in the transition zone and metalimnion of Brownlee Reservoir.

> This load allocation does not require direct oxygenation of the metalimnetic and transition zone waters. It can be accomplished through equivalent reductions in total phosphorus or organic matter upstream, or other appropriate mechanism that can be shown to result in the required improvement of dissolved oxygen in the metalimnion and transition zones to the extent required.

Snake River algal stoichiometry and DO demand processes, including degradation of organic matter and associated nitrification, were used to calculate an equivalent seasonal phosphorus load reduction for IPC's 1,125 tons of oxygen requirement (Exhibit 7.2-2 – Appendix 2). The equivalent phosphorus load of 15,000 pounds (lbs) equates to an average phosphorus load reduction of 82 lbs per day over a 183-day period; the period that ROWQIP can provide the greatest environmental benefits (See Exhibit 7.2-4 for additional analysis and information on stoichiometry and time period for benefits). This period is appropriate relative to meeting the annual DO allocation considering the overall benefits of the inflow load reductions are cumulative and result in reduced long-term storage and cycling of phosphorus within Brownlee Reservoir. Given the dynamic nature of phosphorus spiraling in a phosphorus-rich riverine system, such as the Snake River (ODEQ and IDEQ 2004), all phosphorus reduction from the project has beneficial implications for the DO dynamics in Brownlee Reservoir. Further, the phosphorus reductions upstream of Brownlee Reservoir provide additional water quality benefits for the lower Boise River and the Snake River immediately upstream of Brownlee Reservoir through a reduction in sediment and toxics.

As stated previously, the SR–HC TMDL DO load allocation is 1,125 tons as an annual load. In the SR-HC TMDL, the assumed approach to meet this allocation was reservoir aeration over a low DO critical period from July 1 through September 7. While this was the time of potentially lower DO conditions in Brownlee Reservoir, the SR–HC TMDL states, “this time frame should not be interpreted as an absolute requirement” (IDEQ and ODEQ 2004). The relatively short 65-day period was based on the understanding that potential DO additions that were assumed possible through reservoir aeration would have no benefits outside the actual time when aeration was occurring. Conversely, reductions in phosphorus and organic matter loading address the underlying problem of excessively high DO demand. Therefore, phosphorus load reductions outside the specific low DO critical period will still affect the actual DO levels within the critical period.

The typical time period IPC is proposing to quantify phosphorus load reductions to the Boise and Snake rivers is 183 days beginning April 15 and extending to October 15 (Exhibit 7.2-2 – Appendix 2 and Exhibit 7.2-4). This is conservative because Riverside Irrigation District’s water right allows for diversion as early as March 1. The TP reductions provided by the ROWQIP address the underlying causes of low DO and have cumulative benefits that occur throughout the year, as well as across many years. For this reason, it is appropriate to calculate the load reductions resulting from the implementation of the ROWQIP over the irrigation season.

7.2.1.1.3. Phosphorus-Reduction Calculation Methodology

The phosphorus-load-reduction calculation methodology (Exhibit 7.2-2—Appendix 3 and Exhibit 7.2-4) uses a mass balance analysis to determine the TP load (lbs per day) delivered to areas irrigated with Riverside Canal water. By changing the canal operations, such as diverting less Boise River water, more water from other sources, such as Indian Creek, is used for irrigation. Consequently, less water higher in phosphorus is discharged to the Boise and Snake rivers.

A Riverside Canal model was developed to estimate the TP loads in irrigation water under different canal operations. A simplified schematic diagram (Figure 7.2-2) shows conceptually how the Riverside Canal is structured. The simplified schematic shows how the canal receives water diverted from the Boise River and a tributary containing drainage water. Any excess canal water, including tributary water containing agricultural runoff, then “spills” back to the river downstream of the diversion. When modeling different canal operations, the load from canal tributary inflows is constant. The TP load reductions to the Boise and Snake River are calculated using the difference between delivered and runoff loads between a baseline and water quality operation.

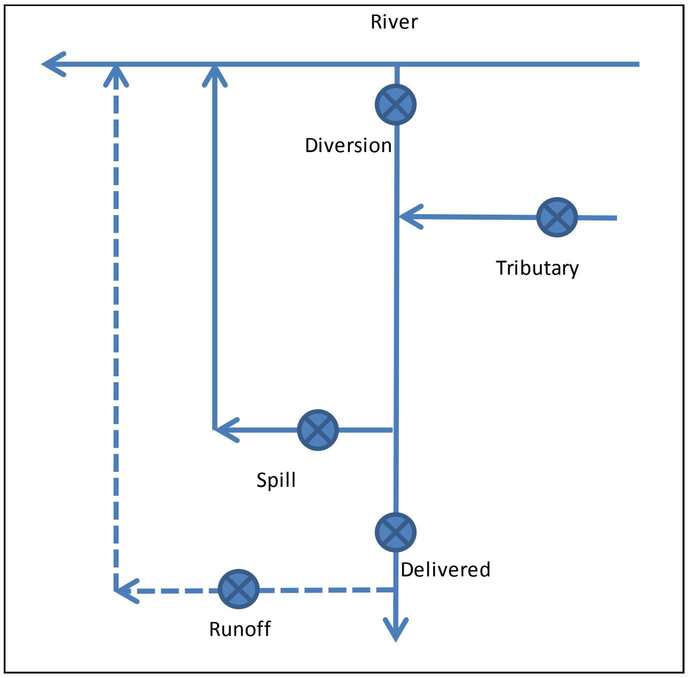

Figure 7.2-2
Simplified schematic of ROWQIP showing main components of the phosphorus reduction calculation methodology

Using a mass balance approach, the TP load delivered to farm land ($L_{Delivery}$) under various canal operations is calculated as follows:

$$\textbf{Equation 1}: L_{Delivery} = L_{Diversion} + L_{Tributary} - L_{Spill}$$

Where:

$L_{Diversion}$ = the load delivered to agricultural areas

$L_{Tributary}$ = the tributary inflow load

L_{Spill} = the load spilled back to the river

A change in the canal operations, such as diverting less Boise River water, will change the load in the canal because the various sources of water to the canal have differing water quality. Consequently, this changes the load delivered to the farm land. The automated operations of the canal under the ROWQIP are designed to reduce phosphorus loading to the Boise and Snake rivers and are referred to as water-quality (WQ) operations. Phosphorus loads delivered to the irrigated lands in the absence of the ROWQIP are referred to as baseline (BL) operations. The load (L) reduction produced by the change in canal operations is calculated by subtraction:

$$\textbf{Equation 2}: L\ Reduction_{\ in\ rivers} = (L_{Delivered} - L_{Runoff})WQ - (L_{Delivered} - L_{Runoff})BL$$

The Riverside Canal model uses a water-balance approach like the load balance (Equation 1), applied over the 31-mile long canal (Exhibit 7.2-2—Appendix 3). Because the phosphorus load is calculated from the flow rate and phosphorus concentration, defining both flow and concentration are key considerations for load reduction calculations. The model assumes both tributary flow and water quality remain the same under WQ and BL operations. Therefore, the load reductions are derived from changes in Boise River diversion rates.

7.2.1.1.3.1. Water-Quality Operations Flows

As stated previously, the load reductions for water-quality-focused canal operations are accomplished by prioritizing the use of high-nutrient agricultural and municipal drainage water. This is accomplished by minimizing the diversion of the comparatively higher-quality Boise River. In 2014, the Supervisory Control and Data Acquisition systems controlled the diversion throughout most of the irrigation season.

7.2.1.1.3.2. Baseline Operations Flows

As shown by Equation 2, defining BL operations is necessary to determine the amount of phosphorus load reduction resulting from the ROWQIP. A definition of the BL diversion is the critical parameter because it determines the flow along the canal, which will then be used to determine phosphorus loads for the BL operations.

The ROWQIP is specifically designed to modify canal operations in a way that reduces phosphorus loading to the Snake and Boise rivers. However, the project does not include any actions to modify or redefine Riverside's overall irrigation requirements or the volume of water diverted as currently specified by adjudicated water rights. Therefore, it is appropriate that the BL relative to water diverted from the Boise River be Riverside's legally established water rights, which total 271.5 cfs (IDWR 2013). Under Idaho law, the adjudication of these rights constitutes a judicial determination that the decreed amount of water was put to use and that the users have the right to continue to put those decreed rates to use. While actual diversion may vary among years and specific times within a given year from the water-right diversion rate, it is the rate allowed under law and therefore the most logical and legally defensible flow estimate for use in BL calculations.

7.2.1.1.3.3. Water Quality

The phosphorus concentrations used to determine loads for both WQ and BL operations are the concentrations measured in water sources flowing into the Riverside Canal. These concentrations are measured for the primary sources during project operations, which are the Boise River, Indian Creek, and West End Drain. Because this project deals mainly with changes in the operation of the water delivery system, rather than on-farm or upstream practices that improve water quality, it is appropriate to incorporate any changes in phosphorus concentrations of inflowing water into the quantification of BL conditions.

7.2.1.1.3.4. Agricultural Runoff

For purposes of estimating load reductions to the Boise and Snake rivers, the runoff load from agricultural land is assumed to remain unchanged. This assumption is considered conservative for several reasons detailed in Exhibit 7.2-2—Appendix 3 and Exhibit 7.2-4, and includes the following:

1. Typically, more than 90% of phosphorus runoff from “clean-tilled row-crop” fields is in the particulate form.
2. Soils typically have the capacity to retain much of the phosphorus applied.
3. The change in canal water quality anticipated for the canal is relatively small and represents less than 3% of the phosphorus needed to produce crops.
4. On-farm water quality and nutrient management has increased over the last 10 years (i.e., since the SR–HC TMDL was established) and will be an ongoing focus of future load reduction efforts.

7.2.1.1.4. Riverside Canal Modeled Load Reductions

To estimate the load reductions under WQ operations, the Riverside Canal model was applied using data collected in 2014 (Table 7.2-1). These data are used to illustrate how to calculate the TP load reductions using Equation 1. This is followed by a summary of total reductions for the 2014 irrigation season. More detailed information on modeling the daily average loads is presented in Exhibit 7.2-2—Appendix 3.

7.2.1.1.4.1 Simplified Average Load Reduction Calculations for 2014

A simplified presentation of the Riverside Canal model, which is based on the schematic diagram (Figure 7.2-2), is used to show how the TP load reduction under BL and WQ conditions in 2014 differ (Table 7.2-1). The measured tributary and delivered flows in 2014 are the same for both operations, while the flow diverted from the Boise River varies. For the WQ operations, the diversion from the Boise River was minimized, while for the BL, the diversion flow is the adjudicated water right of 271.5 cfs. Because Boise River inflows vary between the 2 operational scenarios, the calculated spills back to the Boise and Snake rivers also vary between scenarios. The change in proportions of canal-source water produces the different TP concentrations for the water delivered. The concentrations of TP in source water (diversion and tributary) are assumed to remain constant under both operations.

Table 7.2-1
Example of load-reduction calculations based on 2014 average model results

	Total Phosphorus		
	Flow (cfs)	**Conc. (mg/L)**	**Load (lbs per day)**
2014 Water Quality Operations			
Diversion	67	0.21	76
Tributary	276	0.61	906
Spill	100	0.52	279
Delivery	**242**	**0.54**	**703**
Baseline Operations			
Diversion	271	0.21	302
Tributary	276	0.61	906

Spill	305	0.41	679
Delivery	**242**	**0.41**	**529**
Delivery TP Reduction		**0.13**	**174**

The Riverside Canal model is used to calculate “comparable” concentrations for the water delivered under each of the operations. The change in concentration of the water delivered to irrigators, which is the primary goal of the ROWQIP, can be used directly to calculate the TP load reduction because water delivery is the same for both operations.

7.2.1.1.4.2. Annual Average Load Reductions

The estimated annual average phosphorus load reduction attributable to the ROWQIP has exceeded 15,000 lbs of phosphorus since 2011 (Table 7.2-2, exhibits 7.2-1, 7.2-5, 7.2-6, and 7.2-7). This represents the sum of the modeled daily change in phosphorus load in the Boise and Snake rivers that could occur under full implementation of the ROWQIP over a 183-day irrigation season.

Table 7.2-2
Annual average phosphorus load (lbs) reductions from the ROWQIP since 2011

Year	Load Reduction
2011	36,827
2012	33,711
2013	30,098
2014	31,920
2015	15,826
2016	26,818
2017	23,800

7.2.1.1.5. Planned Project Contract and Duration

The certainty and ability of IPC to use the ROWQIP for purposes of compliance with CWA § 401 certification will be defined and described through a contract between IPC and Riverside. The contract will provide certainty IPC will have the right to utilize the ROWQIP to mitigate for DO conditions in Brownlee Reservoir. The contract will include certainty Riverside will give IPC preference in claiming the ROWQIP as necessary to meet its Brownlee Reservoir DO load allocation.

7.2.1.2. Reasonable Assurance

7.2.1.2.1. Grand View Sediment Reduction Program

The Grand View Sediment Reduction Program is a voluntary incentive program IPC offers to growers near Grand View, Idaho, to convert from furrow to pressurized irrigation. The goal is to reduce upland soil loss and, therefore, sediment and phosphorus delivery to the Snake River. The program is being proposed as reasonable assurance for the ROWQIP. It also provides coverage for the variable inter-year nature of the phosphorus reductions addressed in the ROWQIP. More information on the Grand View Sediment Reduction Program is provided in Exhibit 7.2-8.

IPC compared measured data collected in 2013 from drains and tributaries in the program area to estimates of irrigation induced soil loss using the Surface Irrigation Soil Loss (SISL) model (Exhibit 7.2-8). The comparison supported the conclusion the sediment loss estimated by the SISL model is a reasonable approximation of the sediment load measured in drains and tributaries and, therefore, delivered to the Snake River. The validation of the modeled sediment load supports the use of the SISL model for estimating load reductions resulting from the Grand View Sediment Reduction Program.

Sediment reduction for all furrow-irrigated acres in the Grand View Sediment Reduction Program area estimated using the SISL model is 21,474,000 lbs per year based on a 183-day irrigation season (Exhibit 7.2-8). While many factors affecting soil loss are included in the SISL model, IPC discounted potential sediment reduction to 90% to address any concerns regarding the effectiveness of pressurized irrigation in reducing sediment loss (i.e., pressurized irrigation will reduce sediment loss by 90%). The goal of the Grand View Sediment Reduction Program is 80% conversion of furrow-irrigated acres to pressurized irrigation. This further reduces the annual sediment load reduction estimate calculated by the SISL model to 15,461,280 lbs per year.

IPC evaluated 2013 drain and tributary data from the program area to develop a TP to total suspended solids (TSS) ratio. Data indicated TSS measures were dominated by the inorganic (i.e., sediment) component. As such, TSS and sediment are considered analogous for purposes of this analysis. IPC calculated a 1.56 lbs TP to each ton TSS ratio (Exhibit 7.2-8). This 1.56:1 ratio falls within reported literature values that generally range from 0.8 lbs:1 ton to 2.8 lbs:1 ton (NRCS 2015; Mullins 2009; Mahler et al. 1996).

IPC applied the 1.56 lbs TP:1 ton TSS ratio to the SISL model sediment reduction estimate of 15,461,280 lbs per year for the Grand View Sediment Reduction Program. The potential annual TP load reduction is 12,060 lbs per year (Exhibit 7.2-8). Based on phosphorus processing in the Snake River, and stoichiometry (exhibits 7.2-2, 7.2-3 and 7.2-8), the annual TP load reduction is equivalent to 905 tons per year DO demand reduction.

Grand View Sediment Reduction Program research projects were initiated in 2015 and have been completed on 14 projects totaling over 1,700 acres. Voluntary implementation is expected to continue with full implementation expected to occur within 10 years of HCC license issuance.

7.2.1.2.2. Swan Falls Project Aquatic Vegetation and Debris Removal

IPC has been removing aquatic vegetation and debris that accumulates on the trash rake over the intake turbines at the Swan Falls hydroelectric project (Swan Falls project) since October 2011. This activity was initiated after EPA approval of the SR HC TMDL, therefore, phosphorus reductions associated with the removal of aquatic vegetation and debris represents improvements toward TMDL targets. IPC proposed continued operation as part of the project final license application. IDEQ acknowledged the proposed action in the CWA § 401 certification for the project but did not make it a condition of the certification necessary to ensure compliance with Idaho water quality standards. Since IPC proposed continued operation as part of the license application, FERC included the action in the license issued September 28, 2012. Article 404 requires IPC remove aquatic vegetation and debris that accumulates on the trash rake and dispose of the material in a location where it cannot return to the Snake River.

IPC has removed 56–417 truckloads of material annually between April 15 and October 15 from the Snake River (Table 7.2-3). IPC weighed 8 truckloads from June through September 2014 to estimate a wet weight of material removed from the river. The average truckload of material weighed 14,019 lbs. This material was then converted to TP using a value of 489.2 milligrams TP per kilogram of wet weight. This value is based on 2002-2003 laboratory results of TP concentrations measured in wet material collected upstream at IPC's Upper Salmon Falls "B" hydroelectric project. IPC estimates 1,547 lbs TP is removed annually from the Snake River through aquatic vegetation and debris removal at the Swan Falls project. IPC will continue to annually remove aquatic vegetation and debris at the Swan Falls project at least through 2042.

Table 7.2-3
Annual number of truckloads of aquatic vegetation and debris removed from the Snake River at the Swan Falls project and the associated phosphorus load (lbs) reductions since 2012

Year	Truckloads	Load Reduction
2012	56	384
2013	227	1,557
2014	417	2,860
2015	308	2,112
2016	209	1,433
2017	136	933
	Average	1,547

7.2.1.2.3. Downstream Transport of Phosphorus

IPC evaluated TP data collected at 3 locations in proximity to the Swan Falls project from 2003 to 2006 to assess downstream transport of phosphorus to Brownlee Reservoir. Between-location TP concentrations were not statistically different within a year (Exhibit 7.2-8). While load data indicated minimal, if any, long-term storage of TP occurs, some level of short term storage and subsequent export is likely dictated by streamflow conditions. Naymik and Hoovestol (2008) reported when Swan Falls Reservoir inflow and outflow data were evaluated on an annual basis, TP was slightly retained in 2003 and 2004 (4% and 2%, respectively) with low streamflow. A small amount of export occurred in 2005 (6%) under conditions of slightly higher flows. Export was highest in 2006 (27%) and was associated with the highest annual flows among evaluated years. These findings are generally consistent with those reported in the literature. Wetzel (2001) reported that in a stream dominated by particulate phosphorus, no annual net retention of phosphorus occurred, but transport dynamics included short periods of storage with export occurring during pulses in streamflow. Similar findings representing differing stream types have been reported by others (Nyenje et al. 2014; Ensign et al. 2006). These findings support the concept that TP is functionally transported through the evaluated reach at about a 1:1 ratio on an annual basis even during low water years, when storage might otherwise be expected.

Given that Snake River hydraulics are similar between the evaluated reach and the reach downstream to Brownlee Reservoir, it is reasonable to suggest transport dynamics are similar as well and phosphorus reduction is functionally transported through the Snake River into Brownlee

Reservoir. Full implementation of the Grand View Sediment Reduction Program should provide assurance most of the benefit of the 12,060 lbs of phosphorus reduction is realized downstream. Similarly, IPC believes organic matter reduction and the resulting phosphorus reduction realized from aquatic vegetation and debris removal is functionally transported through the Snake River into Brownlee Reservoir.

7.2.1.3. Monitoring and Reporting

A detailed monitoring and reporting plan for the ROWQIP will be submitted to the ODEQ and IDEQ within 1 year of the new license issuance for the HCC. The monitoring and reporting plan will comply with all conditions and requirements contained in the CWA § 401 certifications issued by the ODEQ and IDEQ. The plan will be developed and incorporated into the ROWQIP to ensure a level of quality consistent with regional and national nutrient trading programs. Specifically, reports will be of sufficient quality to support the ODEQ and IDEQ’s determination of compliance with the HCC CWA § 401 certification requirements, as well as third-party verification, if required. The monitoring and reporting plan may be updated and modified over the course of the project based on technology advances. Any proposed changes will be identified in reports to the ODEQ and IDEQ and will be subject to their approval.

For the associated reasonable assurance measures of Grand View sediment and phosphorus reduction and Swan Falls vegetation removal, annual implementation will be tracked. For the Grand View Sediment Reduction Program, specific projects implemented and acreage treated will be tracked and reported annually.

7.2.1.4. Implementation Timeline

IPC began its participation with Riverside to reduce phosphorus loading to the Boise and Snake rivers in 2010. In 2014, IPC and Riverside signed a contract that identifies operational requirements for Riverside, to ensure the project is operated in a way that results in phosphorus load reductions. Since 2014 the operation of the ROWQIP has been ongoing and providing phosphorus reductions that are sufficient to meet the DO load allocation assigned to the transition zone and metalimnion of Brownlee Reservoir (exhibits 7.2-1, 7.2-6).

Grand View Sediment Reduction Program research projects were initiated in 2015 and have been completed on 14 projects totaling over 1,700 acres. Implementation is expected to continue with full implementation expected to occur within 10 years of HCC license issuance. Swan Falls Project Aquatic Vegetation and Debris Removal is ongoing and will be continued through the term of the new HCC FERC License.

7.2.1.5. Adaptive Management

Riverside will manage inflows to the Riverside Canal by preferentially using sources of water that contain relatively high phosphorus levels for irrigation purposes, resulting in phosphorus reductions to the Boise and Snake rivers, as well as Brownlee Reservoir. The operational plan outlined in this proposal is based on the current phosphorus conditions in each of the water sources. It is reasonable to assume that phosphorus levels in the source water being manipulated by the ROWQIP will change over the term of the HCC CWA § 401 certification. The overall goal of the project is to reduce phosphorus loading to the Snake and Boise rivers and Brownlee Reservoir though water management within Riverside’s water-delivery system. Therefore, it is an inherent part of this plan that actual operations and the manipulation of inflowing source water could substantially change in the future should the phosphorus levels substantially change in source water. As the project evolves, more effort will be focused on reducing agricultural runoff and additional water improvements that could be added to the load reductions produced through the ROWQIP. Additionally, the ROWQIP has the potential to generate further reductions with more refined canal operations and the installation of additional automations should future monitoring demonstrate adequate reductions are not being realized. Like any proposed changes in monitoring and reporting, proposed changes to operations or other management actions to reduce phosphorus loads would be included in the reports and subject to approval by the ODEQ and IDEQ.

7.2.2. Distributed Aeration Systems at Brownlee Powerhouse

IPC proposes upgrading 4 of the 5 turbines (i.e., units 1 through 4) at the Brownlee Powerhouse with distributed aeration systems. At the time of this submittal the upgrade on units 1 and 3 are complete and limited testing of the aeration system on Unit 1 is complete. These systems would be operated within an adaptive management and monitoring framework to add as much additional DO as possible to Brownlee outflow (and correspondingly Hells Canyon outflow, see Section 6.2 DO) on an overall annual average basis. This will address IPC’s proposed DO supplementation goal of 0.4 and 1.2 mg/L during the cool-water aquatic life and salmonid spawning period, respectively. This level of aeration offsets the current downstream DO deficits, incorporates reaeration that is occurring immediately downstream of HCD, addresses the uncertainty in the time frame for full upstream SR HC TMDL implementation and provides assurance that downstream standards will be met in the future. This level of aeration is likely to stay within the limitations of the current TDG criterion. IPC’s proposed operation plan for this DO addition is to add DO during the low DO periods of the aquatic life (April 15–October 22) and salmonid spawning (October 23–April 14) periods. To incorporate the low DO time for both periods, IPC’s proposed plan would provide this benefit when the incoming DO to Brownlee Powerhouse is less than the applicable criteria below HCD.

The proposed distributed aeration systems were designed and are being built by Voith Hydro, Inc., (Voith Hydro). Distributed aeration systems are specifically designed to add air into the draft tube using air passages that lead to the trailing edge of the runner blades. Therefore, the systems planned for the Brownlee units will require complete replacement of the runners, along with other systems, for each unit. The operating principles are very similar to forced-air injection (i.e., blowers), except the runners allow for passive-air introduction without the need for blowers. This passive air introduction is commonly referred to as auto-venting turbine aeration; however, the specific method of using the runner blades is referred to as distributed aeration. The efficiency losses for power production for auto-venting solutions are smaller than the blowers, and there is no need for a blower motor, associated power usage, or maintenance. Therefore, the operational costs of the proposed distributed aeration systems can be much less than forced-air injection. As with blower systems, there is the potential to elevate TDG with the distributed aeration. Because of the TDG limitation, blowers and distributed aeration will have nearly the same potential to increase DO. An analysis of potential TDG levels is included in this section. The configuration of units 1 through 4 at the Brownlee Powerhouse would allow distributed aeration installation. The configuration of unit 5 would not allow aerating runner installation unless a forced-air system was included.

Distributed aeration systems like those proposed at Brownlee Powerhouse are established technologies. Voith Hydro's research and development efforts have successfully developed and evaluated a variety of designs and methods for aeration. Voith Hydro's distributed aeration designs are in operation at the Tennessee Valley Authority's (TVA) Norris and Boone Powerhouses, Duke Power's Wateree plant, USACE's J. Strom Thurmond plant, Ameren's Osage plant, and Exelon's Conowingo plants.

7.2.2.1. Distributed Aeration Performance Modeling and Testing

Prior to upgrading and installing the aeration systems, IPC retained Voith Hydro, the manufacturer of the distributed aeration systems for Brownlee Powerhouse, to conduct a numerical modeling study to evaluate the potential DO uptake and resulting TDG levels associated with the operation of distributed aeration at Brownlee Powerhouse. The DO uptake and resulting TDG levels were estimated using a discrete bubble model methodology with Brownlee turbine draft tube geometry coupled with results from a Computational Fluid Dynamic (CFD) model to predict airflow rates through the system and into the water. The discrete bubble modeling incorporated the following variables that will control the overall DO benefit and corresponding TDG levels from distributed aeration through the Brownlee turbines: individual unit discharge, tailrace water-surface elevation (tailwater elevation), headwater surface elevation, water temperature, incoming DO concentration, incoming DN concentration, airflow rate (determined from the CFD model), and the size of air bubbles emitted. In the distributed aeration systems, the airflow rate will change along with unit discharge and also with manual adjustment to the air intake valves. In the modeling study, no manual adjustment was assumed, so the airflow produced by a given discharge represents the adjustable valves completely open. The results of the DO uptake modeling by Voith showed that during periods of high water temperature (i.e., 23°C) and low incoming DO (i.e., 2 mg/L or 0 mg/L), the uptake from aerating runners could range from 2.5 to over 4 mg/L (Exhibit 7.2-9).

Following the upgrade of Unit 1, 2 tests were completed (i.e., September and December 2017) on the performance of the aeration system for DO uptake and TDG increases. The tests were conducted by operating only Unit 1 (of units 1 through 4) and holding the discharge constant at 6 different settings (i.e., 3000, 3500, 4000, 4500, 5000, and 5500 cfs) for 80 minutes each. During the test, incoming DO and TDG was measured via Unit 1 penstock taps and tailrace DO and TDG measured via a buoy anchored in the tailrace. Airflow valve settings were varied during the September test but held constant at 100% open for the December test. DO uptake ranged from 1.5 to 2.3 mg/L, averaging 1.9 mg/L, over both tests when the airflow valves were 100% open. TDG increased from 9 to 18% saturation, averaging 13.8% saturation increase (Figure 7.2-3).

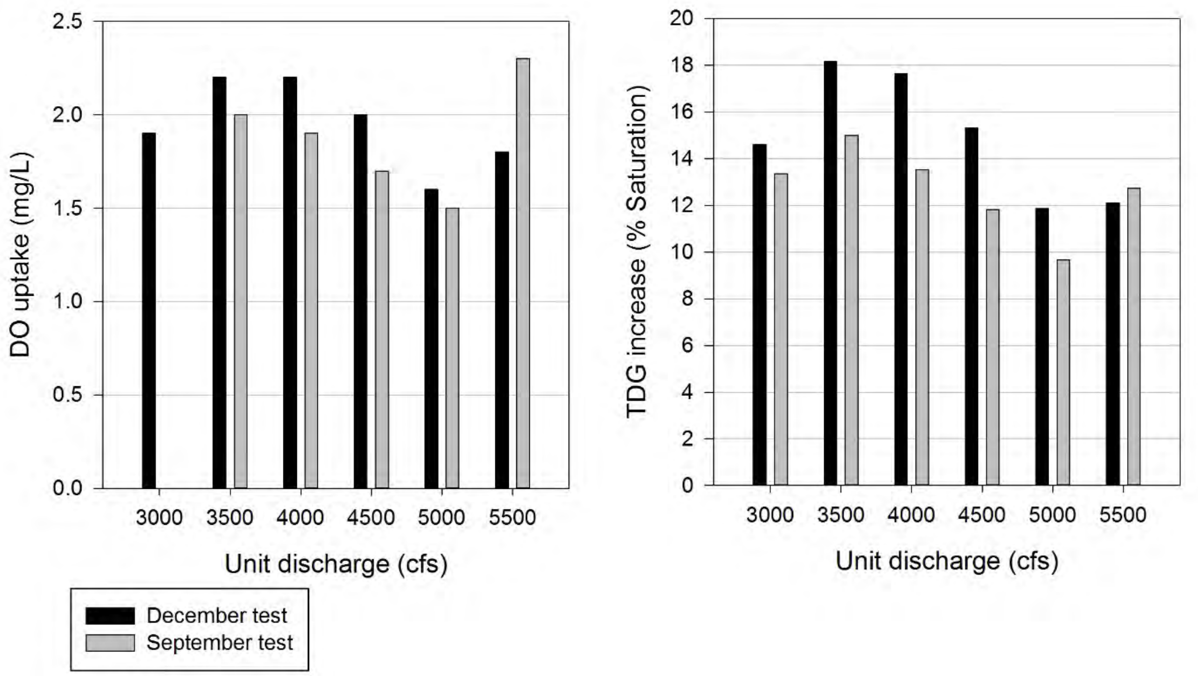

Figure 7.2-3
DO uptake and TDG increases measured during two tests of the aeration system conducted on the first turbine upgrade. Results shown are averaged over the period of time (20 minutes in September and 80 minutes in December) where turbine discharge and airflow settings were held constant.

7.2.2.2. Anticipated Effects of Distributed Aeration

The results of the testing described above were used to show the general potential of the planned distributed aeration systems at Brownlee Powerhouse taking into consideration variable operations of units 1-4 and Unit 5. Potential TDG increases were also evaluated. Many of the parameters known to be very dynamic in the field such as incoming DO, incoming TDG, incoming temperature, and tailwater elevation were not sufficiently captured in the limited testing. As a result, the testing to date provides in-the-field information as a starting point to examine the potential and limitations of the distributed aeration systems. However, the actual effects and limitations of the distributed aeration systems cannot be definitive until systems are installed on all 4 units, tested, operated and monitored. An adaptive management plan is outlined below including testing and monitoring as discussed in Section 7.2.2.3. Implementation Schedule and Monitoring Plan for Distributed Aeration Systems.

As mentioned previously, there are 5 units at Brownlee Powerhouse. Units 1 through 4 are all the same type of unit and are smaller (i.e., hydraulic capacity of approximately 5,500 cfs) than Unit 5 (i.e., hydraulic capacity of approximately 12,000 cfs). Unit operations at Brownlee are dependent on many factors (e.g., daily and seasonal load following, spinning reserves, system stability, and voltage support and water management), which result in multiple combinations of various units in operation over the course of a day (Figure 7.2-4).

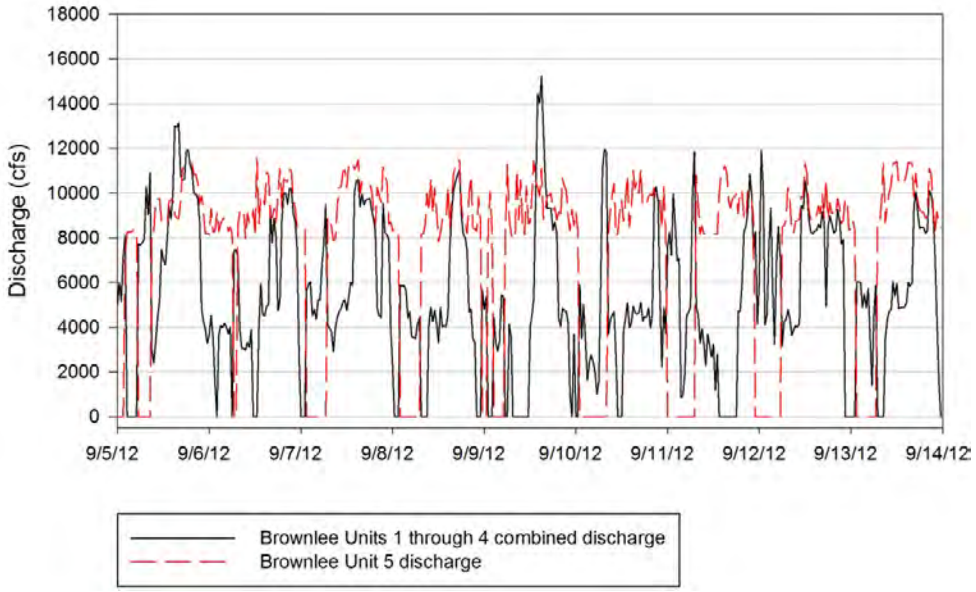

Figure 7.2-4
Brownlee Powerhouse units 1 through 4 combined and Unit 5 discharge over an 8-day period in September 2012. Hydraulic capacity of units 1 through 4 is approximately 5,500 cfs each, while Unit 5 hydraulic capacity is approximately 12,000 cfs.

IPC's distributed aeration proposal is planned to aerate the discharge from units 1 through 4 and not Unit 5. This means that 3 aeration and mixing scenarios will occur directly below Brownlee Powerhouse. When units 1 through 4 (in any combination) are operating alone, additional oxygen would be added to the entire discharge. At times when all units are operating, the additional DO added to discharge from units 1 through 4 would be mixing with the non-aerated (i.e., no additional oxygen added) discharge from Unit 5. Finally, at times when only Unit 5 is operating, there would be no additional oxygen added to the discharge. This condition when Unit 5 is operating alone historically occurs relatively infrequently through the course of a day and not for an entire day or multiple days in a row (figures 7.2-4 and 7.2-5). When Unit 5 is operating, it is typically in the range of 9,000 to 12,000 cfs. The testing results combined with simple mixing scenarios show that during times when Unit 5 is not operating, a mixed condition downstream in Oxbow could be aerated by approximately 1.9 mg/L on average and TDG may exceed 110%. When Unit 5 is operating, a mixed condition downstream in Oxbow would be aerated at levels ranging from approximately 0.3 to 1.2 mg/L depending on the combination of discharge from units 1 through 4 and Unit 5. All or any of the example combinations shown in Figure 7.2-6 can occur at the Brownlee Powerhouse over the course of a day on a very short time step (hourly).

Recent historic operations (2011, 2012 and 2013) were summarized and combined with the aeration testing results to estimate the potential overall annual average DO uptake during the cool-water aquatic life and salmonid spawning periods that could result from IPCs proposal. First, an average mixed DO uptake was calculated for the condition when all units were operating by using the fraction of time observed in each year for various flow combinations of units 1 through 4 and Unit 5. Second, over the cool-water aquatic life and salmonid spawning periods, the fraction of time when all units, only units 1 through 4 and only Unit 5 was determined. The fractions of time were then combined with the mixed DO uptake when both units 1-4 and Unit 5 were operating and DO uptake for only units 1 through 4 (1.9 mg/L) to show overall annual average DO uptake at Brownlee Powerhouse could range from 0.9 to 1.1 mg/L during the cool-water aquatic life period and 1.1 to 1.4 mg/L during the salmonid spawning period (Table 7.2-4).

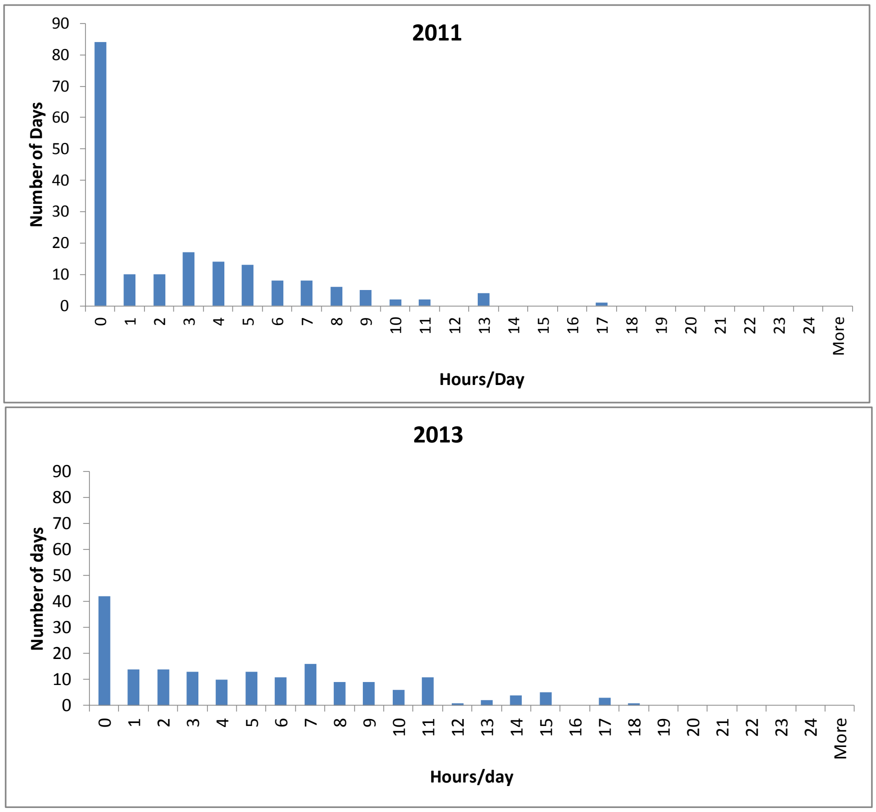

Figure 7.2-5
Frequency distribution showing how often Brownlee Powerhouse Unit 5 is operating by itself over the July 1 through December 31 period in 2011 (higher water year) and 2013 (lower water year)

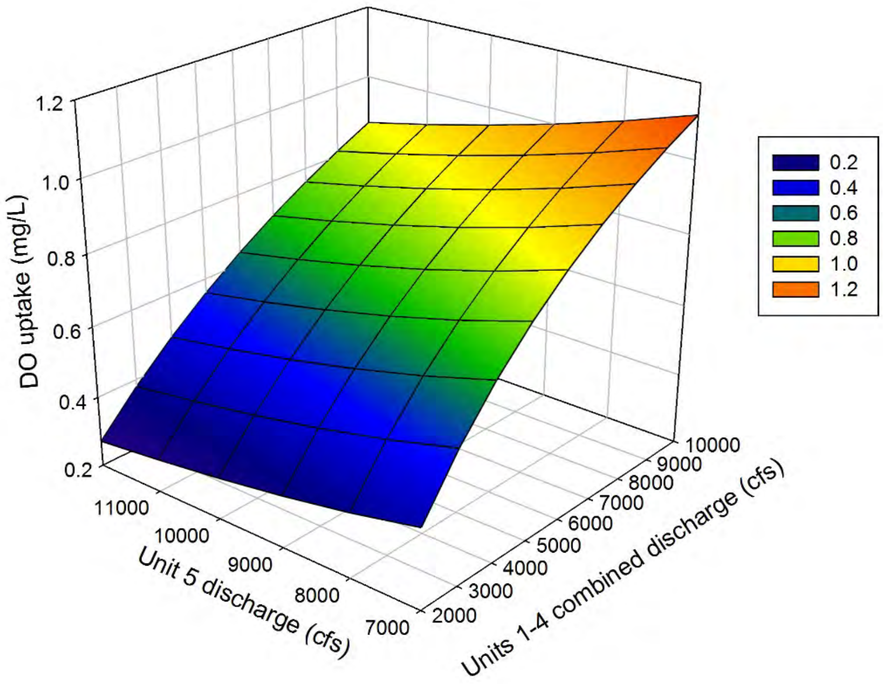

Figure 7.2-6
Simple mixing calculations combining the results of Unit 1 testing with historical operating ranges for units 1 through 4 and unit 5. The discharge ranges and combinations represent approximately 90% of the time when both units are operating at Brownlee. The DO uptake results represent a well-mixed downstream condition based on Unit 1 testing conducted in 2017.

Table 7.2-4
Ranges of estimated annual average DO uptake and TDG increase at the Brownlee Powerhouse over the cool-water aquatic life and salmonid spawning portions of the low DO period (i.e., July 1 through December 31). Fraction of time operating is based on historic operations during 2011, 2012, and 2013.

Brownlee Powerhouse Unit Combinations	Fraction of Time Operating	Estimated DO Uptake (mg/L)	Estimated TDG Increase (% Saturation)
Cool-water aquatic life			
Unit 5 only	0.09 – 0.20	0.0	0.0
Units 1–4 only	0.08 – 0.46	1.9	13.8
All Units	0.32 – 0.83	0.70 – 0.90	5.2 – 6.3
Annual Time Weighted Average		**0.9 – 1.1**	**6.3 – 8.2**
Salmonid spawning			
Unit 5 only	0.13 – 0.21	0.0	0.0
Units 1–4 only	0.38 – 0.61	1.9	13.8
All Units	0.17 – 0.47	0.7	4.8 – 5.3
Annual Time Weighted Average		**1.1 – 1.4**	**7.7 – 9.9**

7.2.2.3. Implementation Schedule and Monitoring Plan for Distributed Aeration Systems

Planning, contracting, and modeling phases of the distributed aeration system installation project are completed, and detailed schedules are continually being developed and updated. The runner fabrication by Voith Hydro and the installation at Brownlee Powerhouse are large efforts that will require each unit to be taken off line sequentially. Multiple units cannot be off-line at the same time. The detailed schedule currently includes the following milestones:

Design engineering, physical modeling, and materials acquisition—Completed

- Unit 1 runner fabrication—Completed
- Unit 1 runner delivery to site—Completed
- Unit 1 installation complete—Completed
- Unit 3 installation complete—Completed
- Unit 4 installation complete—Fall 2018
- Unit 2 installation complete—Fall 2019

IPC will work with the ODEQ and IDEQ as part of the § 401 certification to develop a monitoring and adaptive management plan for the distributed aeration systems. The overall outline of this plan includes a testing phase and compliance monitoring phase. The goal of the testing phase will be to test the effectiveness of the systems as was done for Unit 1 in 2017. The goal of the compliance monitoring phase will be to monitor and report DO uptake and TDG increase on an annual average basis during the cool-water aquatic life and salmonid spawning period separately at the Brownlee Powerhouse.

Testing will be conducted throughout the sequential installation of each new system on units 1 through 4. The complete installation of all 4 units is planned to be completed in by 2020.

Annual reports will be presented to and discussed with the DEQs. These reports will include:

- Updates on the implementation schedule progress
- Results of the testing phase, including:
    - Conclusions as to whether or not the installed units appear to be meeting expectations.
    - Recommendation on long-term downstream monitoring locations and frequency
- Discussion of issues or concerns and recommendations on adaptive management steps.

7.2.2.4. Adaptive Management for the Distributed Aeration Systems

The testing and analysis conducted to date provides reasonable assurance that the aeration systems will be capable of adding the proposed minimum requirements of 0.4 and 1.2 mg/L during the cool-water aquatic life and salmonid spawning period, respectively at the Brownlee Powerhouse. IPC is proposing to monitor aeration performance through the licensing term. The data and information will be used to develop and implement accepted adaptive management principles to ensure that the measures adequately meet IPC's compliance obligations.

Further, in the unlikely situation that issues are identified through the testing phase, or thereafter, relative to future compliance, IPC will develop and consider alternatives and discuss them with the DEQs. The need to identify and consider these issues as implementation of the measures proceed, arises from the ubiquitous concern of applying results of limited testing to dynamic in-field installations. Although the testing conducted thus far on Unit 1and the application of the results to historical IPC data represents the best information at this time, there is still a need to evaluate these measures as they are implemented. Among the issues that could potentially arise, and potential adaptive management measures to address them, are the following:

- If an issue concerning the ability to meet the anticipated DO uptake on an annual average basis arises IPC could:
    - Explore the feasibility of a blower designed for aeration on Unit 5 to increase uptake at Brownlee Powerhouse
    - Explore the feasibility of aeration systems at Hells Canyon and/or Oxbow powerhouses
- If an issue concerning the ability to meet the anticipated efficiency of DO uptake without exceeding the TDG criteria of 110% in a mixed downstream condition arises IPC could:
    - Implement biological monitoring to determine if effects are being seen from any of TDG increases from the aeration systems.
    - Explore the feasibility of applying for a TDG standard modification.
- If an issue concerning a loss in electric generation efficiency from aeration that is larger than expected or other unanticipated issues with unit performance or operation arises, IPC could:
    - Explore the feasibility of a blower designed for aeration on Unit 5 to reduce aeration in units 1 through 4.
    - Explore the feasibility of aeration systems at Oxbow and/or Hells Canyon powerhouses to reduce the aeration needed at Brownlee units 1 through 4.

7.2.3. Destratification Measure for the Oxbow Bypass

IPC proposes to install and operate a destratification system in the Oxbow Bypass. This system would be installed in the deep pool just upstream of the Indian Creek confluence. The pool is a section of the Oxbow Bypass inaccessible by road (Figure 7.2-7). Thermal stratification in the deep pool causes anoxic conditions to develop in the deeper water. Mixing to prevent anoxic conditions will provide improved habitat for aquatic life. The goal of this measure is to introduce oxygen using diffused air bubbles to prevent the development of anoxic conditions in the deep pool.

7.2.3.1. Description

Destratification systems are common throughout the U.S., and several manufacturers offer various configurations and models. At least 2 manufacturers offer designs that are all-inclusive, self-contained mixing units (water is mixed using a propeller in the water column) powered by wind and/or solar energy. These units are anchored in the water over the location to be mixed. There is a risk of damage to the units from high flows through the bypass during periodic spill events if they are not removed from the water. The units are large, heavy, and awkward to move, making temporary removal difficult.

Several manufacturers offer systems that use an air compressor stationed on the shore that pumps air through a pipe to bubble diffusers anchored on the channel bottom. As the bubbles rise through the water column, they entrain water and lift it to a higher elevation. These types of systems are more suitable for the deep pool because they would be somewhat resistant to high spill flows. Also, if the piping or diffusers are damaged during spill, replacement efforts and expenses would be lower.

7.2.3.1.1. Proposed Design

IPC contracted with Mobley Engineering, Inc., to determine the optimal flow rate needed to keep the pool mixed throughout the summer. Knowing the flow rate helps determine the size of the compressor and diffuser required. Based on an estimation of the deep-pool volume, a flow rate of about 6 cfs is needed to exchange all of the water in the pool once every 8 hours. With this flow rate, all the water volume within the pool would be exchanged about 3 times a day. IPC believes this will be a sufficient flow rate to prevent thermal stratification.

IPC will develop a final design of a compressor system appropriate to prevent anoxia. The final design will include siting, power supply, and other necessary components. The operational plan will depend on the final design; however, the goal of the plan will be to operate the system as needed to prevent anoxia.

7.2.3.1.2. Implementation Schedule and Monitoring Plan

The final design and permitting process for the Oxbow Bypass destratification system will begin in the first year following new license issuance.

The installation of the Oxbow Bypass deep-pool destratification system will be completed, and operation will begin within 2 years after new license issuance, provided the required permits and approvals can be obtained in this period.

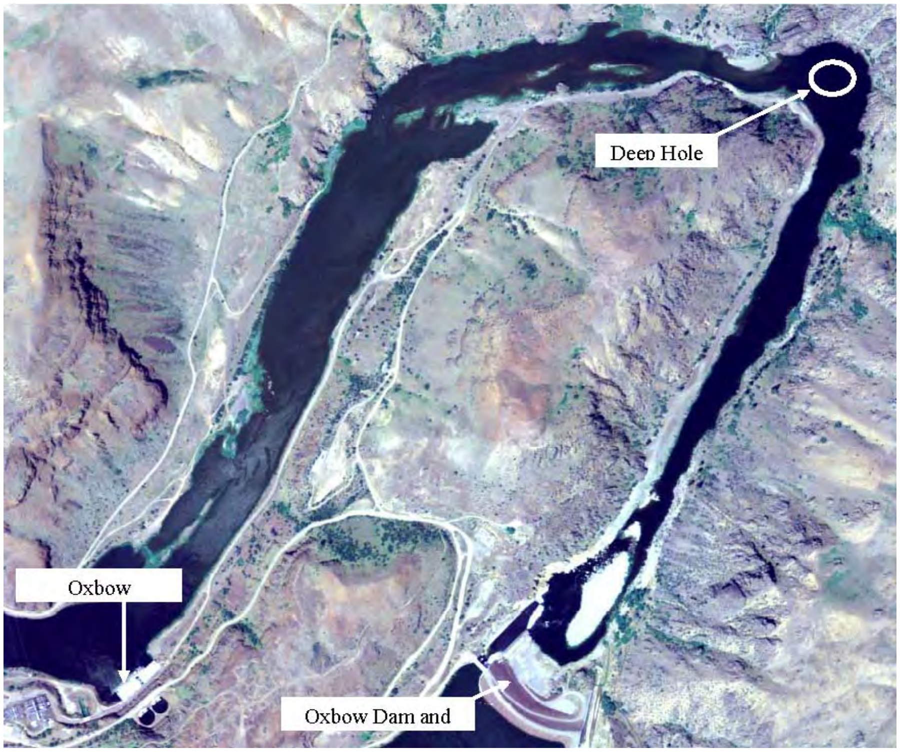

Figure 7.2-7
Aerial photograph and description of the Oxbow Bypass reach and deep pool

7.3. TDG Adaptive Management Plan

The TDG adaptive management plan includes PME measures that research shows to be the best available technologies to reduce TDG levels. These include 1) the continued preferential spilling of water through the Brownlee Dam upper spill gates as an early implementation measure, 2) the installation of HCD sluiceway flow deflectors, 3) the installation of Brownlee Dam spillway flow deflectors, and 4) the installation of a spillway flow deflector at Oxbow Dam.

IPC will monitor TDG levels below spillways and at other locations throughout the HCC and Snake River downstream, as needed, for PME measure effectiveness and compliance relative to the criterion. The specific locations of data collection will be determined in consultation with the ODEQ and IDEQ (see Section 7.3.4. TDG Monitoring). If monitoring indicates the PME measures fail to meet the TDG criterion and protect aquatic life, IPC will adaptively manage TDG in the HCC through the evaluation and implementation of additional PME measures designed to further reduce TDG levels. IPC concurs with the IDEQ and ODEQ (2004) that the TDG criterion is conservative for the protection of aquatic life and, therefore, the load allocation has an implicit margin of safety.

7.3.1. TDG Proposed Measures

7.3.1.1. Preferential Brownlee Dam Upper Gate Spill

IPC proposes to continue the current practice of preferentially spilling water from the Brownlee Dam upper spillway gates. IPC proposes this PME measure as part of the early implementation of CWA § 401 certification.

7.3.1.2. HCD Sluiceway Flow Deflectors

7.3.1.2.1. Proposed Action

IPC proposes to install HCD sluiceway flow deflectors to address the SR–HC TMDL TDG load allocation at HCD and protect aquatic life. Implementation will occur consistent with the schedule in the new FERC HCC license. This schedule would accommodate FERC's required design review process and permitting requirements. It is expected these requirements could be completed within 2 years of the new license issuance. The construction and installation of the flow deflectors would be completed during the following 2 years.

7.3.1.2.2. Proposed Design

The Iowa Institute of Hydraulic Research[48] (IIHR), under contract with IPC, investigated the applicability of flow deflectors at HCD to reduce TDG levels. The distinctive geometry of HCD presents challenges in developing flow deflectors to reduce TDG levels because of the existing upper-nappe deflectors, relatively large head, deep and short stilling basin, and high unit flow (Exhibit 7.3-1). Specifically, flows originating from the upper spillway gates are deflected away from the concrete spillway surface by the nappe deflectors, and the flow becomes a nearly unattached, free-falling jet. Very large deflectors for the upper spillway gates would be needed because the falling jet would overshoot smaller deflectors. When large deflectors were tested in a 1:48-scale, 3-dimensional physical model (figures 7.3-1 and 7.3-2), the deflected flows impacted the riverbed downstream of the stilling basin, which could compromise dam safety during the passage of large spillway flows.

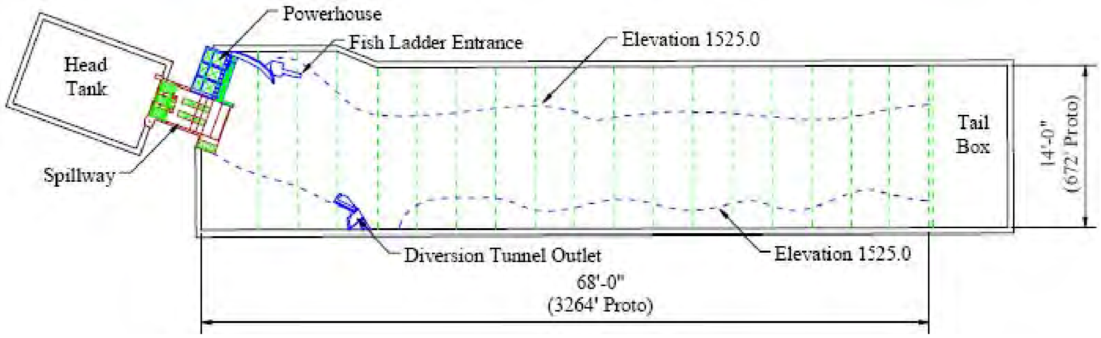

Figure 7.3-1
Plan view of the 1:48-scale, 3-dimensional HCD physical model

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[48] The IIHR recently changed its name. Its current name is the Iowa Institute of Hydraulic Research—Hydroscience and Engineering.

Figure 7.3-2
Photograph of the 1:48-scale, 3-dimensional HCD physical model

The unique geometry of HCD favors the implementation of flow deflectors in the 2 lower-level sluiceways. The concept of flow-deflector design is to favor a flow regime that minimizes air entrainment at depth. As such, flow-deflector elevation is critical. The flow-deflector elevation was determined by analyzing tailwater curves for Snake River flow at or below a design discharge of 60,000 cfs[49] (Exhibit 7.3-1). This accounts for most of the flows recorded from 1968 through 2003 (Figure 6.3-8). The design must remain below the tailwater elevation to prevent vented surface or plunging flows from occurring, which tend to allow air bubbles to penetrate to depth while remaining high enough to keep the performance within the surface-jet flow regime (Figure 7.3-3). The flow-deflector design was qualitatively optimized using a 1:48-scale, 3-dimensional physical model (figures 7.3-1 and 7.3-2). The design consists of a 16-foot deflector at an elevation of 1,468 feet msl with a 5° lip angle (Figure 7.3-4). This design resulted in a surface jet up to total Snake River flow of 60,000 cfs. More detail on the HCD sluiceway flow-deflector design is available in Exhibit 7.3-1.

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[49] The HCD design discharge of 60,000 cfs was based on 3 powerhouse units, each with a hydraulic capacity of 10,000 cfs, and 2 sluiceway bays, each with a hydraulic capacity of 15,000 cfs.

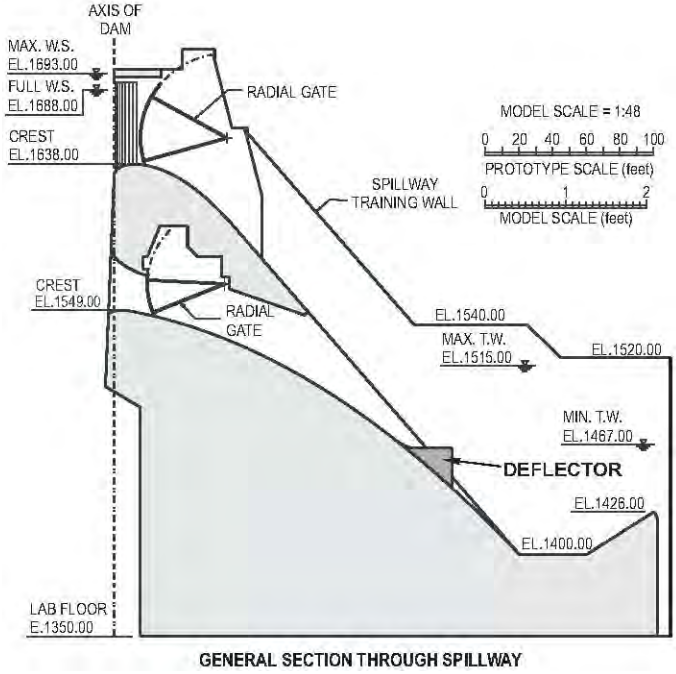

Figure 7.3-3
Sectional view of the HCD model constructed by the IIHR showing the general location of sluiceway flow deflectors

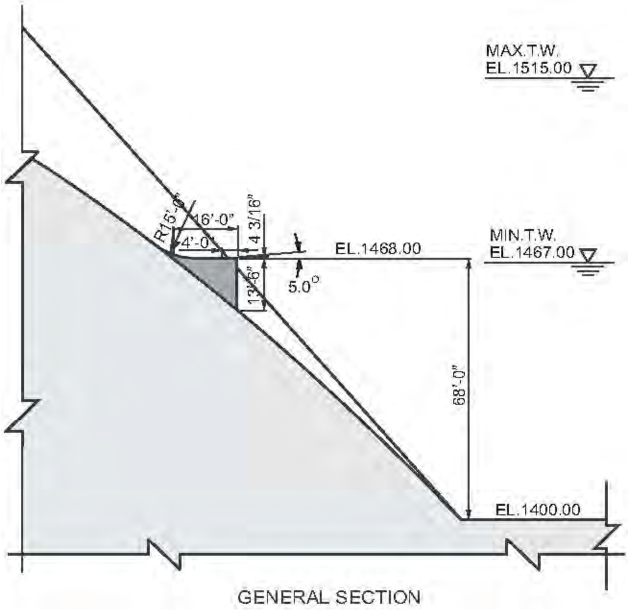

Figure 7.3-4
General view of the HCD sluiceway flow-deflector configuration developed by the IIHR

The IIHR investigated the deflector air entrainment performance and tailrace erosion potential of the qualitatively designed sluiceway flow deflectors. The 3-dimensional physical modeling revealed that the deflector air entrainment performance was preserved when the tailrace bathymetry was incorporated. The sluiceway flow-deflector design did not increase the erosion potential at the probable maximum flood (PMF) design level of 300,000 cfs Snake River flow when compared to spill operations without deflectors. In fact, the 3-dimensional physical model predicted a decrease in scour depths under the design discharge of 60,000 cfs with deflectors installed. More detail on the HCD sluiceway flow-deflector design downstream hydrodynamics and erosion potential is available in Exhibit 7.3-2.

The sluiceway flow-deflector design was qualitatively optimized to be effective at reducing TDG levels at a design flow of 60,000 cfs. Approximately 1% of flows are greater than 60,000 cfs and less than the 7Q10 average flood flow of 71,498 cfs. There remained uncertainty as to the performance of the qualitatively designed sluiceway flow deflector and how a quantitatively optimized flow-deflector design would perform across these higher but very infrequent flows. To address this uncertainty, the IIHR quantitatively optimized the final HCD sluiceway flow-deflector design based on computations using a 3-dimensional finite element CFD model (Exhibit 7.3-3). The CFD model quantitatively evaluates TDG levels based on dam geometry, bathymetry, gas-bubble diffusivity, and fluid dynamics. The IIHR evaluated 3 additional geometries with a modified elevation, length, and transition radius for 2 flows representing potential operations: 25,000 cfs and 45,000 cfs[50]. This evaluation confirmed the qualitatively designed sluiceway flow-deflector design performed better to reduce TDG and had less impact on the tailrace flow pattern. This design was then evaluated at 3 flows inclusive of the 7Q10 average flood flow. The 7Q10 average flood flow requires any flow greater than the combined powerhouse and sluiceway hydraulic capacity of 60,000 cfs to be spilled through the upper spillway gates, plunging downstream of the stilling basin with appreciable TDG production. When large deflectors capable of accommodating spill from the upper spillway gates were tested in a 1:48-scale, 3-dimensional physical model (Exhibit 7.3-2), the deflected flows impacted the riverbed downstream of the stilling basin, which could compromise dam safety during the passage of large spillway flows. The HCD sluiceway flow deflectors still reduced TDG production by approximately 10% at the 7Q10 average flood flow. More detail on the HCD sluiceway flow-deflector design performance and TDG production is available in Exhibit 7.3-3.

7.3.1.3. Brownlee Dam Spillway Flow Deflectors

7.3.1.3.1. Proposed Action

IPC proposes to install Brownlee Dam spillway flow deflectors to address the SR–HC TMDL TDG load allocation at Brownlee Dam and protect aquatic life. Implementation will occur consistent with the schedule in the new FERC HCC license. This schedule will accommodate FERC’s required design review process and permitting requirements. It is expected that construction and installation could be completed within 2 years of construction of the HCD sluiceway flow deflectors. It may be necessary to monitor the effectiveness of the installed HCD sluiceway flow deflectors before developing a CFD model to quantitatively optimize the Brownlee Dam spillway flow-deflector final design. Any delay in the schedule will be vetted with the ODEQ and IDEQ for their approval and submitted to FERC for approval. Until the

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[50] The discharge rates included 7,500 cfs through each of 2 sluiceway bays, with a hydraulic capacity of 15,000 cfs. Therefore, the 25,000 cfs included 1 powerhouse unit, and the 45,000 cfs flow represented full generation capacity.

deflectors are installed, IPC will preferentially spill from the Brownlee Dam upper spillway gates as an early implementation PME measure.

7.3.1.3.2. Proposed Design

Similar to the HCD deflectors, the IIHR, under contract with IPC, investigated the applicability of flow deflectors at Brownlee Dam to reduce TDG levels (exhibits 7.3-4 and 7.3-5). IPC identified, prior to physical modeling, a concern relative to downstream scour following the installation of deflectors. This concern was not only for dam safety but was also identified as having the potential to disrupt power distribution and public transportation. As such, the Brownlee Dam 1:48-scale, 3-dimensional model (figures 7.3-5 and 7.3-6) included not only the spillway section of the dam but also the powerhouse units, training walls, earthen embankments, and 2,900 prototype feet of downstream tailrace bathymetry. The latter 2 elements were included to evaluate scour resulting from a geometric spillway change. While scaled laboratory model tests do not necessarily replicate field results, the comparison was useful in evaluating either a worsening or lessening of scour effects.

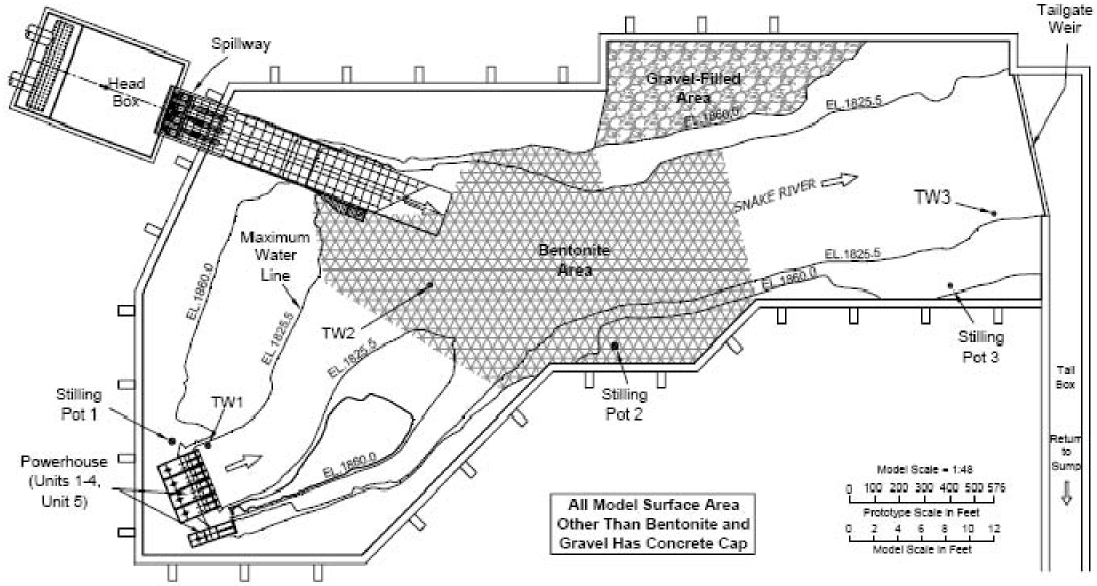


Figure 7.3-5
Plan view of the 1:48-scale, 3-dimensional Brownlee Dam physical model (reproduced from Exhibit 7.3-5)

Figure 7.3-6
Photograph of the 1:48-scale, 3-dimensional Brownlee Dam physical model

Flow-deflector elevation is also critical to the Brownlee Dam deflector design. The Brownlee Dam spillway flow-deflector elevation was determined by analyzing tailwater curves for the Snake River. The elevation was determined based on tailwater flow up to the 7Q10 average flood flow of 67,898 cfs. The qualitatively optimized Brownlee Dam spillway flow deflectors resulted in an observed skimming surface-jet flow regime. The flow-deflector design consists of an 18-foot-long deflector at an elevation of 1,800 feet msl (Figure 7.3-7). More detail on the design of Brownlee Dam spillway flow deflectors is available in Exhibit 7.3-4. Erosion tests were performed with and without the proposed deflector design affixed to the 3-dimensional model. Each test was run with 48 hours of continuous model operation at both the 7Q10 average flood flow and the PMF. No scour occurred anywhere in the erodible materials at the 7Q10 average flood flow (Exhibit 7.3-4). Significant scour was observed in the erodible materials downstream of the spillway, as well as the formation of gravel bars in the tailrace at the PMF, both with and without the proposed deflector design affixed to the model. The model indicates erosion due to sustained PMF causes tremendous erosion downstream of the Brownlee Dam spillway with or without deflectors. During the PMF, the deflectors are overridden and the spillway jet resubmerges, dissipating energy in the stilling basin. The deflector appeared to cause no significant difference in tailrace erosion and does not significantly affect scour downstream of the spillway at the PMF. More detail on the erosion potential of Brownlee Dam spillway flow deflectors is available in Exhibit 7.3-5.

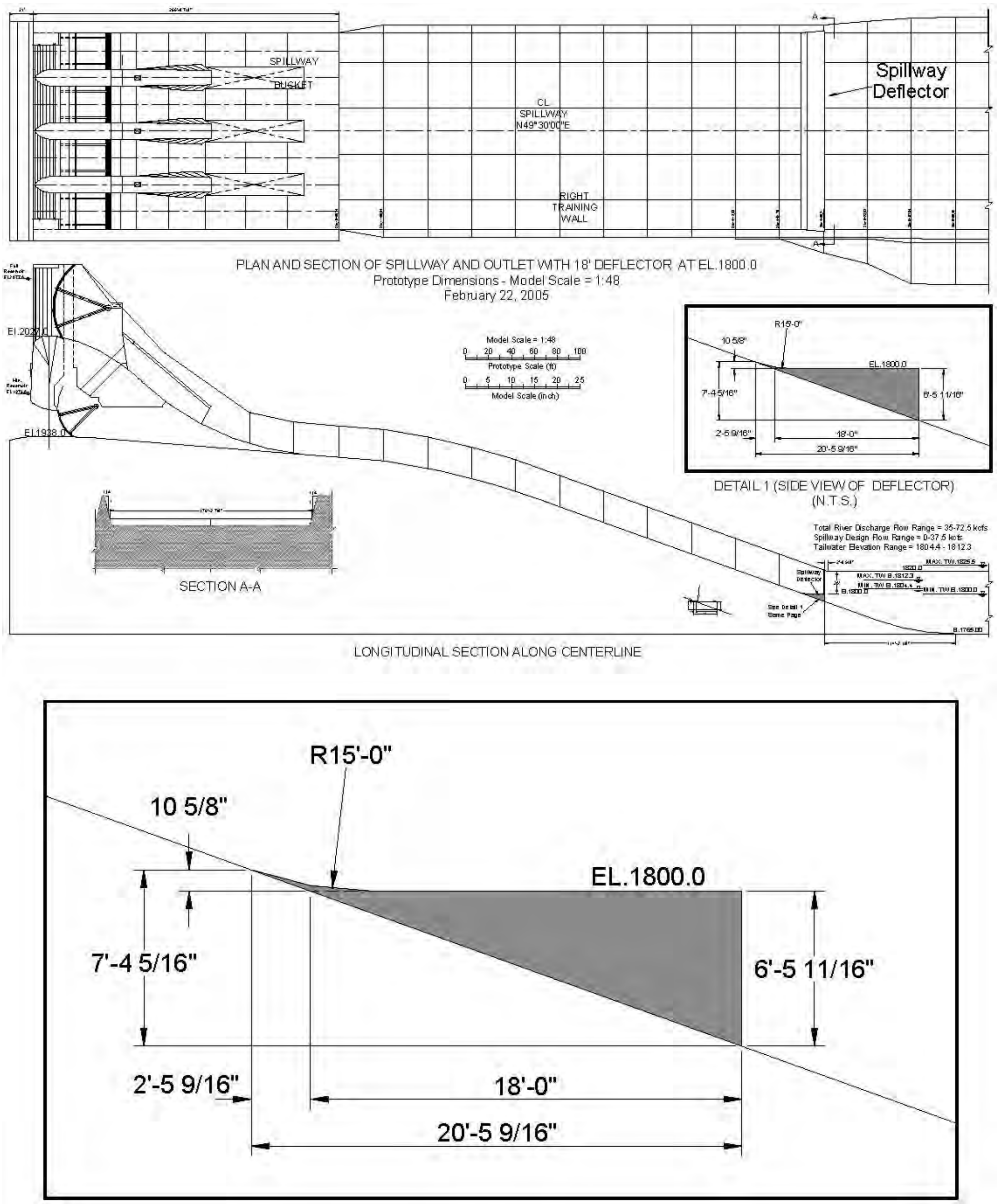


Figure 7.3-7
Plan and sectional view showing the general location of the Brownlee Dam spillway flow deflectors and a detailed sectional view drawing of the proposed design (reproduced from Exhibit 7.3-4)

The Brownlee Dam spillway flow-deflector design was qualitatively optimized to be effective at reducing TDG levels at the 7Q10 average flood flow. IPC proposes the final flow-deflector design to be quantitatively optimized and mathematically evaluated to the 7Q10 average flood flow based on computations using a CFD model and information gained from applying a similar model to optimize deflector design at HCD (Exhibit 7.3-3).

7.3.1.4. Oxbow Dam Spillway Flow Deflector

7.3.1.4.1. Proposed Action

The SR–HC TMDL identified Brownlee Dam and HCD as the sources of elevated TDG in the HCC (IDEQ and ODEQ 2004). Since approval of the SR–HC TMDL, IPC has had the opportunity to collect new information that allowed the evaluation of spill at Oxbow Dam independent of Brownlee Dam spill (i.e., when Oxbow Reservoir forebay TDG levels were less than 110% of saturation). These data showed that when the Oxbow Reservoir forebay was below 110% of saturation, spill at Oxbow Dam increased TDG levels above the criterion in the bypassed reach (Figure 6.3-4).

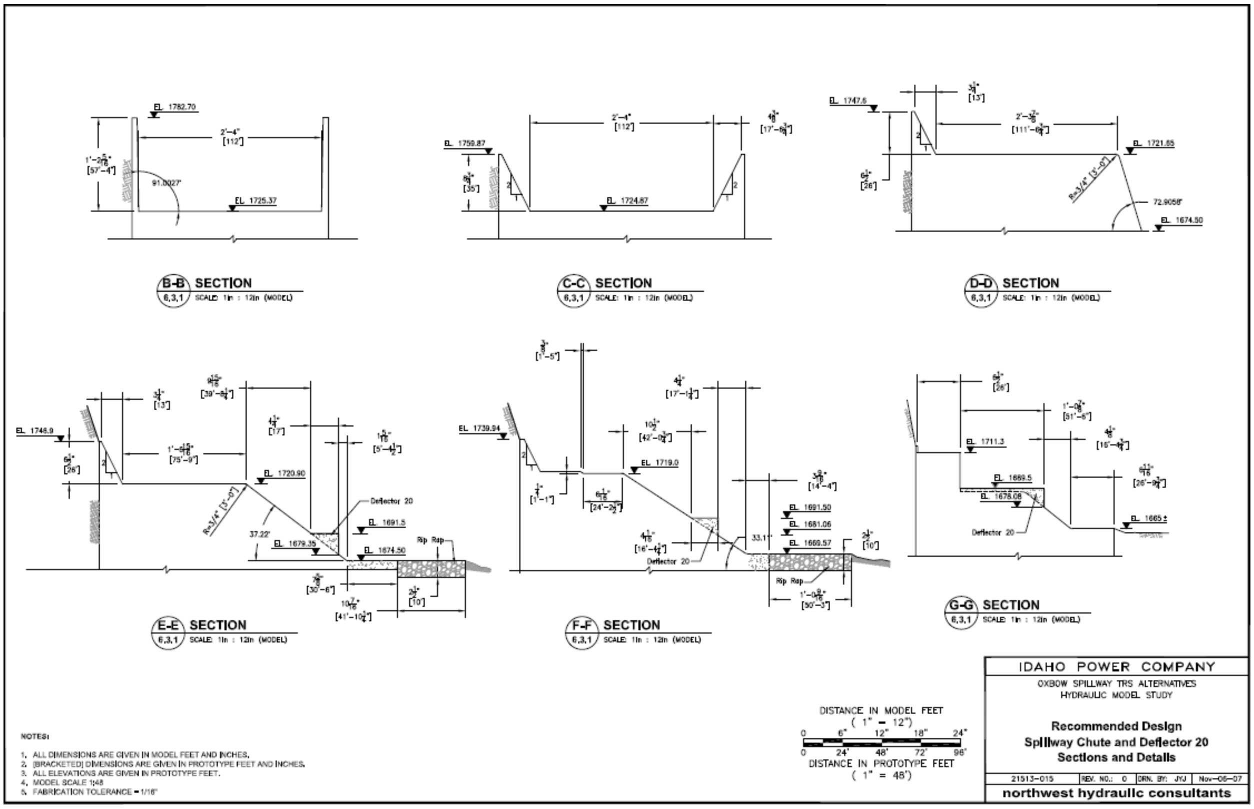
Oxbow Dam is unique in that there are 2 spillways: the principal spillway along the Oregon side of the Snake River (Oxbow Dam spillway) and an emergency spillway along the Idaho side. IPC proposes to install an Oxbow Dam spillway flow deflector to reduce TDG levels and protect aquatic life. Implementation will occur consistent with the schedule in the new FERC HCC license. This schedule will accommodate FERC's required design review process and permitting requirements. It is expected that construction and installation could be completed within 2 years of construction of the Brownlee Dam spillway flow deflectors. It may be necessary to monitor the effectiveness of the installed Hells Canyon and Brownlee dam flow deflectors before developing a CFD model to mathematically optimize the Oxbow Dam spillway flow-deflector final design. Any delay in the schedule will be vetted with the ODEQ and IDEQ for their approval and submitted to FERC for approval.

7.3.1.4.2. Proposed Design

The Northwest Hydraulic Consultants (NHC), under contract with IPC, evaluated TDG reduction structures at Oxbow Dam relative to the potential for reducing TDG levels. The distinctive geometry of the Oxbow Dam spillway presents challenges in developing structures to reduce TDG levels. Spill flows down a chute contained by training walls for a distance of 374 feet, at which point the right (east) side training wall terminates, allowing water to spill off the right side of the chute down a steeply sloping concrete face onto a concrete bench directing flow across the channel (Figure 7.3-8). The chute ends with an asymmetrical apron that generally directs spill in a downstream direction.

Figure 7.3-8
Photograph of Oxbow Dam principle spillway chute and asymmetrical spill apron (reproduced from Exhibit 7.3-6)

The NHC developed a hydraulic model to evaluate potential Oxbow Dam TDG reduction structures. Initial results indicated that a flow deflector on the sloping face at the downstream end of the existing spillway chute had sufficient potential to provide a flow regime conducive to reducing TDG levels (Exhibit 7.3-6). The conceptual design for a spillway flow deflector was developed after evaluating approximately 24 geometric refinements. The proposed Oxbow Dam spillway flow-deflector design is located along the entire side and end-sloping faces of the downstream end of the existing spillway chute (Figure 7.3-9). The flow deflector along the east side of the spillway chute has a length of about 250 feet, a width in the direction of flow of 16 feet, and an elevation of 1,691.5 feet msl. The end deflector has a length in the direction of flow of 40 feet, a width of 49 feet, and an elevation of 1,689.5 feet msl. The proposed design also incorporates a 50-foot training wall on the west side that extends downstream from the end of the spillway chute, the removal of an existing concrete fillet on the west side of the existing bench at the downstream end of the spillway chute, and the placement of an approximately 10-foot blanket thickness by a 40- to 50-foot width of riprap along the upstream 250-foot length of the east side of the spillway chute (Figure 7.3-10). IPC proposes the final Oxbow Dam spillway flow-deflector design will be quantitatively optimized and mathematically evaluated to the 7Q10 average flood flow, based on computations using a CFD model and information gained from applying a similar model to optimize deflector design at Hells Canyon and Brownlee dams. More detail on the Oxbow Dam spillway flow-deflector design is available in Exhibit 7.3-6.



NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
2. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET AND INCHES.
3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
4. MODEL SCALE 1:48
5. FABRICATION TOLERANCE = 1/16"

Figure 7.3-9
Plan and sectional view showing the general location of the Oxbow Dam spillway flow deflector and a detailed sectional view drawing of the proposed design (reproduced from Exhibit 7.3-6)

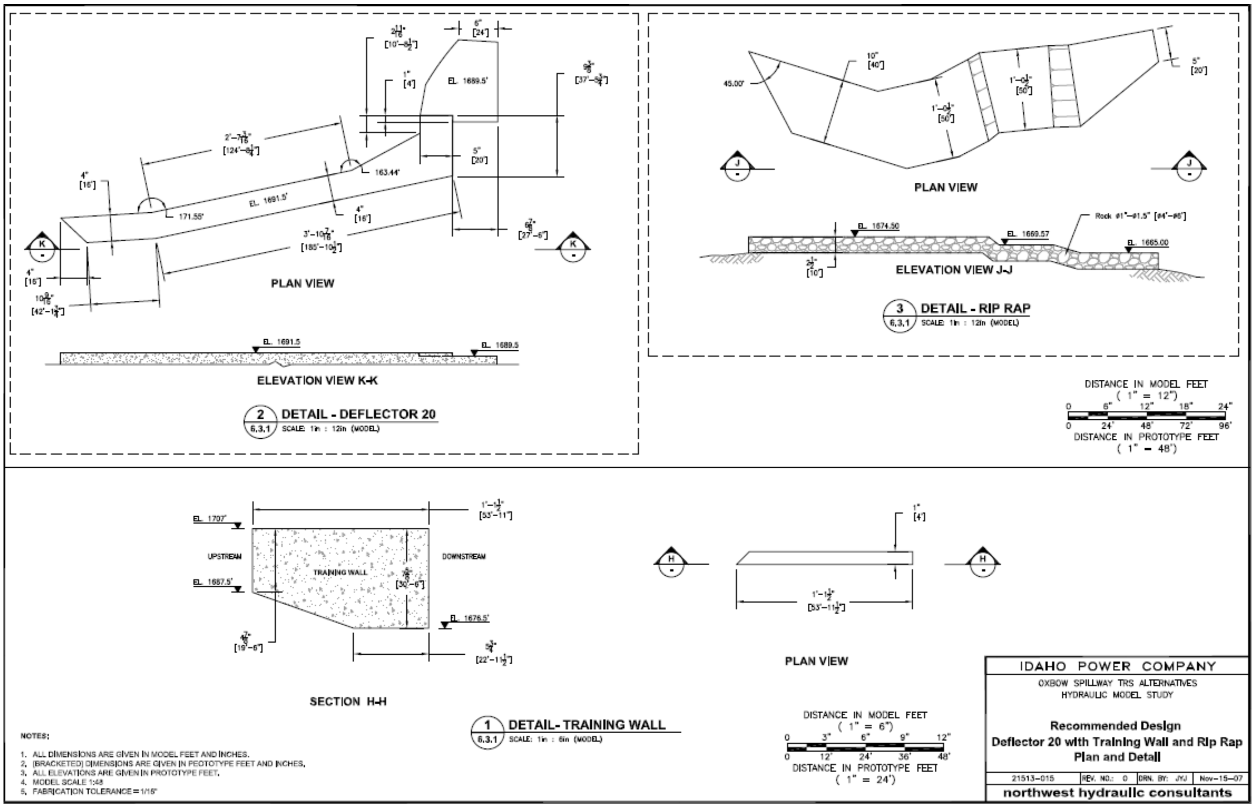


Figure 7.3-10
Plan and sectional view showing the general location of the Oxbow Dam spillway training wall and riprap and a detailed sectional view drawing of the proposed design (reproduced from Exhibit 7.3-6)

7.3.2. TDG Adaptive Measures

IPC proposes preferentially spilling water from the Brownlee Dam upper spillway gates and installing HCD sluiceway flow deflectors, Brownlee Dam spillway flow deflectors, and an Oxbow Dam spillway flow deflector as PME measures to address the SR–HC TMDL TDG load allocation and protect aquatic life. These are the best available technologies, but their performance cannot be definitively evaluated using models alone. Because the performance of these measures must be predicted either qualitatively or quantitatively, IPC proposes monitoring their effectiveness and implementing an adaptive management approach to address any potential uncertainties.

IPC concurs with the IDEQ and ODEQ (2004) that the TDG criterion is conservative for the protection of aquatic life and, therefore, the load allocation has an implicit margin of safety. If monitoring during spill indicates these PME measures fail to meet the TDG criterion and protect aquatic life, IPC will adaptively manage TDG in the HCC through the evaluation and implementation of additional PME measures designed to further reduce TDG levels.

Several additional PME measures are available for evaluation if the proposed PME measures fail to meet the TDG criterion and protect aquatic life. These include, but are not limited to, the following. Any PME measure may not necessarily be a viable measure at a particular project due to site-specific characteristics.

- **Modify the shape or location of the flow deflectors after installation to further optimize performance.** A prior knowledge of deflector performance to attain the 110% of saturation criterion is difficult with exact certainty using modeling alone. Once the deflectors are installed, it may be feasible to further investigate their performance and determine if field modifications can be made toward improvement. Some possible modifications include changing the angle of the deflector, increasing the deflector length, or slightly changing the deflector's elevation.

- **Modify or extend the training walls.** It may be feasible to extend training walls to better separate turbine and spill flows, reducing the volume of turbine flow entrained in the spill flow. This would reduce the overall volume of water that has elevated TDG levels.

    - Physical modeling of Brownlee Dam indicated turbine flow overtops the existing training wall and becomes entrained into the spillway during high spill flows (Exhibit 7.3-5). It would be possible to increase the height of this wall to preclude turbine flows from becoming entrained with the spill flows, improving the spillway flow deflectors' effectiveness.

- **Refurbish or add 1 or more units to allow for increased powerhouse hydraulic capacity.** Increasing the capacity would allow more flow to travel through the powerhouse instead of over the spillway, potentially reducing TDG levels and definitely reducing the volume of water with elevated TDG levels.

- **Modify the stilling basin or spillway apron to reduce the depth bubbles plunge.** It may be possible to modify the depth or shape of the stilling basin to reduce the depth bubbles can plunge, therefore reducing TDG levels. Some of the possible modifications may include adding concrete to the stilling basin to reduce the bottom depth, adding some type of underwater wig-walls or floors, or changing the shape of the apron lip to deflect flow upward.

- **Build an off-gassing structure downstream of the spillway.** Off-gassing structures are typically small weirs allowing for a short free fall of water and are typically constructed across the width of the river channel. These structures create conditions for the turbulent exchange of gas between the water and the atmosphere. This allows supersaturated water with high TDG levels to off-gas.

- **Construct a bypass conveyance to pass spill flows.** Water could be passed through a conveyance instead of over the spillway, and TDG levels or the volume of elevated TDG level water would be reduced.

7.3.3. TDG Reasonable Assurance

7.3.3.1. Preferential Brownlee Dam Upper Gate Spill

Spill test data were collected at Brownlee Dam during a single test conducted on June 4, 1998. The test was conducted while spilling water at 39,000 cfs, an amount greater than the 7Q10 average flood flow of 67,898 cfs when combined with the powerhouse hydraulic capacity.

An analysis of these data indicated TDG levels from the Brownlee Dam upper gate spill were statistically lower (P = <0.001) when compared to TDG levels from the lower gate spill. Figure 7.3-11 shows that TDG levels downstream of Brownlee Dam averaged 114% of saturation while spilling from the upper gates and increased during transition to spilling through the lower gates, resulting in an average TDG level of approximately 128% of saturation (Myers and Parkinson 2003).

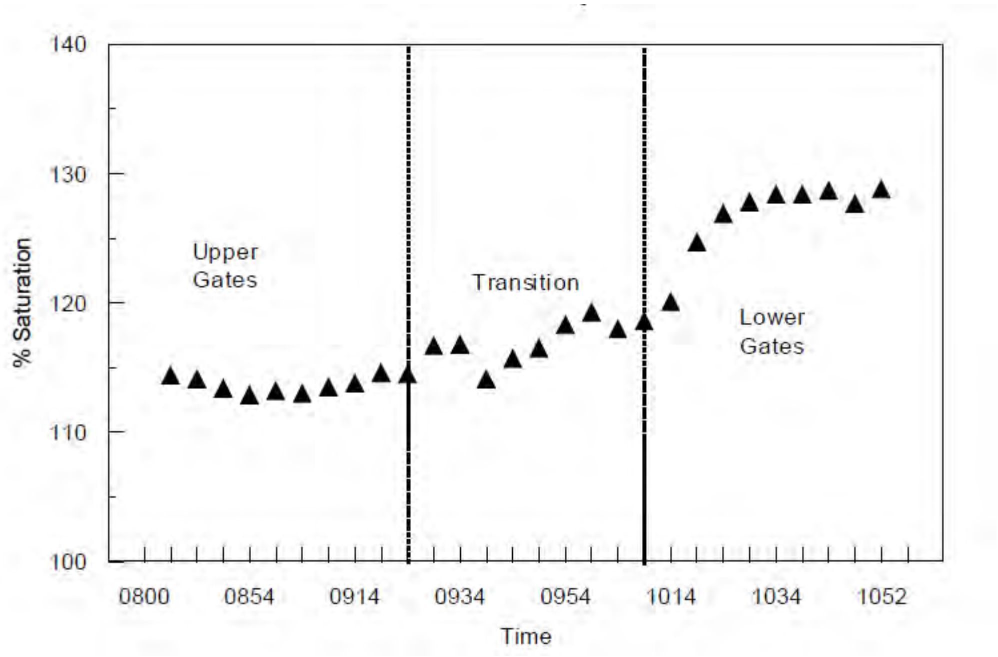


Figure 7.3-11
Measured TDG percent of saturation below Brownlee Dam during the operation of the upper and lower spillgates at 39,000 cfs

IPC's evaluation of Brownlee Dam spill test data indicated that upper gate spill resulted in lower TDG levels. IPC does not contend this preferential spill alone will attain the SR–HC TMDL load allocation; however, this measure will minimize TDG levels to the extent possible until spillway flow deflectors are installed at Brownlee Dam. Further, IPC contends that TDG levels of 114% of saturation, as measured from the upper gate spill greater than the 7Q10 average flood flow, will not have a discernible effect on aquatic life. This is supported by IPC's recent monitoring of resident fish in the HCC (Exhibit 6.3-1) and corroborated by McGrath et al. (2006) and Weitkamp (2008). All researchers reported the conclusion that short-term exposure up to 120% of saturation does not produce significant effects on resident and migratory fish when compensating depths are available.

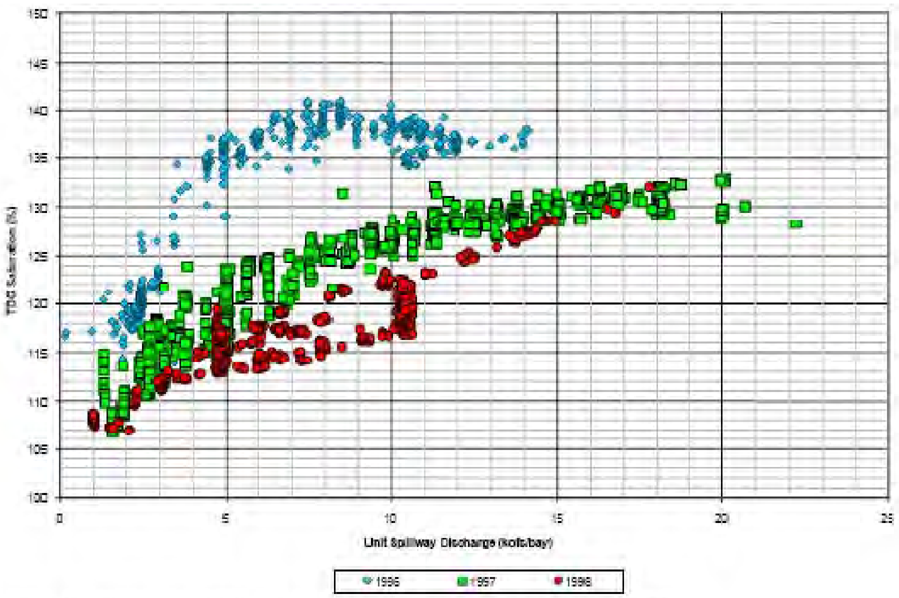
7.3.3.2. HCC Flow Deflectors

Flow deflectors are the best available technology for reducing elevated TDG levels at hydroelectric projects in the Northwest. The USACE has performed most of the research relevant to flow-deflector design, physical model studies, and initial prototype testing. The USACE evaluated numerous alternatives and concluded the best options to reduce TDG levels are to structurally modify the dam to either reduce the volume of air entrained in the water column or to reduce the hydrostatic pressures that act on entrained air by keeping entrained air near the surface (Weber et al. 2000).

The USACE evaluated several alternatives for reducing the volume of air entrained in the water column, including creating submerged spillway conduits, constructing powerhouse and spillway separation walls (training walls), converting turbines to sluices, modifying existing powerhouses to act as hydro-combine powerhouses, using submerged pressure conduits with slots, using flow through existing skeleton bays, and constructing additional powerhouse units. Each of these alternatives reduces TDG levels by preventing spilled water from contacting air. With the exception of submerged spillway conduits, each alternative adds increased structural and fish safety concerns and has significant construction costs.

The USACE also evaluated alternatives to reduce the maximum hydrostatic pressures that act on entrained air, including raising the tailrace channel and raising the stilling basin to develop surface-oriented flow. Generally, altering the tailrace channel or stilling basin involves significantly more effort and cost than implementing flow deflectors to reduce hydrostatic pressures on entrained air. Alternatives that combine the principles of reducing air volume and hydrostatic pressures include spillway deflectors, baffled-chute spillways, side-channel spillways, pool and weir channels, additional spillway bays, new spillway-gate types or openings, and v-shaped spillways. The USACE concluded the 3 most feasible alternatives for most large river dams are 1) submerged spillway conduits, 2) spillway deflectors, and 3) new spillway-gate types or openings. Of these alternatives, the installation of spillway deflectors appears the best available technology for most dams.

As a result of this type of analysis, the USACE has installed flow deflectors on many of the Lower Snake and Columbia River projects. The USACE designs deflectors for a dual purpose—to reduce TDG levels while balancing anadromous smolt passage survival rates. Because of this dual purpose, the USACE often receives waivers to exceed the 110% of saturation criterion for voluntary spill up to 120% of saturation. Likewise, TDG levels measured after the installation of flow deflectors may not represent the optimized effectiveness if only the reduction of TDG levels is the goal. At Ice Harbor Dam on the Lower Snake River, the USACE has measured TDG levels of 140% of saturation prior to the installation of flow deflectors and 130% of saturation after installation (Figure 7.3-12).



Note: No deflectors in 1996, 4 of 10 installed in 1997, 8 of 10 installed in 1998.

Figure 7.3-12
Measured TDG percent of saturation below Ice Harbor Dam, 1996–1998, with and without flow deflectors (USACE 2002)

The IIHR has evaluated flow deflectors for Rock Island Dam and Wanapum Dam, located in Grant County, Washington. Wanapum Dam, a Grant County (Washington) Public Utility District project, has had several prototype spillway deflectors installed. These data provide reasonable assurance that the 110% of saturation criterion can be met using a deflector design that results in a surface jet. The first 2 designs, a deep horizontal deflector and a deep sloping deflector, did not function optimally to meet objectives of reducing TDG levels (Table 7.3-1). The deep sloping design appears to have no observable effect on reducing TDG levels. The next iteration in Wanapum Dam deflector design was a shallow horizontal deflector. This design functioned optimally to meet objectives of reducing TDG levels (Table 7.3-2). TDG levels measured in spill from bays without deflectors reached nearly 130% of saturation (Figure 7.3-13). These levels are comparable to TDG levels measured below projects in the HCC. The shallow horizontal deflector design reduced TDG levels to the criterion of 110% of saturation or less. The proposed HCC flow-deflector designs are comparable to the Wanapum Dam shallow horizontal design.

Table 7.3-1
TDG percent of saturation levels at Wanapum Dam, Grant County, Washington, in 1998 (Weitkamp and Hagen 1999a). The 10-year, 7-day (7Q10) average flood flow is 12,916 cfs per spillway (Jeske 1999).

The Wanapum Dam Powerhouse has the ability to increase flow passage, which would decrease the 7Q10 average flood flow to 8,333 cfs per bay.

Spillbay	Deflector Design	Flow (cfs)	TDG (%)
2	Deep horizontal	2,800	108–109
		6,000	109
		11,300	114–116
3	None	2,800	123–125
		6,000	128–129
		11,300	123–124
4	Deep sloping	2,800	121–122
		6,000	127–128
		11,300	122–123
5	None	6,000	123–124
		6,000	123–125

Table 7.3-2
TDG percent of saturation levels at Wanapum Dam, Grant County, Washington, in 1999 (Weitkamp and Hagen 1999b). The 10-year, 7-day (7Q10) average flood flow is 12,916 cfs per spillway (Jeske 1999). The Wanapum Dam Powerhouse has the ability to increase flow passage, which would decrease the 7Q10 average flood flow to 8,333 cfs per bay.

Spillbay	Deflector Design	Flow (cfs)	TDG (%)
2	Deep horizontal	2,800	—
		6,000	107–108
		7,500	108–110
3	None	2,800	121–122
		6,000	127–128
		7,500	—
5	Shallow horizontal	2,800	103–105
		2,800	105–106
		6,000	108–109
		6,000	108–109
		6,000	107
		7,500	109–110
		7,500	109–110

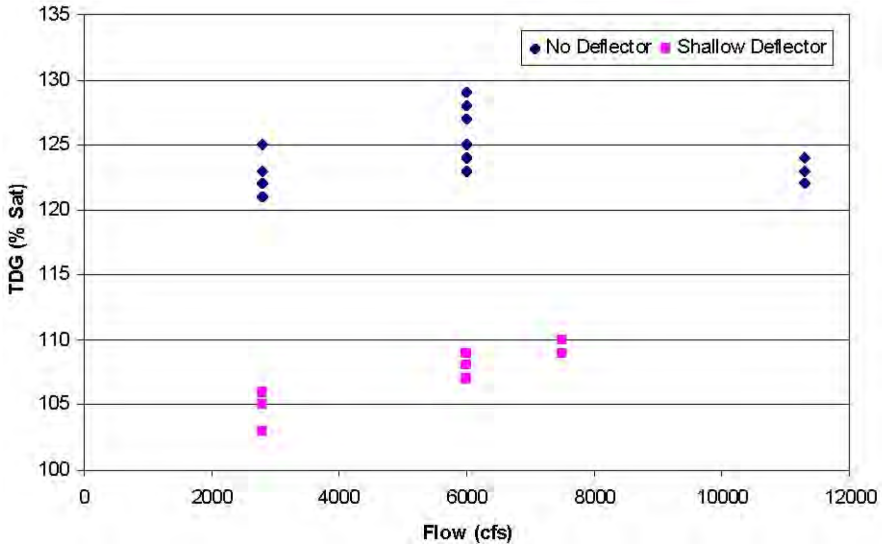


Figure 7.3-13
TDG percent of saturation (% Sat) at Wanapum Dam, Grant County, Washington, with no spillway deflector and a shallow horizontal design deflector at various flow in cfs (Weitkamp and Hagen 1999a,b)

The IIHR 3-dimensional models for HCD and Brownlee Dam were developed to qualitatively optimize flow-deflector designs to minimize air bubbles at depth (Figure 7.3-14). Currently, physical or mathematical models do not exist to conclusively predict TDG levels prior to the installation of flow deflectors. Analytical tools have recently been developed and are continually being improved to better model potential future TDG levels, but these tools have had limited field application. One such model is the IIHR CFD model, which has only been applied to Wanapum Dam but with promising results. While a CFD model will be used to optimize the final design of the HCC flow deflectors to address the TDG criterion, the only definitive way to demonstrate compliance with the 110% of saturation criterion is to implement the PME measures and monitor TDG levels during spill.

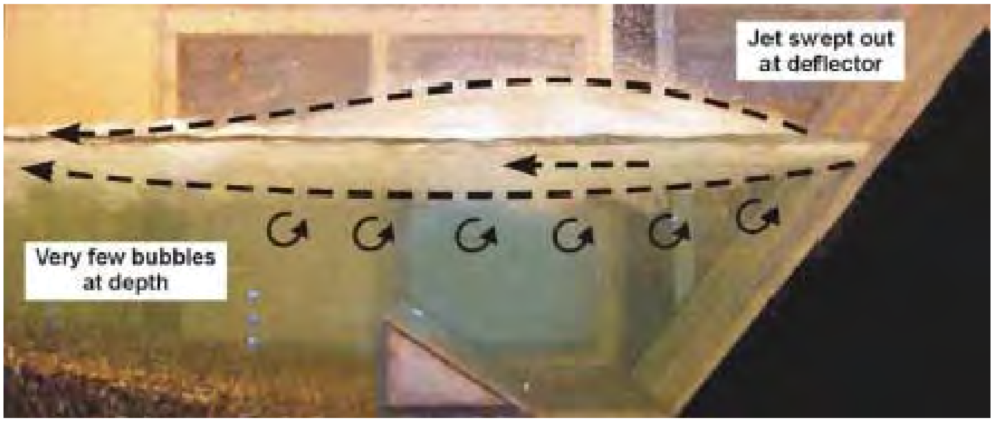


Figure 7.3-14
Sectional view photograph of a surface-jet flow regime expected from the HCD sluiceway and Brownlee Dam spillway flow-deflector designs (Weber 2005). Note the lack of observed air bubbles at depth, either in the stilling basin or downstream.

7.3.4. TDG Monitoring

As described in the SR–HC TMDL, IPC will work with the ODEQ and IDEQ as part of the HCC CWA § 401 certification to develop a TDG monitoring plan with specific compliance locations and protocol for monitoring (IDEQ and ODEQ 2004). The plan will include specific locations to define the edge of the aerated zone below each project for determining compliance with IPC's SR–HC TMDL TDG load allocation and to protect aquatic life, and a specific methodology for monitoring during spill, including equipment and the need to evaluate adaptive PME measures. Additional monitoring may be needed to collect data necessary to run a CFD model to finalize flow-deflector designs. IPC will coordinate with the ODEQ and IDEQ, as much as practicable, to develop these methods.

7.3.5. TDG Adaptive Management Schedule

Spilling at the HCC projects is almost exclusively involuntary, occurring usually as a result of flood-control constraints or high-runoff events (IDEQ and ODEQ 2004). Spilling typically occurs for short periods in higher water years when Snake River flows exceed the project's flood storage capacity, as mandated by the USACE, or the hydraulic capacity of generation turbines. Other unusual situations, including emergencies or unexpected unit outages, can induce a spill episode at any of the projects. As such, IPC is compliant with the TDG criterion and, therefore, the load allocation, in all but higher water years when spill occurs. In addition, the IDEQ and ODEQ (2004) concluded the TDG criterion is conservative for the protection of aquatic life; therefore, the load allocation has an implicit margin of safety.

IPC proposes the following schedule for the implementation of proposed PME measures. This schedule allows IPC to address the SR–HC TMDL TDG load allocations as soon as practicable based on water years for which IPC has responsibility associated with spill. There may be a need to monitor the effectiveness of PME measures prior to the final design and the implementation of successive PME measures. Monitoring must occur during higher water years when spill occurs. Monitoring will be limited to no more than 1 year before the next step is initiated. Any delay in the schedule will be vetted with the ODEQ and IDEQ for their approval and submitted to FERC for approval.

- Continue preferential spill from the Brownlee Dam upper spillway gates. This PME measure is currently in practice and will continue as part of the early implementation of CWA § 401 certification.

- Monitor during spill events, when necessary, to provide data for the CFD model development and use in the final design of PME measures as part of the early implementation of CWA § 401 certification.

- Complete the final engineering design of the HCD sluiceway flow deflectors, based on the final CFD model design, within 1 year following the issuance of the new HCC FERC license.

- Construct and install the HCD sluiceway flow deflectors consistent with the schedule in the new HCC FERC license that incorporates FERC's required design review process and permitting requirements. It is expected these requirements could be completed within 1 to 2 years after the new license issuance. The construction and installation would occur serially during the following 2 years, likely due to ESA considerations and potential power outages. This tentatively schedules operational HCD sluiceway flow deflectors following the fourth year after the new license issuance.

- Optimize the Brownlee Dam spillway flow deflectors, based on a CFD model, evaluate performance to the 7Q10 average flood flow, and complete the final engineering design within 1 year of initiating the construction and installation of the HCD sluiceway flow deflectors. It may be necessary to monitor the effectiveness of the HCD sluiceway flow deflectors before developing a CFD model to optimize the Brownlee Dam spillway flow-deflector final design.
- Construct and install the Brownlee Dam spillway flow deflectors consistent with the schedule in the new HCC FERC license that incorporates FERC’s required design review process. This tentatively schedules operational Brownlee Dam spillway flow deflectors following the sixth year after the new license issuance. Until the flow deflectors are installed, IPC will preferentially spill from the Brownlee Dam upper spillway gates as an early implementation PME measure.
- Optimize the Oxbow Dam spillway flow deflector based on a CFD model; evaluate performance to the 7Q10 average flood flow; and complete the final engineering design within 1 year of initiating the construction and installation of the Brownlee Dam spillway flow deflectors. Since Brownlee Dam TDG levels influence Oxbow Dam TDG levels, it may be necessary to monitor the effectiveness of the Brownlee Dam spillway flow deflectors before developing a CFD model to optimize the Oxbow Dam spillway flow-deflector final design to more accurately understand the dynamics of the effects of Brownlee Dam on Oxbow Dam TDG levels.
- Construct and install the Oxbow Dam spillway flow deflector consistent with the schedule in the new HCC FERC license that incorporates FERC’s required design review process. This tentatively schedules the operational Oxbow Dam spillway flow deflector following the ninth year after the new license issuance. Conduct monitoring to determine if the TDG criterion is met at the edge of the aerated zone below each project and aquatic life is protected. If monitoring indicates TDG levels do not meet the criterion and protect aquatic life with the above measures implemented, adaptive steps (as described in Section 7.3.2. TDG Adaptive Measures) will be evaluated and implemented.

7.4. HAB Proposed Measures

Some blue-green algae are referred to as toxigenic, and there is the potential for exposure to HAB-related toxins during recreational activities in the HCC. Assessing the potential for the development of harmful cyanobacterial blooms and the risk posed by toxic cyanobacteria, and linking this to effective measures for the protection of public health, is complex. IPC proposes HAB monitoring in the HCC. The goal is to provide the OPHD and IDHW information for HAB-related public-health action.

7.4.1. HAB Monitoring Plan

IPC will work with the ODEQ and IDEQ as part of the HCC CWA § 401 certification to develop a HAB monitoring plan. The plan will include monitoring protocol, sampling locations and sampling frequencies, as well as specific reporting requirements to the OPHD and IDHW, including any additional sampling following the issuance of public health advisories.

Monitoring should focus primarily on the protection of human health and secondarily on the health of pets and livestock. Visual assessment is an important tool in recognizing the potential for the development of HABs. Monitoring will, at a minimum, consist of periodic visual assessments of HAB status, such as areas of discoloration or surface scum collection, during peak recreational periods. Figure 7.4-1 provides an index of recreational use throughout the HCC in 2013. IPC will photo-document potential HABs and, as needed, collect surface grabs when a potential HAB (e.g., surface scum) is encountered for species identification and enumeration and testing for relevant toxins. IPC will notify the OPHD and IDHW of any potential HAB and provide the monitoring results.

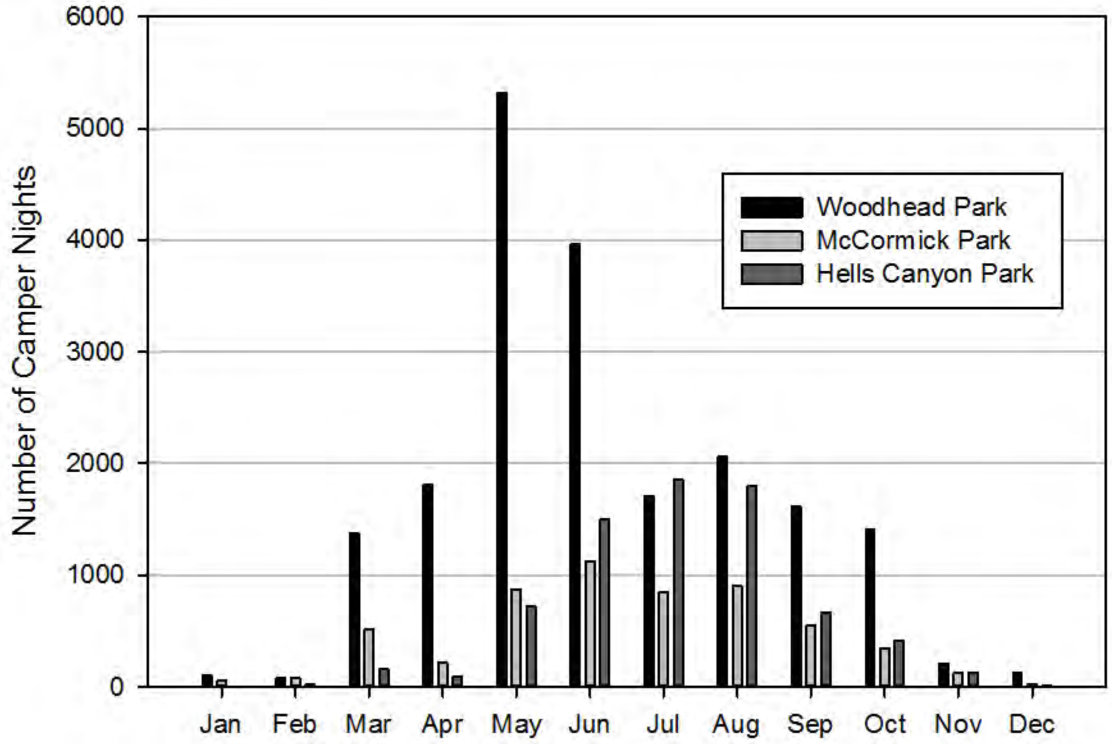


Figure 7.4-1
Index of recreational use in the HCC during 2013

IPC also proposes to adaptively manage HAB monitoring in the HCC. IPC may evaluate large geographic surveillance and alert methods to identify blooms as they develop allowing for early public alerts. IPC will evaluate monitoring results after 5 years and may request the modification or termination of some or all the monitoring described in the HAB monitoring plan.

7.4.2. HAB Implementation Schedule

IPC proposes to finalize a monitoring plan within 1 year of initiation of consultation. The monitoring plan will be filed immediately following the issuance of the new HCC license from FERC for approval. Monitoring for HABs will begin immediately following FERC approval.

7.5. Biocriteria Proposed Measures

The biocriteria standard provides that all waters are to be "of sufficient quality to support aquatic species without detrimental changes in the residential communities" (OAR 340-041-0011). This general standard is addressed through each of the more-specific numeric criteria, targets, and allocations that support and enhance beneficial uses related to aquatic species. In addition to the specific measures targeted at meeting water-quality numeric standards included in this application, several measures are being developed outside of this 401 certification process that are designed to support and enhance specific components of habitats related to the resident biological communities and native fish assemblage consistent with elements of the biocriteria standard. Many of these measures were proposed in the license application for the HCC and have been included as a part of the staff recommendations in the FEIS completed by the FERC in 2007 (FERC 2007). Various measures related to species listed under the ESA have also been further refined and developed through informal consultation with state and federal fishery managers. These measures are summarized below and IPC expects the measures will be incorporated, as license articles, into the HCC license. As such, the measures should be recognized as reasonable assurance relative to compliance with the biocriteria standard.

7.5.1. Stranding and Entrapment

IPC has developed a *Stranding and Entrapment Plan* (Brink and Chandler 2011) related to concerns of operational impacts to bull trout and juvenile anadromous salmonids, especially SRFC, downstream of HCD. The primary operational concern was related to the current 1-foot-per-hour ramp rate below HCD as part of the proposed operations. The specific concern related to bull trout was the potential of stranding sub-adult and adult bull trout as they use habitats below HCD during the winter months and experience fluctuating flows relative to HCC operations. IPC, in close coordination with the FWS, conducted stranding bar surveys during the winter months between 2005 and 2012 to look for evidence of bull trout stranding during periods of down ramping. During this period, IPC found no evidence of bull trout stranding and, in general, found very few fish being stranded. Based on these findings, the FWS no longer considers stranding related to the 1-foot-per-hour ramp rate a significant risk to bull trout. This finding could be expanded to other fish included as part of the native species assemblage.

The concern related to SRFC was stranding and entrapment of juveniles during the rearing period between March 15 and June 15. FERC staff recommended a 4-inch-per-hour ramp rate during this period in place of the 1-foot-per-hour proposed ramp rate (FERC 2007). IPC has been conducting surveys since 2005 to identify and monitor areas of potential entrapment of juvenile SRFC and other juvenile anadromous salmonids. From this effort, IPC has developed operational protocols to ensure entrapment areas are reconnected to the river daily during the rearing period, which reduces the potential impact related to entrapment. In addition, IPC has included a temperature monitoring component such that entrapment areas will be managed to not exceed 23°C. Management of temperature may include operational changes, such as reducing the range of fluctuation during certain periods. Greater detail of these protocols, decision framework, and communications involved in implementing this adaptive management are included in the entrapment plan. Implementation of the entrapment plan will reduce impacts to the native fish assemblage (primarily SRFC) downstream of Hells Canyon Dam during this period and is proposed in lieu of the 4-inch-per-hour ramp rate.

7.5.2. Fall Chinook Salmon Flow Program

Since 1991, IPC has implemented a flow program designed to protect spawning and incubation habitat for SRFC. The program includes providing stable flows during the SRFC spawning period. The stable flows are initiated the second Monday in October and extend to the second Friday in December. The number and distribution of SRFC redds are monitored during this period in the Snake River between HCD and Lewiston. Following the stable flow period, a minimum flow is established to ensure all SRFC redds are protected from dewatering during the incubation period, which generally extends into mid-May. This flow program establishes an approximate 7 to 8-month continuous period where a minimum flow is maintained specifically to protect SRFC. This protection benefit extends to other native fish downstream of HCD. It also ensures a consistent area of productive and continually wetted streambed to enhance other aquatic life.

7.5.3. Ecological Monitoring/Long-Term Status

The primary effects of operations of the HCC on aquatic species through stranding, entrapment, and dewatering are addressed through the measures described above. Beyond these effects, the effect of HCC operations on the overall productivity, bioenergetic expenditures, or forage/prey availability to the aquatic community are difficult to quantify. Based on relative metrics/indices of population abundance and the condition of individual key aquatic species, such as bull trout or white sturgeon, there is not clear evidence that the operations of the HCC significantly affect these species. However, prior to the studies associated with the relicensing application for the HCC, there was not a well-established baseline to allow for comparison or to quantify change for many of these resources. As part of the proposed measures associated with the HCC license, IPC will monitor various indicators of the health of key aquatic resources through the next license, including white sturgeon, bull trout, SRFC, and the macroinvertebrate and periphyton communities (see below). This monitoring, along with the water-quality monitoring associated with the improvements described in this application, will provide a solid foundation to understanding the long-term dynamics of these resources and their responses to environmental change.

7.5.4. Macroinvertebrate and Periphyton Monitoring

The macroinvertebrate and periphyton community provide the base of the food web structure in an aquatic community. The effect the operations of the HCC may have on this community has not been specifically evaluated. The Snake River is unique in its ecological setting such that there is not a meaningful comparison or reference conditions to compare its overall composition and function. However, as part of long-term establishment of trends in the status of key aquatic resources downstream of HCD (described above), IPC will implement a monitoring program to establish trends in these benthic aquatic communities using key metrics related to species composition and abundance. This monitoring will help understand potential mechanisms in the dynamics of the aquatic community.

7.5.5. Bull Trout Passage

The FWS, as part of their authority under Section 18 of the FPA, prescribed passage associated with bull trout. This plan will involve passing bull trout from downstream of the HCD to the larger tributaries identified as core bull trout areas, including the Wildhorse River, Indian Creek, and Pine Creek and returning them to below HCD. The initial focus will be on Pine Creek, Oregon. Establishing a functioning migratory component of bull trout to these tributaries will further enhance the biological integrity of these tributaries relative to this native species. Implementation of this prescription includes establishing long-term monitoring of bull trout populations within these basins and downstream of HCD. Because this monitoring includes collection of other species associated with the methods of sampling bull trout, the monitoring will provide additional information on the long-term status of other species in these basins, including redband trout and the non-native eastern brook trout.

7.5.6. Pathogen Risk Assessment

Associated with the bull trout passage plan, the risk of introducing deleterious pathogens both upstream and downstream of the HCC will be assessed and monitored relative to the potential effects to the aquatic communities. The full extent of the monitoring has yet to be developed but will involve working directly with fish pathologists from both Oregon and Idaho on what the components of the monitoring will involve. The monitoring is intended to provide the states of Oregon and Idaho and the FWS the information needed to make adaptive decisions relative to the movement of fish in these systems.

7.5.7. Tributary Habitat Enhancement

The SRSP as proposed in this 401 application and the *Tributary Habitat Enhancement Plan* (THEP) as proposed in the HCC license application will both promote quality habitat and native aquatic species within tributaries to the HCC and within the HCC. The THEP includes multiple elements of habitat improvement prioritized by primary threats identified for bull trout within the tributary basins upstream of HCD. One of the significant threats for Pine Creek includes the lack of a safe migratory corridor because of low flows and unscreened irrigation diversions.
The THEP has five programs targeting different aspects of habitat improvement, primarily targeting increased stream flows and fish passage at water diversions. The program elements include the following:

- Water efficiency
- Fish passage/screening
- Riparian management

- Off-channel stock watering
- Partnerships

Upon issuance of a Hells Canyon license, prioritization of annual funding will occur through the establishment of an Aquatic Resource Technical Advisory Committee comprised of state, federal, and tribal representatives. Addressing these primary habitat threats associated with bull trout in these basins will provide an additional benefit to the resident biological communities in these basins.

7.5.8. Marine-Derived Nutrient Supplementation

A program to supplement the core bull trout population areas with marine-derived nutrients (MDN) was proposed in the license application for the HCC. The program will use either carcasses from anadromous broodstock associated with the IPC hatchery program (if approved relative to pathogen transfer risk) or MDN analogs. The distribution of these MDNs would target bull trout production areas within the core area tributaries and would potentially enhance productivity for bull trout and other components of the biological community. There is no clear indication that the availability of nutrients is limiting production of bull trout or other resident species within these basins. This measure, coupled with the long-term monitoring of these basins associated with the bull trout passage plan, will help inform managers as these measures are adaptively developed.

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Exhibit 4.3-1

Names and addresses of Oregon contiguous property owners to the Hells Canyon Complex (HCC) project boundary

Exhibit 4.3-1. Names and addresses of Oregon contiguous property owners to the Hells Canyon Complex Project Boundary.

Project/County	Owner	Address	City	State	Zip
Hells Canyon					
Wallowa Co	L C Binford, et al.	P O Box 506	Halfway	OR	97834
Hells Canyon					
Baker Co	Kim Schultsmeier	8393 Southside Blvd	Nampa	ID	83686
	Douglas & Joann Hahn, et al.	6828 Fairfield Ave	Boise	ID	83709
	John P Binford, et al.	P O Box 506	Halfway	OR	97834
	Patricia J Sowers	P O Box 910	Halfway	OR	97834
	Stanley E & Lynne T Thompson	52668 Homestead	Oxbow	OR	97540
	Robert D Maynard	2760 9th St	Baker City	OR	97814
	Tom Grossen & Nancy Armitage	P O Box 72	Indian Valley	ID	83632
	Balazs Nagy	52462 Homestead Rd	Oxbow	OR	97840
	Baker County	1995 3rd St	Baker City	OR	97814
	G C & D M Carson	2266 Center Ave	Payette	ID	83661
	George D Reid	2088 W Sycamore Rd	Fillmore	CA	93015
	RLF Homestead Properties, LLC	523 S Cascade Ave	Colorado Springs	CO	80903
	Mark D & Lisa K Butler	51324 Holmstead Rd	Oxbow	OR	97840
	Julie Stormer, et al.	49922 Holmestead Rd	Oxbow	OR	97840
Oxbow					
Baker Co	David G Moore, Trustee	88 Linda Isle	Newport Beach	CA	92660
	Ira Haskett, et al.	3706 Greenbriar	Boise	ID	83705
Brownlee					
Baker Co	Larry Smith	66698 Williamson Rd	Enterprise	OR	97828
	Stanley, Roger & Kerry Gulick	39486 Pine Town Lane	Halfway	OR	97834
	Hans C & Susan M Finke, et al.	P O Box 1565	Wilsonville	OR	97070
	David G Moore, Trustee	88 Linda Isle	Newport Beach	CA	92660
	Versatile Business Inc· c/o Gerald R Novotny, Sr	P O Box 415	Glenbrook	NV	89413
	Gary L & Joann K Marlette	2031 Court Ave, Apt 8	Baker City	OR	97814
	Gregory L & Christine Barreto	62819 Lower Cove Rd	Cove	OR	97824

Project/County	Owner	Address	City	State	Zip
	Baker County	1995 3rd St	Baker City	OR	97814
	Bryl Eugene & Tiz Landers Trustee	41315 Robinette Rd	Richland	OR	97870
	John & L Anita Ames	37150 Sullivan Lane	Richland	OR	97870
	George & Wadean Holcomb Trust	41997 Holcomb Rd	Richland	OR	97870
	Patricia Lumsden	502 Sunset Dr	La Grande	OR	97850
	Garnett Kaleli	P O Box 519	La Grande	OR	97850
	J & S Management Co c/o John T Kirkpatrick	2321 Rolling Hills Dr	Clarkston	WA	99403
	Bruce & Ann Kirkpatrick Trust	3140 N 2nd St	Baker City	OR	97814
	Edward H & Patricia Elms Trustee	P O Box 844	Baker City	OR	97814
	Dean D and Sheri Sass	6057 Castleton Ln	Garden City	ID	83714
	The Heirs of Leonard Ritch	1600 Eldon St Apt 14	Baker City	OR	97814
	John & Lora Anita Ames	37150 Sullivan Rd	Richland	OR	97870
	Betty Jane Ellis	111 Prospect Place	South Orange	NJ	07079
	Richard Murray	46247 Snake River Rd	Richland	OR	97870
	Georgia Sieg, Trustee	1045 E St	Baker City	OR	97814
	Timothy D & Tammy L Hunt	1117 Walnut	Baker City	OR	97814
	Vern W. & Pearl E Dumars	52408 Moody Rd	Richland	OR	97870
	Dan L Forsea & Sons, Inc	42070 New Bridge Rd	Richland	OR	97870
	Thomas D McKim	2711 West Conifer Dr	Eagle	ID	83616
	Ross Bond	378210 10th St	Baker City	OR	97814
	Mary Jo Rode	2311 Laurel Dr	Ontario	OR	97914
	Darrell & Gwen Prince	PO Box 221	Union	OR	97883
	John C & Ruth E Weaver	P.O. Box 428	Payette	ID	83361
	Alex & Lotte I Finke Trustee	P O Box 23562	Portland	OR	97281
	Leonard & Alice Bacon	1559 Baker St	Baker City	OR	97814
	Edith Rynearson	P O Box 309	Huntington	OR	97907
	Seventh Generations c/o Kenneth R Mahafferty	P O Box 3417	Berkley	CA	94703
	Marley Martin, et al.	P O Box 23219	Portland	OR	97281
	Robert E & Cathy A Griffiths	936 2nd Ave S	Payette	ID	83661
	Joan Hooper	603 Ontario Heights Rd	Ontario	OR	97914
	Amy Rebholtz	3985 Erick Lane	Boise	ID	83704
	Steven M & Regina A Kittleson	10900 Netherland Dr	Boise	ID	83709
	Russell and Mary Jane Peska	24297 S Kirchner Rd	Oregon City	OR	97045

Project/County	Owner	Address	City	State	Zip
	Marihelen Ciesiel	1935 Mathews Loop South	Salem	OR	97302
	Amy C Ross	250 E 4th	Weiser	ID	83677
	Patrick G & Geraldine Glenn	7037 SE Pleasant Home Rd	Gresham	OR	97080
	Gladys Blinsman, et al.	24271 S Larkin Rd	Beaver Creek	OR	97004
	R & N Retreat, LLC	P O Box 762	Baker City	OR	97814
	Ray & Ross Gardner	68 Village Ln	Ontario	OR	97914
	Dan L & Sheryl K Blankenship	18481 W Campbell Loop	Baker City	OR	97814
	Craig W and Cherie Ward	19271 Hughes Ln	Baker City	OR	97814
	Patricia J Young	2309 SW 1st #743	Portland	OR	97201
	Olen D & F Adele Ragsdale	1565 East St	Baker City	OR	97814
	Clea & Melvin Barton Trustees	9320 Bienapfl	Boise	ID	83709
	Mike & Sarita Raney	P O Box 171	Huntington	OR	97907
	Larry G & Deborah Riepma	34559 Snake River Rd	Huntington	OR	97907
	Howard & Sandra Britton	3480 Place St	Baker City	OR	97814
	Five Way, LLC	PO Box762	Baker City	OR	97814
	Alan and Linda Schmeits	3510 Cedar St.	Baker City	OR	97814
	James & Elizabeth Gordon	1295 SW 15th Ave	Ontario	OR	97914
	Gateway to the Wilderness, LLC	428 Mt Rushmore Rd	Custer	SD	57730
	Trevenex Resources, Inc.	1314 S Grand Blvd, Ste 2-176	Spokane	WA	99223
	Rodney J Butler	P O Box 1301	Napavine	WA	98565
	James N & Mary Jo Grove	935 E St	Baker City	OR	97814
	OSLRR Co	P O Box 2500	Bloomfield	CO	80020
	Barber Ranch, LLC	5207 W Elmer St	Boise	ID	83703
	Mary G Bokides	1750 Sunset Dr	Weiser	ID	83672
Brownlee					
Malheur Co	Bennie F Wigley Jr.	P O Box 358	Huntington	ID	97907
	Margaret A Petty	23328 SE 113th St	Issaquah	WA	98027
	James W & Vicky L Shipp	5980 US Hwy 3	Huntington	OR	97907
	Kenneth & Barbara A Arnold	5970 US Hwy 3	Huntington	OR	97907
	Richard D Herriman c/o Russell Herriman	1000 Foothill Dr	Ontario	OR	97914
	Huntington Equities, LLC	5945 Hwy 30	Huntington	OR	97907
	Malheur Mining Corp Ltd Co Red Abbey LLC	2330 W Joppa Rd Suite 330	Lutherville	MD	21093
	Dwight M & Leila M Lockett	5850 Lockett Rd	Huntington	OR	97907
	William & Shirley Grace Trust	255 Ivy Rd	Ontario	OR	83709

Project/County	Owner	Address	City	State	Zip
	Merle J & Kathleen R Kidwell	58166 NW Wilson River Hwy	Forest Grove	OR	97116
	Robert H Lynch	5085 Red Cap Rd	Huntington	OR	97907
	James R & Linda K Suitts	8644 Targee	Boise	ID	83709
	Manuel Deleon	959 Conductor Rd	Huntington	OR	97907
	Chad Dolven Etal	100 Sterling Ct	Battle Creek	MI	49015
	Harlan Crawford et ux	5645 Hwy 201	Ontario	OR	97914
	William F & Rosa M Rupp	1420 Rd 49	Pasco	WA	99301
	Jimmie & Glendoris Harkleroad	6180 Hwy 201 N	Huntington	OR	97907
	David G & Julia M Silva	6170 Hwy 201 N	Huntington	OR	97907

Exhibit 4.3-2

Idaho Power Company’s Hells Canyon Complex (HCC) relicensing policies and activities in relation to Baker, Malheur, and Wallowa county plans

Exhibit 4.3-2. Idaho Power Company's Hells Canyon Complex relicensing policies and activities in relation to Baker, Malheur, and Wallowa county plans.

Lands within the Applicant's Hells Canyon Complex (HCC) Federal Energy Regulatory Commission (FERC) project boundaries subject to Baker, Malheur, and Wallowa county comprehensive plans (*i.e.* not federal lands) are limited. They include a single private parcel in Wallowa County (Appendix A) and several private parcels that comprise either small islands in the Snake River or a strip of Brownlee Reservoir shoreline in Malheur County. Private lands within the FERC project boundaries are more extensive in Baker County.

Baker, Malheur, and Wallowa county plans address the first 14 Oregon statewide planning goals. Goals 15 through 19 address resources not present in any of the counties. This analysis will therefore also follow that format.

The Baker County Comprehensive Plan

Citizen Involvement

A) Baker County citizen involvement and public meetings policies include the following (summarized):

1. The Planning Commission is assigned the responsibility for implementing and evaluating the citizen involvement program.
2. The Planning Commission makes recommendations to the governing body on the citizen involvement program and its implementation.
3. The adopted "Baker County Citizen Involvement Program, 1978" is to be reviewed annually and revised as needed.
4. The governing body may appoint area advisory committees to provide input to the planning process.
5. All meetings involving land use actions shall be open, public meetings.
6. Notification of the public of the time, place, and purpose of meetings is required, and required information shall be provided to newspapers with general circulation in the county.

B) Policies 3, 4, 5, and 6 are indirectly applicable to the Applicant's proposed project. In order for citizens to be involved in the planning processes, they require information to which they can respond. Idaho Power Company (IPC) investigators reviewed existing environmental literature from the Hells Canyon region to identify known natural resource issues associated with the HCC before organizing its public consultation process for relicensing and § 401 water-quality certification. Resource specialists for appropriate management agencies who knew Hells Canyon region were also consulted. In addition, IPC also reviewed available technical literature and critically evaluated work by previous investigators. This review resulted in a series of resource inventories and descriptive studies that were used to develop a baseline understanding of the environment. The studies conducted were targeted based on criteria used by the FERC for appraising resource values to the public and on the value of a proposed study with respect to the general requirements for preparing a license application. These studies were incorporated into the *Formal Consultation Package for Relicensing: Hells Canyon Project* (FCP) that was submitted for stakeholder review.

A collaborative relicensing process was formed in January 1996 to improve the level of understanding of resource issues and the potential for agencies, tribes, and interested parties to resolve these issues. The process augmented the traditional FERC relicensing process by including earlier and more open discussion of studies and resource issues. The collaborative process was also designed to allow IPC to meet all FERC requirements while providing additional opportunities for stakeholders to communicate and cooperate.

The collaborative relicensing process for the HCC was comprised of a Collaborative Team (CT) and various resource work groups (RWG). The CT was intended as a forum to engage all participants in the process, while the RWGs focused on technical issues of each of their groups (terrestrial, aquatic, recreation, and cultural). Meetings were held between 1996 and 2002 to involve of these groups in IPC's relicensing effort. Hundreds of documents were produced to inform the RWG and CT participants about the environmental issues they were addressing throughout this period of public discussion. All of these documents can be found in the *New License Application: Hells Canyon Hydroelectric Complex*, Consultation Appendix.

C) Baker County's policies for citizen involvement addressed in B) indirectly relate to water quality. The policies provide input of public and agency values into the issues regarding development of water quality protection, mitigation, and enhancement (PME) measures that address impacts of the Applicant's proposed project.

Land Use Planning

A) Baker County land use planning policies include the following (summarized):

1. The governing body provides for accumulation and publication of relevant technical information and inventory data for planning.
2. *Technical Information and Inventory Data for Land Use, Baker County* will be reviewed and revised as necessary.
3. The Planning Director has primary responsibility for reviewing and revising data and information provided, though revised drafts require approval by the governing body.
4. The land use plan is available to the public at the county library.
5. Supporting materials to the land use plan are available for public inspection at the county planning office.
6. Manner of use of supporting maps in land-use decisions is set forth under appropriate goals.

7. Lot sizes in specific subdivisions (stated) are frozen to minimize impact on surrounding resources.

8. Additional land use policies will be enacted to implement this plan, including land use zoning, subdivision, airport zoning, urban growth boundaries, Sumpter Valley management plan and ordinances, plan map, zoning map, exceptions areas, and floodplain ordinance.

9. This land plan and implementing ordinances should be coordinated with those of affected governmental units in the county.

10. Proposed plans and ordinances will be sent to affected governmental units, and a reasonable period of time will be allowed for response before decisions are made.

11. Affected governmental units include local, state, and federal agencies and special districts that have problems, land ownership, or responsibilities within the area.

12. The Oregon Fish and Wildlife Commission's current state agency coordination program, which requires that only fee simple land acquisitions for wildlife management areas valued at $50,000 or more be subject to public hearing and commission approval, should be modified. Such modifications would mean that acquisition of easements or long-term leases would be subject to these conditions and that the value constraint would be removed so that change in land use, not value, would trigger the public hearing and approval process.

13. This plan will be reviewed and modified as necessary at least every five years, although revisions to the plan and ordinances may be made at the discretion of the governing body.

B) Policy 8 directly relates to the Applicant's proposed project; policies 9 and 10 indirectly relate. The existing uses of IPC's lands in Baker County conform to the various documents listed in Policy 8. Furthermore, the *Hells Canyon Resource Management Plan* (HCRMP) developed by IPC as part of its license application to the FERC establishes land-use designations within the entire planning area that are consistent with these documents. Regarding policies 9 and 10, IPC coordinated its license application and plan with the Baker County Comprehensive Plan, although IPC is not a government entity.

C) IPC's conformance with the various land use documents listed in Policy 8 and coordination of IPC's planning with that of the county indirectly relate to water quality since these documents are intended, in part, to protect natural resources, including water quality.

Agricultural Lands

A) Baker County's agricultural lands policies include the following (summarized):

1. Inventoried agricultural lands will be administered in accordance with the exclusive farm use (EFU) provisions of Oregon statutes, and they will be planned, zoned, and administered consistently with state goals 3 (on agricultural lands) and 9 (on the economy of the state).

2. Increased productivity will be promoted throughout agricultural lands.
3. Changing technology in agricultural enterprises will be allowed for, providing a minimum parcel size to accommodate innovative, smaller-scale operations. A commercial agriculture operation shall contribute substantially to the agricultural economy and help maintain agricultural processors and established markets. In defining commercial agricultural enterprises, how and how much of their products are marketed will be considered.
4. Pre-existing, substandard-size parcels will be reviewed against criteria in the zoning ordinance in public hearing to determine whether they qualify as commercial farm units.
5. Grazing and tillage of land will both be considered farm use.
6. All divisions of land in the county shall promote increased production of the agricultural resource base.
7. Forty acres with sufficient irrigation water, or more land if less water is available, is a commercial unit.
8. Agricultural or forest lands containing an existing or potential multiple use reservoir site may be rezoned for the reservoir. Rezoning for reservoirs greater than 1,000 acre-feet will be required, be based on application of the Goal 2 rule, and require a plan amendment.
9. Agricultural or forest lands containing essentially mineral and aggregate resources may be rezoned for mining and processing of such resources. Rezoning will be based on application of the Goal 5 administrative rule.
10. Agricultural or forest lands subject to superseding federal regulation may be zoned consistently with such regulation.
11. Agricultural or forest lands that are essentially recreational in nature may be rezoned for those and other compatible uses. Such rezoning requires a Goal 2 exception demonstrating that these lands are physically developed or needed for nonresource use.
12. Irrigated farmland in the EFU zone will not be subdivided.
13. Upon consolidation of farms, dwellings and other buildings may be separated from the farm under specific provisions.
14. In hardship cases, one mobile home may be permitted in conjunction with an existing dwelling as a temporary use if it is occupied by the existing resident or a relative.
15. A “mortgage” or “financial segregations” will be allowed to facilitate loans secured by a substandard-size tax lot if both parent and separated lots remain in the same name.

B) Policies 1, 5, 7, 9, and 12 are indirectly applicable to the Applicant's proposed project, while policies 8, 10, and 11 are directly applicable. The policies noted to be indirectly applicable are relevant because the conditions that they describe are relevant to Baker County zoning within the proposed project boundaries. Zoning designations within the proposed project boundaries include primarily EFU, with several smaller areas on Brownlee Reservoir and its Powder River arm that are zoned as *recreation residential*. In the area of the Homestead, Oregon community, a number of smaller areas are zoned for mineral extraction, as is the land adjacent to the Wallowa County line. Additionally, on IPC's lands that are not used for project facilities, grazing is the most common use. Policies in IPC's HCRMP allow agricultural use on most of these lands, along with provisions requiring that such uses be compatible with natural resource conservation and protection.

Regarding Policy 8, IPC's reservoirs existed prior to adoption of the plan and application of existing zoning. Therefore, the County either considers existing zoning appropriate for the reservoir or the reservoirs are grandfathered under the zoning ordinance. In accordance with Policy 10, the federal *power site reserve* that exists in the project area would justify the existing zoning that allows the reservoirs. Policy 11 allows for the *recreation residential* zoning that has occurred in some areas on Brownlee Reservoir.

C) The activities discussed in B) are indirectly related to water quality. The zoning around the reservoirs indicates the type of use allowed, which in turn has impacts, both beneficial and adverse, to water quality. While agricultural zoning maintains open spaces that provide absorption and filtering of runoff, grazing and use of chemicals can destroy vegetation, allowing erosion, and introduce pollutants to water bodies. IPC's HCRMP policies attempt to monitor and thus control such potential conditions on lands that are under grazing and agricultural use through the requirement of a management plan from the lessee.

Forest Lands

A) Baker County forest lands policies include the following (summarized):

1. A *Timber-Grazing* zone and a *Primary Forest* zone will be implemented to retain nonprimary and primary forest lands for forest use.

2. Federal jurisdiction for land-use decisions is maintained by the federal government within the federally managed *Primary Forest* zone.

3. Divisions of inventoried forest land of fewer than 80 acres are subject to ordinance criteria and public hearing, except as authorized by the zoning ordinance.

4. Nonforest activities are allowed on forest land, subject to the Goal 4 rule. Such activities will be subject to a public hearing to ensure that an affected parcel is generally unsuitable for forest use, among other provisions.

5. Forest-related dwellings are limited to those necessary for and accessory to commercial forest use and to parcels of adequate size to support commercial forest use.

6. A forest management plan for commercial development of a parcel is required for division of forest land to establish forest-related dwellings.

7. Prior to issuing zoning approval for a building permit for a dwelling on inventoried forest land, the owner shall fully tree farm the land in accordance with Goal 4 requirements.

8. Development on inventoried forest land is encouraged to use the protective guidelines in *Fire Safety Considerations for Developments in Forested Areas*, available from the Oregon Department of Forestry.

9. Home occupations shall be reviewed as a conditional use by using the criteria to ensure that they are compatible with forest uses.

10. A Goal 2 exception and plan amendment will be required before zoning approval can be obtained for a land use that is incompatible with defined forest uses.

11. Where mixed agriculture and forest uses exist within the *Timber-Grazing* zone, the land will be designated as a mixed-use forest zone.

12. The *Timber-Grazing* zone will be designed and administered to qualify for tax assessment under Oregon statutes.

B) IPC does not own land within the proposed project boundaries that could be classified or that is zoned for forest uses, and so Baker County's policies listed above do not apply to IPC lands. IPC, however, does allow the use of its private roads for logging purposes with a use fee.

C) Allowing the use of IPC's roads for forestry purposes may decrease the need for new roads, minimizing disturbed areas and thus soil erosion into water bodies.

Open Spaces, Scenic and Historic Areas, and Natural Resources

Baker County's policies on these resources include the following (summarized):

1. Open space will be addressed and accommodated in related aspects of other land use goals, including agricultural and forest lands; air, land, and water quality; and recreational needs.

2. Resources of scenic views and sights will be identified. These resources are not in known conflict with other land uses and have no impact areas.

3. Land uses designed to conserve the natural beauty of the region will be promoted.

B) All three of the Baker County's policies are applicable to the Applicant's proposed project. The proposed project area provides large areas of open space, consistent with Policy 1, that will continue to contain only limited development in the future (no additional development is proposed in the applications for license or § 401 certification). Although the County includes no specific policies here for historic areas and natural resources, IPC's license proposals include many policies and activities intended to protect these resources. Consistent with policies 2 and 3, IPC's license application includes many measures to better blend the visual appearance of its facilities with the natural landscape, including changing the color and appearance of a number of facilities, cleaning up construction spoils piles in the proposed project area, establishing architectural standards for new and modified buildings and structures, modifying landscaping to transition into natural vegetation, and controlling weeds. These actions will help substantially to conserve and improve the beauty of the area. Additionally, the HCRMP includes a section of policies for managing recreation and aesthetics in the planning area.

C) Maintenance of open space is directly related to water quality because it preserves natural conditions that allow absorption of runoff. Provisions for protecting scenic resources in some cases may be indirectly related to water quality. For example, the Applicant's efforts to remove construction spoils that are scattered through portions of the proposed project area will eliminate their exposure to runoff, which could pollute water bodies. In other cases, scenic quality policies would have no relation to water quality.

Air, Water, and Land Resources Quality

A) Baker County's air, water, and land resource quality policies include the following (summarized):

1. Applicable state and federal laws and standards will be reasonably and effectively administered.

2. The formulation and dissemination of best management practices (BMPs) for agricultural operations that are designed to maintain soil stability and protect air and water quality will be encouraged.

3. Development and use of watersheds and reservoirs to reduce springtime flooding and erosion and to maintain stream flows in the low runoff periods will be encouraged.

4. Zoning restrictions for noise-polluting uses will be adopted, and techniques such as buffering and restricted hours of operation in conditional-use processes will be considered.

5. All use permits involving air, water, or land quality regulations will be conditioned as subject to Oregon Department of Environmental Quality (ODEQ) permits, particularly in mining proposals.

6. The ODEQ's Pendleton staff will be notified of conditional-use permit applications involving air, water, or land quality regulations to obtain their recommendations for the public hearing.

7. The county will cooperate with the Soil and Water Conservation District, Baker Valley Irrigation District, Oregon Department of Fish and Wildlife (ODFW), Natural Resources Conservation Service (NRCS), and private landowners to reduce high water problems by opening existing drain ways and constructing new drains.

8. The county will seek specific and current information from the Oregon Department of Water Resources (ODWR) or the local watermaster's office when water rights for surface and groundwater or stream flow are relevant to a land-use decision.
9. The county will cooperate fully with ODEQ staff by providing them with office space and telephone service, dispensing their application forms and certain information, and receiving complaints from county residents.

B) Policies 2, 4, and 6 are indirectly applicable to the Applicant's proposed project, and policies 1, 3, 5, 7, and 8 are directly applicable. In its HCRMP, IPC has included a policy that "Best Management Practices (BMPs) for resource protection should be defined and followed for development, improvement and maintenance activities." This is consistent with Policy 2, though IPC is not an agricultural operation. Additionally, IPC has included policies regarding noise pollution and buffering (Policy 4) for the management of its lands and waters as follows.

"Use of lands and waters in a manner that produces noise at a level detrimental to public use and enjoyment is unacceptable. Visitors disturbing others may be asked to leave the property."

"Location and/or buffering should protect residential uses from other activities allowed in *community* (designated) areas."

Consistent with the concept of Policy 6, the ODEQ has been involved in the Applicant's development of its federal license application, described in the HCRMP, section 4.3.2.1.1. (about citizen involvement policies for Wallowa County).

Policies 1 and 5 call for the county to ensure that state and federal regulations are met by uses approved in land-use decisions. While county land use approvals are not required for the proposed project, IPC is working with all state and federal agencies having jurisdiction in some aspect of the project to be consistent with their regulations and standards (a list of all agencies with which IPC has consulted is included in the *New License Application: Hells Canyon Hydroelectric Complex*, Consultation Appendix). Note also that the proposed project avoids air emissions that would result if the power provided by the project were generated by using fossil fuels. The existing and proposed project already provides flood protection and supplements normally low flows, as called for in Policy 3. The Applicant's license application includes a measure to consider and possibly modify culverts on Hells Canyon and Brownlee reservoirs, a measure that would comply with Policy 7. Additionally, the existing and proposed project reservoirs provide storage for high water volumes contributed by land-use practices and natural storms. Information regarding water rights may be desired in the consideration of the proposed project. In accordance with Policy 8, it may be obtained from the ODWR or the local watermaster, and such information is provided in the Applicant's federal license application.

C) BMPs to protect resources are directly relevant to water quality. By using practices, such as minimizing vegetation removal and installing materials to hold soil in place, erosion can be minimized and pollutants to water bodies reduced. Control of noise pollution is not related to water quality. Coordination with state and federal agencies in developing the license application for the project, including input from the ODEQ, is directly relevant to water quality. Measures that IPC has committed to implement in the relicensing process will improve water quality. The generation of hydropower, rather than power from burning fossil fuels, is also directly related to water quality since hydro generation will result in some impacts, both beneficial and adverse, to water quality. Supplementation of low flows in the fall can have a direct effect on water quality by increasing the amount of water and the velocity of the river. Obtaining information on water rights is not relevant to water quality.

Areas Subject to Natural Disasters and Hazards

A) Baker County policies on areas subject to natural disasters and hazards include the following (summarized):

1. Such areas have been inventoried, although in some cases a more detailed and conclusive inventory is needed. Therefore, regulations will be strengthened as more information becomes available.

2. Development subject to damage or that could result in loss of life will not be planned or located in known hazardous areas without appropriate safeguards.

B) Both of these policies are directly applicable to the Applicant's proposed project. The FERC requirements for dam safety are considerable. In addition to having responsibility for day-to-day safety throughout the life of the proposed project, the Applicant must conduct substantial monitoring at various time intervals. When a project is constructed, various geologic studies, including evaluation by outside specialists, are made, and the results are major considerations in deciding whether or not to permit the project. At five-year intervals, a permittee is required to conduct dam safety inspections, which are required to involve technical specialists outside IPC. In the early 1990s, as part of the conduct of the dam safety inspection on the HCC, a seismic network was installed by IPC to monitor seismic activity in the area of the project. Monitoring of the data from that network was conducted between 1991 and 1999, at which time the FERC authorized discontinuing the monitoring. In 1993, an independent report was prepared that evaluated the potential for seismic damage to the project. An independent consultant conducted a dam safety inspection on the HCC this year, and the resulting report will be submitted by the FERC in November 2003.

The HCC provides substantial flood protection to areas downstream of the dams. In accordance with FERC requirements, IPC has prepared an emergency action plan to address unlikely but possible threats of dam failure. Included in the HCRMP is a policy for IPC to minimize the paving of large areas to limit impervious surfaces and, thus, maintain natural absorption, maintaining the flood-carrying capacity in the floodplain area. The hydroelectric use also maintains privately owned lands in open space.

C) Most of the activities described in B) have no relationship to water quality. The HCRMP policy calling for minimization of paving would indirectly affect water quality by conserving areas that provide absorption and thus filter runoff. The maintenance of open space in the project area also contributes to runoff absorption and water filtering in wetland/riparian areas.

Recreational Needs

A) Baker County's recreational needs policies include the following (summarized):

1. Assess the recreational needs of the county, including the State Comprehensive Outdoor Recreation Plan findings, and provide for those needs in the public interest.
2. Work cooperatively with IPC, the Bureau of Land Management (BLM), and volunteer citizens to provide at least minimal sanitation facilities along the Snake River Road.
3. Encourage continued support for the Sumpter Valley Recreational Railroad.
4. Require an exception from any state resource goal prohibiting promotion of recreational facilities.
5. Regulate use of private lands within the boundaries of the Hells Canyon National Recreation Area (HCNRA) and within interim or designated wilderness areas by the applicable resource goal-Goal 3 (agricultural lands) or 4 (forest lands)-and through pertinent federal regulation.
6. Support the development of water-based recreational opportunities based on findings regarding the need for planned recreational areas along the Snake River, slack waters of the Powder River, and Unity Lake.
7. Establish a *Destination Resort Overlay Zone* and amend it to the Comprehensive Plan and Zoning Ordinance. The zone will enhance the economic and recreational diversification of the county consistent with its environmental attributes.
8. Adopt a map of eligible areas as part of the Comprehensive Plan and Zoning Ordinance.
9. Ensure that destination resorts are compatible with the site and adjacent land uses by application of ordinances.
10. Locate and design improvements to avoid or minimize adverse effects on surrounding uses; specifically, protect farming and forest operations.
11. Map important natural features during the resort approval process and protect them during development.
12. Limit uses in destination resorts to visitor-oriented accommodations, overnight lodging, developed recreation facilities, commercial needs of visitors, and uses consistent with resource preservation and maintenance of open space.
13. Revise and refine the map of eligible sites to reflect changes in the county at the most recent periodic review.
14. Require resorts to be self-contained and self-sufficient. All services needed to serve guests will be provided. All costs of services, including system extension and increased capacity, will be paid by the developer.

15. Require a feasibility study to ensure that a proposed destination resort has the market to succeed.
16. Monitor the effects that increased tourism, particularly destination resorts, has on the economy, social and natural environments, and overall quality of life. Revise policies according to the successes or problems measured.

B) Policies 2, 5, 6, 7, 9 and 10 relate directly to the Applicant's proposed project. Policy 4 applies indirectly to the proposed project. Regarding Policy 2, IPC is the subject of this policy and, in its current license application, has committed to work with the County to provide additional sanitation facilities along the Snake River Road. In accordance with Policy 4, IPC owns lands within the HCNRA that are subject to Goal 3. However, IPC's lands in the HCNRA are specifically exempted (grandfathered) from the provisions of the HCNRA Act by language in that act. In its license application, the Applicant has proposed water-based recreation facilities adjacent to Brownlee Reservoir in Baker County, among other locations. These proposals are based on extensive studies conducted as part of the license application regarding recreation needs. IPC's HCRMP also contains policies regarding development of water-based recreation. These policies generally do the following: allow public use of IPC's reservoir lands for recreation; advocate clustered, as opposed to dispersed, recreation development; require buffering from sensitive uses; designate specific areas for various types of recreation; establish policy for private docks; and commit to working with other private property owners to protect their lands from damage from recreational activities (Policy 6). Relating to Policy 7, the HCRMP Policy 6.3.2.22. states, "Commercial retail concessions are allowed in *developed recreation*, *community*, *recreation reserve*, *and resource conservation* land-use designations within the Planning Area through IPC's authorization process. The focus of these uses is expected to be recreation and recreation support." Such a development on IPC's lands would have to be processed through IPC's land use authorization process (HCRMP Policy 6.3.1.9.). Consistent with Policy 9, in IPC's land use authorization process "all new development and other significant human actions will be sited, designed, and conducted with input from the IPC Interdisciplinary Team" (HCRMP Policy 6.3.2.4.). This group will deal with sensitive environmental factors, as well as compatibility of land uses. Several HCRMP policies of IPC relate to Policy 10.

"Recreation development and recreational use should be clustered, rather than dispersed, to help maintain extensive, undisturbed areas in which to sustain natural and cultural resources."

6.3.9.12. Recreation development should be designed to minimize disturbance to natural and cultural resources from human activities. Screening, berming, fencing, and other buffers should be used to achieve this.

All of the preceding description of the relation of the Applicant's proposed project to the County's recreation policies also relate to County Policy 4: recreation development could be proposed by the Applicant on its lands in the future. In this case, the Applicant would cooperate with the county to secure the necessary zoning exception to allow the development to occur.

C) The discussion in B) relating to county Policy 2 is probably the only activity relating directly to water quality. Provision of improved sanitation facilities along the Snake River Road (Brownlee Reservoir) would have a direct beneficial effect on water quality. The remainder of the measures discussed above would be indirectly related to water quality because they address desirable land uses, which in turn may affect water quality.

Economic Development

A) Baker County's economic development policies include the following (summarized):

1. Provide the overall economic policy of the county in Chapter 184 of the Oregon statutes.
2. Diversify and improve the agricultural economy by increasing water availability, improving soils, improving weed control, diversifying crops, improving processing and marketing facilities, reclaiming mined sites, allowing multiple use, increasing forage production, and preserving farmland.
3. Diversify and improve the forest economy by encouraging a sustained yield goal, increasing use of wood fiber, increasing harvest of diseased and fire-killed trees, reclaiming mined sites, allowing multiple use, and encouraging state tax incentives to preserve forest lands.
4. Diversify and improve other lands by expanding tourist and recreational facilities, expanding secondary processing facilities for resources, reclaiming mined sites, expanding secondary processing facilities for mineral resources, and expanding facilities for industrial fabrication/assembly.
5. Reevaluate the county's industrial land inventory, considering accessibility to different modes of transportation and local access opportunities. Ensure compatibility with Goal 12 (see Goal 12 under transportation below) when rezoning sites.

B) Policies 2 and 4 are directly relevant to the Applicant's proposed project. The Applicant's current license application proposes to improve weed control on its own lands and cooperate on weed control with counties and other governmental agencies. IPC's lands are currently used for multiple uses, including recreation, power generation, transmission, and (in some cases) grazing. Policies in the HCRMP call for continued multiple uses of these lands. Agriculture may be permitted on most of these lands, with conditions. The policy of clustering development rather than dispersing it will preserve county lands zoned EFU (relates to Policy 2). Regarding Policy 4, policies in IPC's HCRMP allow for commercial concessions to be permitted on its lands, although such uses would be limited to certain areas, considered and approved through an authorization process, and would be required to meet certain standards. The policy also states, "The focus of these uses is expected to be recreation and recreation support."

C) The types of use advocated for lands, particularly those near water bodies, have a direct relationship to water quality. By preserving lands for agricultural use, the open space will allow for absorption of runoff; however, cultivation and/or grazing could include practices (e.g., fertilizing, exposing bare soil, destroying vegetation that holds soil in place) that would cause adverse effects to water quality. Allowance of recreational concessions on IPC's lands would also have a direct, but incremental, effect on water quality. On the affected lands, areas covered by structures or paving would no longer absorb runoff and could contribute pollutants (e.g., oily residue from parking lots, organics from fertilizers) to water bodies.

Housing

A) Baker County's housing policies include the following (summarized):

1. Make lands available for a variety of housing needs, including housing that will accommodate the range of county income levels.
2. Reduce transportation costs to places of employment.
3. Support and maintain agricultural, industrial, commercial, mining and processing, and tourist and recreational use of land.

B) These policies are applicable to the Applicant's proposed project. IPC makes housing available for a number of its HCC employees at Brownlee and Oxbow villages. Such housing reduces transportation costs for its employees, as well as associated costs for roads for local and state governments. IPC's policy, stated in the HCRMP, that development of undeveloped areas should be minimized and that development should be clustered rather than dispersed (Policy 6.5.1.1.) is consistent with the need to preserve land for other uses.

C) Provision of employee housing in the canyon relates to water quality only in that removal of that land from undeveloped areas reduces land available for absorption of runoff and introduces human practices (e.g., livestock grazing, fertilizing) that could contribute pollutants to water bodies (but advantages to air quality probably exceed any detrimental effects to water quality). Clustering development has a beneficial effect on water quality because it reduces coverage of land by hardscape, allowing absorption of runoff to occur.

Public Services and Facilities

A) Baker County's public services and facilities policies include the following (summarized):

1. Cooperate with the cities by zoning land for waste disposal sites and by contributing to the construction of such sites in the case of smaller cities.
2. Regulate solid waste disposal on county lands as required by law.
3. Provide standards and criteria to regulate densities of land use in appropriate zoning and partitioning regulations.
4. Provide for rural services appropriate to the type and level of rural development described in the comprehensive plan and to the degree desired by the area residents and fundable by the county.

B) None of these policies are relevant to the Applicant's proposed project. While Policy 4 might appear to be relevant to provision of electric power, this policy actually relates only to those services provided by the County (possibly sewer, water, fire, sheriff). Once the County has approved or allowed development to occur, electric service generally must be provided.

C) Since none of the County's policies are relevant to the proposed project, there are no policies relevant to water quality.

Transportation

A) Baker County's transportation policies include the following (summarized):

1. The U.S. Forest Service (USFS) should improve access, providing scenic views, from Baker County to the western rim of Hells Canyon.

2. Burnt River Canyon Road should be included in the Oregon State Highway System to improve connection between Highway 245 on Dooley Mountain to the Interstate at Durkee.

3. The airport and surrounding lands should be protected from incompatible land uses.

4. Formation of a broad-based Airport Authority or Port District should be considered to own and operate the Baker Municipal Airport.

5. The USFS should be encouraged to complete North Pine Road to a standard similar to the connecting USFS road in Wallowa County.

6. Industrial and commercial pipeline terminals serving local demands should be developed to support economic development.

7. Interstate rail and bus service for both passengers and freight in the county should continue.

8. Local mass transit (private) passenger service should be expanded as need and economic practicality occur.

9. Public-subsidized bus transportation should be continued as need is demonstrated and budgetary priorities allow.

10. The county should cooperate with the Oregon Department of Transportation (ODOT) to support foot and bicycle paths in accordance with the real demand.

11. Reinstatement of regularly scheduled commuter airline service in the county should be supported.

12. The county should plan, construct, and maintain county roads to acceptable standards based on safety, use, and economics.

B) Policy 12 applies indirectly to the Applicant's proposed project. IPC assists the County with maintenance on the Homestead Road.

C) Road maintenance can be directly relevant to water quality, depending on the type of surface and practices used in maintenance. The road referenced is dirt and gravel, and runoff therefore could affect water quality. In its HCRMP, IPC has committed to using maintenance practices that are not detrimental to water quality. The implementation measure for operations and maintenance practices and specifications in the HCRMP states, "IPC's ongoing daily operations involve a number of major and minor human actions that could conflict with natural and cultural resources and recreation. To minimize such conflict and to provide a standard for IPC and others, standard practices will be documented for [road maintenance practices].” The Manager of Operations for the HCC will lead this program.

Energy Conservation

A) Baker County’s energy conservation policies include the following (summarized):

1. Protect potential energy-producing sites from irreversible loss and encourage their development.

2. Encourage exploration for and development of geothermal heat sources.

3. Encourage conversion of wood wastes to usable heat energy.

4. Encourage use of available heat energy from natural warmwater springs.

5. Encourage the development of high-density land uses along high-capacity transportation corridors.

6. Encourage location of residences near places of employment.

7. Encourage siting and design of buildings to utilize incident solar radiation for supplemental heat energy.

8. Encourage use of construction materials and methods that can reduce energy requirements for heating and cooling of buildings.

9. Encourage recycling of usable metallic and nonmetallic waste and scrap when economically practical.

B) Policies 1 and 8 are directly relevant to the Applicant’s proposed project. The commitment of the County to protect *potential* energy-producing sites from loss indicates that the county would also support protection of *existing* energy-producing sites from loss. IPC’s existing and proposed project is such a site. IPC has used construction materials and methods in the project that reduce energy requirements for heating and cooling. For example, brick housing has been constructed for employees, and paint colors have generally been light or otherwise reflective to minimize heat absorption. These materials and methods will be continued in the proposed project; however, modifications in colors will be made in the future to ensure blending of the structures with the immediate landscape.

C) The protection of the existing HCC for energy production is directly relevant to water quality, as described above in the section on air, water, and land resources quality, subsection C). Use of construction materials and other methods to minimize energy requirements is not relevant to water quality.

Urbanization

A) Baker County's urbanization policies include the following (summarized):

1. County ordinances adopting various urban growth boundaries shall rule in the case of conflicts regarding such boundaries.
2. The county shall administer land use regulations applicable to urban lands, subject to any agreements with cities, using the standards and requirements of the cities' land use regulations.
3. Any change in urban growth boundaries shall be made using a cooperative process between the county and the city.

None of these policies are relevant to the Applicant's proposed project.

The Malheur County Comprehensive Plan

Citizen Involvement

A) Malheur County citizen involvement policies include the following (summarized):

1. The County Planning Commission will continue as the Citizens Involvement Committee.
2. Citizens advisory committees will be appointed to study particular areas of land use planning.
3. Broad participation in citizens advisory committees and other planning activities will be solicited to provide a cross-section of geographical and professional interests; individual citizens will be given an opportunity to participate in the early formative stages of the planning process.
4. After the Land Conservation Development Commission has acknowledged the comprehensive plan, the citizens advisory committee will review their respective elements of the plan at least every three years to ensure that the plan is in tune with the changing needs of the community.
5. After periodic review described in Policy 4 above, if the citizens advisory committees conclude that update of the plan is necessary, they will develop their recommendations at publicized meetings in which the public will be encouraged to participate.
6. The citizens advisory committees, and any other special committees formed to aid the input process, may be asked to assist the Planning Commission and County Court between periodic reviews. Reoccurring problems will be referred to the appropriate committees for their recommendations.
7. The Planning Department and the citizens advisory committees shall continually work to assemble information from the public that will assist in an effective review process.

8. The public will be encouraged to participate in all periodic reviews and updates of the plan.

9. All planning activities will be publicized to make residents aware of upcoming decisions that may affect them.

10. Information materials will be prepared for distribution and/or presentation to schools, civic groups, and individual citizens to explain the plan and planning procedures.

11. Copies of the comprehensive plan and all other planning documents will be available to all residents.

B) Policies 7, 9, and 10 are indirectly applicable to the Applicant's proposed project. Again, Malheur County policies for citizen involvement are very similar to those of Baker County, therefore, the discussion regarding the relationship between the policies and the Applicant's proposed project for Baker County is relevant here also (see Baker County Comprehensive Plan: *Citizen Involvement*).

C) All of Malheur County's policies for citizen involvement addressed in B) indirectly relate to water quality. The policies provide input of public and agency values into the issues regarding development of water quality PME measures that address impacts of the Applicant's proposed project.

Land Use Planning

A) Malheur County's land use planning policies include the following (summarized):

1. The county will maintain the County Planning Department and the County Planning Commission. The County Court will continue in its role as governing body in determining land use. Members of the Planning Commission shall serve no longer than two consecutive four-year terms.

2. The Malheur County Comprehensive Plan and background reports will be recognized as the primary documents of factual information and policy statement used as the basis for planning decisions.

3. The county will develop a set of zoning and subdivision ordinances to implement the comprehensive plan. All ordinances relating to land use will be consistent with the comprehensive plan.

4. After the Land Conservation Development Commission has acknowledged the comprehensive plan, it will be reviewed by the Planning Commission and citizens advisory committees at least every three years to ensure that inventory information, policies, and land allocations are updated.

5. The Planning Department will maintain a file of suggested revisions to the comprehensive plan, and those revisions will be considered as part of the plan review procedure.

6. A public hearing will be held by the County Court before making any changes in the comprehensive plan.

7. All planning decisions will take into account the comments of the affected property owners and the plans of local, state, or federal agencies that might have an effect on, or be affected by, the decision.

8. As additional inventory information becomes available, it will be considered in planning decisions.

9. Findings made in the process of land use planning decisions will be related to specific planning policies, ordinance requirements, or background information, and such findings will be documented.

10. Units of land or parcels under the same ownership will be considered as one parcel in meeting provisions of the zoning ordinance and comprehensive plan; except that lots created by subdivisions or partitions approved by the Planning Commission in accordance with the subdivision ordinance will be considered separate lots, regardless of whether they are under one ownership.

11. Prior to any potential private land acquisitions by a public agency, a recommendation will be requested from the county regarding the transaction.

12. *Affected local, state, and federal agencies will be notified of all proposed plan changes.*

B) Policies 2, 3, 7, and 8 could be interpreted to directly relate to the Applicant's proposed project. The proposed project is evaluated for consistency with these policies as follows:

1. Regarding policies 2 and 3, Baker County's Comprehensive Plan and zoning and subdivision ordinances are to be applied to planning decisions in the county. However, the Applicant's *federal relicensing of the existing project* does not require County approval under the County's adopted ordinances. Furthermore, as a federally-licensed project, the proposed project would not necessarily be required to comply with locally adopted plans and ordinances, even if it were a new project. This evaluation of consistency, instead, is prepared under the State requirements for filing application for a § 401 Water-Quality Certification.

2. Policy 7 calls for plans of local, state, or federal agencies that could have an effect on, or be affected by, the proposed project to be considered in decision-making. The Applicant has prepared an evaluation of consistency of the proposed project relicensing with 12 plans of federal and state agencies for Idaho and 29 such plans for Oregon, in addition to this evaluation of the plans of three Oregon counties, to be used by the FERC, and are available to the State of Oregon, in making decisions on this project.

3. Policy 8 calls for inventory information to be used and considered in planning decisions. The Applicant has prepared more than 120 studies on local environmental conditions that are now available to the County for its use in making planning decisions.

C) The policies and discussion in B) regarding the Applicant's proposed project are directly related to water quality issues. The policies and requirements of the County's Comprehensive Plan and zoning and subdivision ordinances are intended in part to protect natural resources, including water quality, as are many of the plans and policies of federal, state, and other local agencies. Much of the resource information prepared by the Applicant in its studies deals with water quality and conditions relating to water quality and would thereby enable the County to evaluate the proposed project's effect on that resource.

Agricultural Lands

A) Malheur County's agricultural lands policies include the following (summarized):

1. Public and private land classified by the NRCS as being in Capability Classes I through VI, as well as any other lands determined to be suitable and needed for farm use, are considered to be agricultural lands.

2. Whenever possible, land having the highest agricultural capabilities will be given the greatest protection (Class I has the highest capability; Class VI has the least)

3. In addition to the NRCS soil classification system, County Assessor's records will be considered in evaluating individual parcels for the purpose of planning and zoning.

4. Urban growth boundaries, exclusive farm use zoning, and farm use assessment will be the major tools used to protect agricultural lands.

5. Other methods of preservation will be studied to determine their practicability.

6. The Planning Department will work with the Soil and Water Conservation District, the Oregon State University Extension Service, and the Water Resources Committee to help improve soil conservation methods and water quality.

7. The county will work toward increasing the storage capacity for irrigation water in the county.

8. The county will work closely with the irrigation and drainage districts when land use decisions affect the distribution of water for irrigation purposes.

9. The county will support other organizations working to minimize or eliminate tax arid cost factors that prohibit younger persons from entering the farming and ranching professions.

10. A non-farm dwelling in an agricultural zone will be allowed where: (a) it is compatible with established or possible farm uses; (b) it will not now, or in the future, interfere with established farm practices; (c) it will not alter the stability of the overall land use pattern of the area; and (d) it is situated on land generally unsuitable for the production of farm crops and livestock.

(No Policies 11 or 12 included)

13. Existing non-farm uses will be allowed to exist and continue as non-conforming uses in farming and ranching areas.

14. Normal farming and ranching activities will be allowed to exist and continue without interference from non-farm users of the land.

15. The zoning ordinance will establish EFU, Exclusive Farm/Forest Use (EFFU), and Exclusive Range Use (ERU) zones to protect agricultural lands, and it will include provisions limiting development of those lands.

16. The zoning ordinance and subdivision ordinance will include requirements for appropriate setbacks from agricultural lands.

17. The County Court will appoint a citizens advisory committee on agriculture to review the agricultural lands element of the comprehensive plan every three years, or whenever the Court finds a more urgent need.

18. The county will support proposals to the State Legislature to exempt "marginal lands" from Goal 3 requirements.

19. The county will not discourage the creation of special land use districts so that landowners can impose more restrictive land use regulations than those imposed by the county.

B) Policies 1, 2, 4, 6, 10, 14, 15, 16, and 19 are indirectly related to the Applicant's proposed project. Policy 13 is directly related.

Policies 1, 2, 4, 15, and 16 define methods the County will use to protect agricultural lands. The lands within the proposed project boundaries in Malheur County subject to the County's plans and ordinances (*i.e.* not federal lands) are generally agriculture and rangeland. Uses on these lands, whether owned by the Applicant or by others, are currently consistent with agricultural use. The Applicant's proposed project plans and policies, identified in its HCRMP, are also consistent with agricultural use of these lands.

Policy 6 states measures the County will take to improve soil conservation and water quality. The proposed project application to the FERC and applications to the Oregon and Idaho agencies for water-quality certification include several measures necessary to meet the Applicant's total maximum daily load (TMDL) allocations and to improve water quality in the reservoirs. Policy 10 provides criteria for allowing non-farm dwellings in agricultural zones. While this applies to such lands within the proposed project boundaries, the Applicant has no plans to develop such residences on its lands, and, in fact, includes a policy in the HCRMP that would prohibit residences on its lands in this area.

Policy 13, applicable directly to the Applicant's proposed project, states that existing non-farm uses may continue in agricultural areas. This establishes the proposed project's consistency with the agricultural lands in the area. Policy 14 indicates that non-farm activities should not interfere with agricultural uses. While it is possible that recreationists attracted to the area by the proposed project's reservoirs may interfere with agricultural uses, they are an indirect result of the proposed project. The HCRMP states that the Applicant will work with private property owners to lessen such impacts, presumably through public education.

Policy 19 allows for land use controls more stringent than County zoning allows. The HCRMP establishes land use classifications, which provide for compliance with all government regulations (including local zoning), but may be more restrictive than underlying zoning.

C) The Applicant's consistency with the agricultural lands policies addressed in B) are indirectly related to water quality. By maintaining undeveloped areas for agriculture, areas that absorb precipitation and run-off are preserved, avoiding run-off and erosion directly into the reservoir. The Applicant's license application, including many specific policies in the HCRMP, advocates preservation of open areas within the proposed project boundaries for various resource protection and recreation purposes.

Forest Lands

A) Malheur County's forest lands policies include the following (summarized):

1. By the first plan update, the county will determine the precise boundaries of commercial forest lands in Malheur County based on the cubic foot site class rating system.

2. The zoning ordinance will create an EFFU zone that will apply to commercial forest lands, and limit development within that zone to protect forest lands for all forest uses as defined by Statewide Planning Goal 4.

3. Noncommercial forest lands, which are mainly used for livestock grazing, will be zoned for ERU. The ERU zone limits development to protect rangelands and noncommercial forest lands for all forest uses as defined by Statewide Planning Goal 4.

4. The county will treat forest lands and agricultural lands equally, in that both resources will be protected in the same manner.

5. No residential subdivisions will be allowed on designated forest lands.

6. The county will work with the Oregon State Forestry Department and the Soil and Water Conservation District to support cost-share programs for forest management practices.

7. The Planning Department will work with appropriate public agencies to initiate necessary soil surveys to accurately describe and identify forest lands capable of producing commercial timber.

8. The County Court will appoint a citizens advisory committee on forestry to review the forest lands element of the comprehensive plan every three years, or whenever the Court finds a more urgent need.

B) None of the County's policies regarding forest lands are relevant to the Applicant's proposed project since none of the lands within the proposed project boundaries are forest lands.

C) No discussion of relevance of county policies, the Applicant's proposal, and water quality is necessary since none of the County's policies apply to the proposed project.

Open Space, Scenic and Historic Areas, and Natural Resources

A) Malheur County's policies on these resources include the following (summarized):

1. The county will establish land use regulations that will substantially preserve the open character of the undeveloped areas of the county.

2. The county will cooperate with other public agencies that manage open land in Malheur County.

3. The county will continue to study mineral and aggregate sites throughout the county to determine the precise location, quality, and quantity of these resources.

4. The county will establish land use regulations that protect mineral and aggregate resources from incompatible uses.

5. The county will cooperate with other government agencies in the enforcement of mining regulations.

6. The county will encourage the identification, exploration, and development of geothermal and other energy sources in the county.

7. The county will continue to study the location, quality and quantity of energy sources in the county.

8. The county will establish land use regulations that will protect the land base upon which subsurface energy sources are located.

9. Exploration and development of subsurface energy resources will be in conformance with the requirements of the Oregon Department of Geology and Mineral Industries.

10. The county may adopt an ordinance protecting access to the sun for solar energy.

11. The county will continue to cooperate with local, state, and federal agencies to identify the location, quality, and quantity of fish and wildlife habitat.

12. The county will consider the impacts of proposed development on fish and wildlife habitats when making land use decisions.

13. The ODFW's "Fish and Wildlife Habitat Protection Plan" will be recognized as a guideline for planning decisions.

14. The county will continue to recognize the contribution that fishing and hunting make to the economy and the total recreational needs of the county.

15. Within the next three years, the Planning Department will review the Nature Conservancy Inventory of potential natural and scenic areas and identify those sites that Malheur County believes are significant and should be protected as natural and scenic areas.

16. The Planning Department will continue to inventory the location, quality, and quantity of each natural and scenic area to be protected.

17. The county will cooperate with agencies responsible for the management of designated natural and scenic areas and encourage the expanded protection of these resources on publicly owned land.

18. The county will continue to inventory the location, quality, and quantity of its water resources.

19. The county will implement its water quality management plan.

20. The county will continue to consult the County Sanitarian in land use decisions.

21. The county will notify and consult with appropriate state agencies during review of development proposals that might affect surface or groundwater quality.

22. The county will encourage the public to take advantage of erosion control and resource management assistance offered by the NRCS and other agencies.

23. The county will cooperate with the ODEQ in protection of surface and groundwater resources.

24. The county will participate in the planning process and hearings procedure for the designation of wilderness areas.

25. The county will cooperate with public agencies that manage wilderness areas to assist in their protection.

26. The county will continue to inventory the location, quality, and quantity of all archeologic and historic buildings, sites, and artifacts in Malheur County.

27. The county will explore the availability of grants or other sources of funding to help preserve and protect the historic sites and structures in Malheur County.

28. The county will cooperate with the BLM in its efforts to preserve and protect the archaeologic and historic sites located on public land.

29. The county will protect its significant historic structures from conflicting uses, including major exterior alteration and demolition, by proceeding through steps 2 and 3 of the Goal 5 rule process on a site-specific basis at such time as conflicting uses are proposed. All alternatives for protection will be examined and the State Historic Preservation Office will be notified and permitted to comment.

30. The county will develop, adopt and apply a historic protection implementing measure consistent with Goal 5 requirements by the first plan update.

31. When sufficient information becomes available to identify the precise location of historic sites designated 1B, the county will continue through the Goal 5 rule process.

32. The county will investigate the possibility of waiving property taxes for historic structures subject to preservation regulations.

33. The county will cooperate with the Malheur County Historic Society to protect historic resources.

34. The county will protect individual land owners where structures or sites are located to ensure their property rights are safeguarded, gain their approval, and ensure compensation is made if privately owned land or buildings are condemned for the purpose of historic preservation.

35. The county will cooperate with other agencies in the development of recreation trails in the county, providing funds are made available from the state, and will initiate steps to ensure protection of private property, if and when any proposed trails cross private property.

36. If the trail designation is made, the county will apply the steps of the Goal 5 rule to that resource.

37. The county will cooperate with the state and the BLM in their efforts to protect the segments of the Owyhee River designated as a scenic waterway and will initiate efforts to protect the rights of private property owners whenever they overlap.

38. In the process leading to the possible future designation of additional segments of the Owyhee River as a State Scenic Waterway or a National Wild and Scenic River, the county will apply the steps of the Goal 5 rule to those resources.

B) Policies 1, 15, 16, 17, 22, 23, 27, and 28, relate indirectly to the Applicant's proposed project, while policies 6, 11, 12, 13, 14, 18, 19, 21, and 26 relate directly. Policy 1 advocates land use regulations to preserve open areas. All of the Applicant's land within the project boundaries is open, and is intended to remain open, consistent with this policy. Policies 15, 16, and 17 deal with identification and protection of natural and scenic areas. The Hells Canyon area is both a natural and scenic area. The Applicant has proposed measures in *New License Application: Hells Canyon Hydroelectric Complex* to lessen project impacts to visual resources. Policies 22 and 23 advocate coordination with the NRCS and the ODEQ to protect water quality. The Applicant is coordinating with these agencies in the relicensing of its hydroelectric project. Policies 27 and 28 commit County involvement in protecting historic sites and structures. The Applicant has conducted historic and archaeologic surveys, studies and evaluation in the county, and has made that information available to appropriate public agencies.

Policy 6 encourages the identification, exploration, and development of energy sources in the county. The Applicant's proposed project is an energy source and is therefore supported by this policy. Policies 11 and 12 address cooperation with state and federal agencies to identify fish and wildlife habitat, and consideration of impacts on such habitat from the proposed project. The Applicant has conducted widespread study on fish and wildlife habitat working with these agencies on its license application, and has assessed the project impacts to these habitats and proposed mitigation. Policy 13 establishes a plan of the ODFW as a guideline for planning decisions. The Applicant has evaluated the proposed project's consistency with ODFW plans as part of its federal license application. Policy 14 recognizes the importance of hunting and fishing for recreation and the local economy. The Applicant, as part of its federal license application conducted many recreational studies that also demonstrated their importance, as well as providing much more information about recreational use and needs. Furthermore, the Applicant has also proposed to provide substantial recreation improvements in the area as part of its new license requirements.

Policy 18 calls for the County to continue inventorying water quality within its boundaries. The Applicant has again conducted various studies of the water quality of the Snake River within the proposed project boundaries, which will provide the County with such information. Policy 19 states that the County will implement its water quality management plan. The Applicant has participated in the State's effort to develop a TMDL plan for this part of the Snake River Basin and will implement its committed measures to improve water quality once the TMDL is final. Policy 21 calls for consultation between the County and state agencies regarding proposed development. The Applicant has consulted with the County and the ODEQ during preparation of its federal license application.

Policy 26 states that the County will continue to inventory archaeology and historic buildings, sites and structures. The Applicant has conducted widespread surveys for historic and archaeologic resources that will contribute to the County's inventory.

C) Those policies discussed in B) that address fish habitat and water resources are linked directly to water quality. Policies 11 through 13 discuss fish habitat, which includes water bodies. Policies 18, 19, 21, 22 and 23 speak to location, quality, quantity, and protection of water resources. Those policies addressing open space, energy sources, and natural areas relate indirectly to water quality. Policy 1 would preserve the open character of undeveloped areas; providing for absorption of run-off. Encouragement of energy development in Policy 6 would include hydropower development, which affects water and water quality. Preservation of natural areas, advocated in Policies 15 through 17, also preserves absorption of run-off. The remaining policies discussed in B) are not related to water quality.

Air, Water, and Land Resource Quality

A) Malheur County's air, water, and land resource quality policies include the following (summarized):

1. The county will encourage monitoring throughout the county to determine present air pollution levels.

2. The Planning Department will gather information from private industry on any environmental quality monitoring that may be taking place.

3. Implementation of the Malheur County Water Quality Management Plan will be accomplished at the local level, providing the necessary funds are given to the county by the state without the need for additional taxes.

4. The County Court will designate the Malheur Soil and Water Conservation District as the management agency responsible for implementing the water quality management plan.

5. The County Court will give the Water Resources Committee the responsibility of advising the Court and the Soil and Water Conservation District on the implementation and revisions of the water quality management plan.

6. A five-year voluntary program period will be allowed prior to enforcement of regulatory water quality requirements of the plan.

7. Under the voluntary period of the water quality plan, BMPs will be considered as general guidelines for improvement of water quality by individual land owners.

8. In areas where water quality problems persist after the five-year voluntary period, appropriate BMPs will be determined following a site-specific analysis completed on a case-by-case basis.

9. Financial and technical assistance will be given to individual land owners through existing federal and state programs before implementation of BMPs will be expected.

10. The county will cooperate with the Soil and Water Conservation District, the Oregon State University Extension Service, and the Water Resources committee to help improve soil and water quality and conservation methods.

11. The county will update the comprehensive solid waste management plan of 1974.

12. The effects of transportation, industry, and other sources of excessive noise will be considered in evaluating proposed uses and development.

13. The county will require all developments and land uses to comply with state and federal environmental quality statutes, rules, and standards.

14. The county will work with the BLM and the U.S. Air Force to mitigate the impacts of low-flying aircraft if feasible.

B) Policies 2 and 13 apply directly to the Applicant's proposed project. Policies 3, 4, 5, 6, 7, 8, 9, and 10 apply indirectly. Policy 2 states that environmental quality monitoring information will be gathered from private industry. The Applicant has and continues to collect very large amounts of environmental monitoring data, which have been made available in its federal license application. Policy 13 requires all developments and land uses to comply with state and federal environmental quality requirements. The Applicant is working, through its federal license and state water quality certification applications, to comply with these requirements.

Policies 3 through 9 address implementation of the Malheur County Water Quality Management Plan. Policy 10 commits county cooperation with relevant agencies to conserve and improve soil and water quality. The Applicant has participated in development of the Snake River-Hells Canyon TMDL for both Oregon and Idaho, and has committed to achievement of its assigned allocations. Several water quality mitigation measures have been proposed in its federal license application and water-quality certification application.

C) All of the policies discussed in B) are directly relevant to water quality. Environmental monitoring information to be obtained in Policy 2 would include information on water quality. Policies 3 through 9 address implementation of the County's water quality plan and other water quality measures to improve surface and subsurface water resources. Policy 10 addresses water quality improvement through coordination with relevant agencies. Policy 11 addresses improvement of groundwater quality through solid waste management. Compliance with state and federal environmental requirements called for in Policy 13 includes water quality standards.

Areas Subject to Natural Disasters and Hazards

A) Malheur County's policies on areas subject to natural disasters and hazards include the following (summarized):

1. The county will establish a flood damage prevention ordinance using available studies and research data, and involve citizens in the review process.

2. The zoning ordinance will create a flood plain management zone.

3. Provisions of the flood plain management zone and the flood damage prevention ordinance will apply to the flood plain boundaries designated by the U.S. Department of Housing and Urban Development and the Federal Insurance Administration until flood plain boundaries can be redefined, taking into consideration the major flood control efforts that have taken place.

4. The county will request an comprehensive study by the U.S. Army Corps of Engineers to redefine the flood plain areas in Malheur County.

5. All development within the flood plains will be required to minimize potential hazards and losses of life and property.

6. All new inhabitable structures within the flood plains will be required to comply with standards established by the Federal Insurance Administration.

7. The location of emergency services facilities and other activities that may be identified by the County Court will be prohibited in the flood plains.

8. The county will continue to participate in the National Flood Insurance Program.

9. The Planning Department will work with the cities to establish conformity of city and county flood plain ordinances.

10. The county's subdivision ordinances will include provisions limiting subdivisions in the flood plain and establishing standards to ensure public health and safety.

11. The county will encourage the study of geologic hazards in the more populated areas of the county.

12. The county will cooperate with other governmental agencies to help protect life and property from natural disasters and hazards.

13. The county will distribute to the public all available information concerning natural disasters and hazards.

14. The county will support and cooperate with the Malheur County Emergency Services Office.

B) All of the 14 policies listed above are indirectly related to the Applicant's proposed project. The existing and proposed project includes a reservoir that is used by the U.S. Army Corps of Engineers to provide flood control within the floodplain of the Snake River. Therefore, policies 1 through 10, which deal with flooding and flood plains, are indirectly related to the proposed project. The project's FERC license requires study and monitoring of the potential for geologic hazards of all licensed dams. Considerable study of geologic hazards in the project area has therefore been undertaken by the Applicant, consistent with Policy 11. Policies 12 through 14 call for County coordination, activities, and support with other entities to protect life and property from natural disasters and hazards, including a possible earthquake or flood that would undermine the Applicant's project on the Snake River. The Applicant has prepared an Emergency Action Plan that is consistent with these policies.

C) Policies 1 through 11 are indirectly related to water quality. The remaining policies are not related. Flooding and floodplain issues can affect water quality by eroding soil and blowing out tributaries into the Snake River, and moving structures and substances into the river. Geologic hazards similarly can result in slides, faults and erosion that adversely affect water quality.

Recreational Needs

A) Malheur County's recreational needs policies include the following (summarized):

1. An on-going inventory will identify the needs and opportunities of county residents for parks and recreational facilities.

2. Continued recreation planning will be the responsibility of the Planning Department under the direction of the County Court.

3. The zoning ordinance will establish a park management zone to protect parks and recreation areas from incompatible uses.

4. The county will encourage development of their parks and recreation areas.

5. Communities will be encouraged to develop their own parks and recreation areas.

6. The county recognizes the importance of tourism to Malheur County's economy and will encourage tourism through the development of recreation opportunities.

7. The County Court will appoint a citizens advisory committee on recreation to review funding sources for park improvements and develop and implement tourism incentives.

8. The county will cooperate with the Oregon State Parks and Recreation Division, the BLM, and the other state and federal agencies that provide recreation opportunities in the county.

9. The county will cooperate with and encourage private enterprise to provide recreation opportunities such as camp facilities and resort areas.

10. When considering proposals for recreational development, the county will protect the resource base by considering factors such as wildlife habitats, range protection, and proximity to existing development.

B) Policies 1, 3, 6, 7, 8, and 10 are indirectly related to the Applicant's proposed project. The Applicant's reservoirs and lands in Malheur County and in adjoining counties are used extensively for recreational purposes. The Applicant's studies prepared for its federal license application include a great deal of information from user surveys about their recreational desires. Many of these users are from Malheur County. To identify needs and opportunities for park and recreational facilities, Policy 1 could incorporate use of the Applicant's survey information into decision-making. The Park Management Zone discussed in Policy 3 could be used to protect parks and recreational areas in the Applicant's proposed project area from incompatible uses. The Applicant's proposed project attracts tourism, consistent with Policy 6. The citizens' advisory committee discussed in Policy 7 could act to improve and develop tourism incentives provided by the Applicant's proposed project. In accordance with Policy 8, the Applicant has proposed improvements and maintenance to the Oregon State Parks and Recreation Division and the BLM recreation areas in its federal license application. Policy 10 mandates County protection of the resource base, including wildlife habitat and rangeland, when considering recreation proposals. In its federal license application, the Applicant analyzed resource conditions through a sensitivity analysis and established a plan to protect wildlife and habitat resources while enabling recreational use within the proposed project boundaries.

Policy 9 calls for county cooperation with and encouragement of efforts of private enterprise to provide recreation opportunities. The Applicant, a private enterprise, is providing recreational opportunities, consistent with this policy.

C) Policies 1, 3, 6, 7, 8 and 9 may be indirectly related to water quality since recreational use and development can cause erosion, thereby affecting water quality. Policy 10 is directly related to water quality since it commits the County to protect the resource base in its consideration of recreational development proposals.

Economic Development

A) Malheur County's economic development policies include the following (summarized):

1. The county will work with public and private sectors to maintain the high quality of life presently in the county.
2. The county will work with local, state, and federal agencies to improve the transportation network.
3. The county will zone adequate land for needed industrial and commercial development.
4. County land use regulations and land use decisions will encourage the continuation and expansion of existing industry and promote the development of new industry in Malheur County whenever possible.
5. The county may not arbitrarily prohibit, deter, delay or increase the cost of appropriate development, but shall enhance economic development and opportunity for the benefit of county citizens.
6. The county may zone non-urban land for industrial uses if the county finds the proposed industries are more appropriately located outside urban growth boundaries.
7. In implementing land use regulations and making land use decisions, the county will strive to achieve the following:
    a. develop available natural resources;
    b. create employment opportunities;
    c. expand and maintain existing industry;
    d. diversify agricultural products and the economic base; and
    e. broaden the tax base.

B) Policies 1 and 7 are interpreted by the Applicant to be indirectly relevant to the Applicants proposed project. While other policies might be interpreted to be related to the project in terms of industrial use and creation of jobs, none of the Applicant's hydroelectric facilities lie in Malheur County, and so in reality these other policies do not relate, even indirectly, to the Applicant's proposed project.

In accordance with Policy 1, the Applicant is a private sector business with whom the county coordinated in the early stages of its current relicensing project. Policy 7 calls for the County to support land use decisions that will develop natural resources and broaden the tax base. The Applicant's proposed project has developed natural resources (hydro power), and the Applicant's lands result in property taxes being paid to the County.

C) Both of the policies discussed in B) are directly related to water quality. Regarding Policy 1, although the County has not coordinated with the Applicant regarding water quality specifically, certainly water quality is a condition that directly affects quality of life. For Policy 7, the County's policy to support land use decisions that develop available natural resources could have an adverse or beneficial effect on water quality, as could such decisions that are made to broaden the tax base.

Housing

A) Malheur County's housing policies include the following (summarized):

1. The county will encourage the development of a variety of housing types and locations in a range of housing prices.
2. The county will riot discourage the use of manufactured housing or mobile homes and will encourage the cities to provide adequate land available for mobile homes within their urban growth boundaries.
3. The county will review the 1980 census information and other future census data and update the housing element of the comprehensive plan when necessary.
4. The county will work with private developers and governmental agencies to increase the number of rental units and keep vacancy rates at appropriate levels.
5. The county will work with the Farmers Home Administration, the Malheur Council on Aging, Oregon Human Development Corporation, and the Housing Authority of Malheur County to coordinate efforts so that needed housing programs are not duplicated or omitted.
6. The county will work with private developers, the Homebuilders Association, and the Board of Realtors to meet the housing needs of Malheur County residents.
7. The county will provide through zoning enough residential building sites to keep the cost of such sites at a reasonable rate.
8. Housing will be encouraged on land with the least agricultural productivity, in locations that complement existing development, make the most efficient use of required facilities, and present the least conflict with agriculture in the area.
9. In order to keep costs to citizens as low as possible, the county will approach the planning process with a view toward simplifying procedures and assisting citizens in accomplishing their objectives.
10. The county will work with the Farm Labor Sponsoring Association, the Housing Authority of Malheur County, and other interested individuals and groups to encourage the repair and upgrading of temporary migrant housing.
11. The county will encourage the rehabilitation and weatherization of existing housing.

12. The zoning ordinance will establish rural residential zones and provide standards for their development.

13. Adequate setbacks between rural residential zones and agricultural zones will be required in order to minimize potential conflicts.

14. Manufactured housing and mobile homes will be considered to be like all other single-family dwellings for the purpose of the zoning ordinance.

15. Lot sizes will be required to be large enough to adequately support a septic tank and well on each parcel.

16. The Planning Department will maintain, publish, and distribute housing statistics to help make private and public agencies aware of the county's needs.

B) None of these policies are relevant to the Applicant's proposed project.

C) Since none of the policies are relevant to the proposed project, there are no policies relevant to water quality.

Public Services and Facilities

A) Malheur County's public services and facilities policies include the following (summarized):

1. The county will seek and consider information from local fire and police departments concerning provision of services to future rural land developments.

2. The county will require all major development projects to have an adequate fire protection plan.

3. The subdivision ordinance will include fire protection standards for subdivisions.

4. The county will support and encourage the formation of fire protection districts whenever warranted by sufficient concentration of structures.

5. The county will encourage the selection of new school sites through cooperative planning by the school districts, cities, and the county.

6. The county will seek and consider information about school services, including bus service, in making land use proposals and decisions.

7. The subdivision ordinance will require school district recommendations on the approval of residential subdivisions.

8. When evaluating proposals for residential and other non- farm development, the county will consider water rights and the potential impact of the proposed development on nearby irrigated lands.

9. The county will require developers to he financially responsible for any undergrounding or other modification of irrigation and drainage canals made necessary by their development activities.

10. The Planning Department will work with the irrigation districts to establish policies concerning development proposals and water movement.

11. The county, in considering land use proposals, will ensure that the physical characteristics of the land that affect sewage disposal, water supply, and water quality are carefully considered.

12. The county will work closely with the cities to promote the orderly expansion and development of municipal water and sewage systems within the urban growth boundaries of Ontario, Nyssa, and Vale.

13. In rural service centers such as Farewell Bend and McDermitt, community sewage systems will be considered the appropriate type and level of water and sewage facilities.

14. In most other areas outside the Urban Growth Boundaries, individual wells and septic tanks will be considered the appropriate type and level of water and sewage facilities.

15. Privately owned water and sewage treatment facilities will be considered as an alternative to wells and septic tanks in some rural residential areas.

16. The county will update its 1974 Solid Waste Management Plan and seek ODEQ approval of the updated plan.

17. The county will continue to develop and manage the Lytle Boulevard landfill site to meet the county's year 2000 solid waste disposal needs.

18. The county will require utility companies to have proof of valid mobile home placement or building permits before extending or connecting utility services.

19. County road policies are stated under Goal 12 of this section.

20. To the greatest extent possible, new residential, commercial, and industrial areas shall be adjacent to areas that already are developed to permit the most efficient extension of public facilities and services.

B) Policy 11 may relate directly to the Applicant's proposed project since it addresses "land use proposals", and that characteristics of the land that affect water quality should be carefully considered. The various studies prepared by the Applicant on water quality enables the County to be consistent with this policy in any comments it might provide on the proposed project.

C) Policy 11 is directly relevant to water quality since it addresses water quality specifically.

Transportation

A) Malheur County's transportation policies include the following (summarized):

1. The County Court will adopt a road design, construction, and improvement ordinance.
2. All county road activities (except those concerning state highways) will comply with the Malheur County road design, construction, and improvement standards.
3. Plans for new transportation facilities will identify impacts on: (a) the transportation needs of all citizens, including the handicapped and the elderly; (b) environmental quality; (e) energy use and resources; (f) existing transportation systems; (g) fiscal resources; and (h) natural resources.
4. Transportation improvements and services that meet the needs of elderly and handicapped residents will be encouraged.
5. During design or improvement of transportation facilities, consideration will be given to pedestrian, bicycle, and equestrian traffic.
6. Conservation of energy will be a primary factor in the design and construction of transportation improvements.
7. Access to existing and potential aggregate resource sites will be maintained and protected through zoning regulations.
8. The extent and location of transportation facilities will be consistent with the comprehensive plan's policies for urban expansion.
9. Transportation facilities will minimize the division of existing economic farm units.
10. Access management on arterial highways will be coordinated with the ODOT.
11. Access control along collectors and arterials will be limited to the minimum required for reasonable use of the highway by the abutting property owner and, where possible, adjoining properties will share access.
12. The subdivision ordinance will provide access control,
13. Structures or storage within industrial areas having rail or air access will not preclude future rail or air access and/or spur extensions to other industrial and commercial sites in the vicinity; possible adjoining properties will share access.
14. The county will cooperate with cities and other governmental agencies to improve the transportation system.
15. The county will encourage the provision of adequate access to industrial zones in and around cities so that industrial zones can be accessed without going through downtown and residential areas.

Exhibit 4.3-2

16. County road improvements and maintenance needs will be identified and prioritized by the County Court, the Road Department, the Planning Department, and road districts on a regular basis.

17. County road improvements or maintenance projects that alleviate unsafe traffic conditions or improve safety will be given priority.

18. Any county road improvements or construction within an urban growth boundary will comply with the city's street improvement and construction standards.

19. The county will establish agreements with the cities that, whenever lands are annexed to a city, all county roads or segments thereof that are within or along the boundaries of the proposed annexation will be incorporated into the city's street system, thereby removing such roads from the county's road system.

20. Developers creating a demand for improvement of unimproved county or public use road rights-of-way will be responsible for those improvements. After the improvements have been made, the developer may petition the County Court to accept such roads, upon meeting county standards, into the county road maintenance program,

21. All realignments and new rights-of-way associated with county roads will be surveyed by the Road Department and recorded on the appropriate deeds, commissioners' journal, and/or other permanent county records.

22. County roads will be classified as principal arterials, minor arterials, major collectors, and local roads. Local roads will be further divided into primary local roads, secondary local roads, or special-use local roads.

23. Utility installations, cattle guards, and culverts within county road rights-of-way will comply with county standards, and the Road Department or appropriate road districts will be informed of installation dates and have control over the location. Permits must be acquired and approved by the County Roadmaster or appropriate road districts.

24. Any fence lines along county roads will be located on the right-of-way line between the county road and the adjoining property. The Road Department or appropriate district will be informed prior to installation and such installation will be at the landowners' expense.

25. Where state law permits, whenever a county road has been established and is not opened within two years from the date of the order establishing it or has not been used for vehicular traffic by the public for a period of 16 years, the road shall be reviewed by the County Court for vacation.

26. Any county road considered for vacation will be designated as a public use road unless it can be clearly shown that such right-of-way will never be desired for future public access.

27. All road maintenance agreements between the Road Department or road districts and other agencies, including but not limited to the cities, utility companies, the BLM, and the

USFS, will be in writing and filed with the County Court. These agreements will be reviewed at the annual meeting of the Road Advisory Board.

28. The County Court will coordinate road improvement and maintenance activities between the Road Department, road districts, and local, state, and federal agencies.

29. Keep with the State-County Directional signing and submit a sign order to the ODOT.

30. The County Court will appoint a Road Advisory Committee to review the county's transportation needs and to review the transportation element of the comprehensive plan every three years, or whenever a more urgent need exists.

31. The Road Department will be responsible for bridge inspections in the county. (The road Department may delegate this responsibility to agreeing road districts.)

32. The county will encourage the protection and improvement of present airport facilities.

33. The county will adopt and implement an airport approach zone to ensure the safe operation of airports and the development of a compatible environment around airports.

34. The county will participate in and encourage the adoption of airport master plans.

35. The Aeronautics Division will be included in the review process for development or use proposals that potentially impact airports in the county.

B) None of the County's policies supporting this goal are relevant to the Applicant's proposed project.

C) Since none of the policies are relevant to the project, there are no policies relevant to water quality.

Energy Conservation

A) Malheur County's energy conservation policies supporting include the following (summarized):

1. The county will recognize hydroelectric, geothermal, alcohol, solar, and wind, and solid waste as potential renewable energy sources and encourage their use.

2. Whenever possible, the county will use renewable energy resources in new county-owned buildings; all architects retained by the county will be directed by the County Court to consider renewable energy sources in the design of new county buildings.

3. The county will work with and support the U.S. Bureau of Reclamation in developing the proposed hydroelectric project at the Owyhee Dam site.

4. The county will encourage educational institutions to teach residents about conservation and potential renewable energy sources.

5. The county will make available to county residents and industry all information about the Known Geothermal Resource Areas and Potential Geothermal Resource Areas in the county.
6. The county may adopt an ordinance protecting access to the sun for solar energy.
7. The county Court will direct the Planning Department to apply for research funds and/or interns from state colleges and universities to research wind energy.
8. The county will consider an incinerator/recycling program as a method available for solid waste management arid a renewable energy source.
9. The county will encourage weatherization programs for new as well as existing buildings.
10. The county will direct the Planning Department to work with Oregon State University Extension Service specialists and educators to inform the public about weatherization and other energy conservation methods, as well as development of potential energy sources.
11. The County Court will evaluate the weatherization needs of all county buildings.
12. The zoning ordinance will encourage residential development in rural service centers, within urban growth boundaries, or in clusters or groups to minimize energy consumption.
13. The zoning ordinance will encourage industry to develop along existing highway, rail, and air transportation routes.
14. The county will encourage owners of existing structures to insulate and to meet standards designated in the Uniform Building Code.
15. The county will adopt a citizens advisory committee on energy to review the energy element of the comprehensive plan every three years, or whenever a more urgent need exists.
16. The County Court will appoint a task force to review the possibility of an incinerator/recycling program for solid waste disposal.

B) Policy 1 is directly related to the Applicant’s proposed project, while Policies 2, 4, and 10 are indirectly related. In Policy 1, Malheur County recognizes hydroelectric energy as potential renewable energy sources and encourages their use. The Applicant’s proposed project is a hydroelectric complex, and is therefore recognized by the County as renewable energy and encourages its use. In Policy 2, the County commits to use of renewable energy, which includes the Applicant’s hydroelectric energy, in its buildings. Policy 3 encourages educational institutions to inform residents about the use of renewable resources, which includes the Applicant’s proposed project. Education of the public about development of potential energy sources, which would include the Applicant’s project, is advocated in Policy 10.

C) Policies 1, 2, 4 and 10 discussed above relate directly to water quality since hydroelectric energy is a renewable energy resource and a potential energy source, and can have an effect on water quality.

Urbanization

A) Malheur County's urbanization policies include the following (summarized):

1. The county will work with the cities of Ontario, Nyssa, and Vale in establishing and amending urban growth boundaries and joint management agreements.

2. The county will coordinate all land use decisions within the urban growth boundaries.

3. The County Court will continue to hold joint city/county meetings to ensure coordination of planning efforts.

4. The county will establish and administer zones for each of the rural service centers, taking into account the desires of the citizens living in and around these centers.

5. The zoning ordinance will create rural residential zones and provide standards for their development.

6. The zoning ordinance will include provisions for the existing commercial, industrial, and residential uses in the rural areas of the county.

B) None of these policies are relevant to the Applicant's proposed project.

C) Since none of these policies are relevant to the project, neither is there a relevant link to water quality.

The Wallowa County Comprehensive Plan

Citizen Involvement

A) Wallowa County's citizen involvement policies include the following (summarized):

1. Select Planning Commission members to be broadly representative through public process.

2. Notify citizens of planning activities through the media to increase awareness of affected residents.

3. Make explanatory materials and their interpretation available to citizens.

4. Present planning issues to groups and interests to explain land use planning issues.

5. Provide opportunities for the public to respond to preliminary planning documents.

6. Form citizen committees to provide citizen input on issues of concern.

7. Provide written responses to planning inquiries and maintain these records.

B) Policies 2, 3, 4, 5, 6, and 7 are indirectly applicable to the Applicant's proposed project. Policy 1 requires Wallowa County implementation and, therefore, cannot be affected by IPC. The Wallowa County policies for citizen involvement are very similar to those of Baker County, therefore, the discussion regarding the relationship between the policies and the Applicant's proposed project for Baker County is relevant here also (see Baker County Comprehensive Plan: *Citizen Involvement*).

The Wallowa County Court was identified as a stakeholder in the collaborative relicensing process in 1996 and was invited to participate through a letter to that court. The County responded by attending CT meetings in 1997 and 1998. The County, in response to the FCP, submitted oral and written comments in 1997. Notices of meetings were then continually provided to the County by IPC during the remainder of the collaborative process. The County also sent representatives to one CT and two Recreation and Aesthetics RWG meetings in 2001. Also in 2001, at the request of the County, IPC provided a presentation to the County's Natural Resource Committee in Enterprise, Oregon regarding the development of the HCRMP and its content. The County's primary concern apparently was the compatibility of the HCRMP with the *Salmon Habitat Recovery Plan with Multi-Species Habitat Strategy* developed by the County and Nez Perce Tribe. Additionally, the County provided written comments on the *New License Application: Hells Canyon Hydroelectric Complex*.

C) All of Wallowa County's policies for citizen involvement addressed in B) indirectly relate to water quality. The policies provide input of public and agency values into the issues regarding development of water quality PME measures that address impacts of the Applicant's proposed project.

Land Use Planning

A) Wallowa County's land use planning policies include the following (summarized):

1. Coordinate planning decisions with other agencies that may affect, or be affected by, the decision.

2. Include consideration of city, regional, and county goals, objectives, and policies when making plan decisions.

3. Consider alternative uses for different locations in the adoption and revision of the plan.

4. Find occurrence of changes in conditions or related uses and areas, or errors in the original plan, before making plan changes.

5. Consider alternative sites for the proposed use(s) and determine that the proposal compares favorably with other areas that might be used for the same purpose, before making plan revisions.

6. Account for physical, social, economic, and environmental effects in plan changes.

7. Base planning decisions on fact.

8. Establish need (by the area, county, or other public) prior to making plan changes to accommodate uses that are more desirable and can be developed in other locations.

9. Require consistency of plan revision processes to the original planning process, with changes limited to no more than once every two years.

10. Utilize a public hearing process for minor plan changes, such as corrections or boundary realignment, by the Planning Commission and county court.

Policies 11 through 22 describe the purposes of the various zones established in Wallowa County, which are mostly irrelevant to the Applicant's proposed project since nearly all project lands in the County lie within the HCNRA and are therefore not subject to county zoning.

B) Wallowa County's policies on this issue address adoption of and revisions to the County's comprehensive plan, which is carried out solely by the County and, therefore, not relevant to the Applicant's proposed project. Furthermore, the proposed project, including the relicensing and § 401 certification of the HCC, involves an *existing land use*, which was considered and included in the adoption of the current and previous County comprehensive plans. However, Policy 7 calls for planning decisions to be made on a factual basis. IPC has provided 123 technical studies (about 17,075 pages) regarding many different aspects of the Proposed project and the surrounding environment. These reports provide factual information on which the County can base its decisions regarding the proposed project.

C) IPC conducted a number of the technical studies directly relevant to water quality issues. Others are indirectly related since they investigate resources and activities for which water quality is an important element of their habitat (anadromous, salmonid, and resident fish) or that may have some effect on water quality (e.g., riparian vegetation or human activity).

Agricultural Lands

A) Wallowa County's agricultural lands policies include the following (summarized):

1. Preserve capability classes II, III, IV, V, and VI wherever such land is suitable for continued agricultural use.

2. Approve conversion to residential/urban uses only if: (a) there is a need consistent with relevant plan objectives/policies; (b) suitable alternative locations are not available; (c) physical, social, economic, and environmental factors have been considered; (d) proposed uses will not interfere with normal farming practices; and (e) proposed uses will not create a burden on existing water rights and uses.

3. Protect rural character and open space activities of agricultural use to preserve scenery and lifestyle.

4. Separate urban uses from agricultural activities by transition areas.

5. Limit service extensions to those appropriate only for the needs of agriculture and farm and authorized non-farm uses.

6. Permit single family residential dwellings not related to farm use only upon finding that such proposed dwellings: (a) are compatible with farm uses; (b) do not interfere substantially with normal farming practices; (c) do not materially alter the stability of the overall land use pattern of the area; (d) are situated on generally unsuitable land for agriculture; and (e) comply with other conditions considered important by the County Court.

7. Qualify all acreages of 160 acres or more as farm units.

8. Retain public lands for multiple uses, emphasizing the agricultural bases where compatible with other uses.

9. Continue present use of private lands within the HCNRA.

B) Nearly all lands within the Applicant's proposed project boundaries in Wallowa County fall within the HCNRA and are therefore not generally subject to the County's policies for agricultural lands. However, policies 2, 3, 5, 6, 8, and 9 are applicable to IPC's HCRMP policies that are part of the license application for the proposed project. Several of the management policies included in the HCRMP are consistent with these policies, specifically including the following:

6.3.2.1. Development of areas in Hells Canyon that are currently undeveloped should be minimized because of the canyon's importance to natural and cultural resources and to the recreation experience in a relatively natural environment. Development should generally be clustered within an appropriately designated area, rather than dispersed.

6.3.2.11. Except for private residences associated with operations and maintenance of the HCC, IPC will not permit private residences on its lands. Where private residences already exist and have accidentally encroached on IPC lands prior to August 1, 2000, appropriate permits/easements may be issued.

6.4.1.1. *Community* areas are the foci of human activity in Hells Canyon. Clustering uses related to human activity will facilitate and protect these activities, and valuable natural and cultural resource areas will be protected from encroachment of human settlement.

Regarding the County's Policy 9, the proposed project would constitute continuance of present usage of private lands within the HCNRA and, therefore, would be consistent with this policy.

C) HCRMP policy 6.3.2.1. is directly relevant to water quality because retaining undeveloped environment contributes fewer pollutants to water bodies than development does and allows absorption of runoff. Policy 6.3.2.11., by minimizing private residences on IPC's lands, conserves greater open space, which, if maintained undeveloped, will contribute fewer pollutants to water bodies and continue to absorb runoff. Policy 6.4.1.1. will also contribute toward maintaining open space and natural environment, minimizing pollutants and runoff.

Forest Lands

A) Wallowa County's forest lands policies include the following (summarized).

1. Consider forest lands for multiple forest uses.
2. Approve conversion of timbered or grazing lands to residential uses based on the following: (a) compatibility with the Oregon Forest Practices Act; (b) lack of substantial interference with the physical, social, economic, and environmental conditions; and (c) not causing economic hardship to the county to provide facilities and services.
3. Minimize road development for forest uses. Revegetate temporary roads with forage, or erosion-controlling species, where necessary.
4. Confine powerline and non-road rights-of-way to minimum width; maintain forage and small trees, where compatible with rights-of-way purpose.
5. Restock harvested forest land in accordance with the Oregon Forest Practices Act.
6. Develop and implement harvesting logging systems in accordance with the Oregon Forest Practices Act.
7. Optimize sustained yield of timber and grazing resources.
8. Retain recreation potential and support services, where compatible with other uses.
9. Oppose further designation of wilderness areas.
10. Discourage clearing of Class I and II lands for agricultural purposes. Determine best use by comparing production capability.
11. Retain farm practices on Class III lands where compatible with other uses.
12. Encourage farm forestry and management plans on Class I and II forest lands.
13. Allow development of mineral resources, where compatible with other uses.
14. Prior to further withdrawals of public timberlands, provide economic impact statements and opportunity for agency and public response.

B) Nearly all lands within the Applicant's proposed project boundaries in Wallowa County fall within the HCNRA and are therefore not generally subject to the County's policies for forest lands. However, policies 2, 3, and 8 are applicable to the Applicant's proposed project and/or HCRMP. (Policy 4 isn't relevant to the project because transmission lines are not a part of this project but will be licensed through appropriate federal agencies.)

Several of IPC's management policies included in the HCRMP are consistent with the applicable policies. The following two HCRMP policies directly relate to the County's Policy 2. They are intended to avoid destruction of natural resources by residential development.

6.3.2.12. Except for private residences associated with operations and maintenance of the HCC, IPC will not permit private residences on its lands. Where private residences already exist and have accidentally encroached on IPC lands prior to August 1, 2000, appropriate permits/easements may be issued.

6.4.1.2. *Community* areas are the foci of human activity in Hells Canyon. Clustering uses related to human activity will facilitate and protect these activities, and valuable natural and cultural resource areas will be protected from encroachment of human settlement.

The following three HCRMP policies directly relate to the County's Policy 3. They are intended to require revegetation of disturbed areas, including temporary roads, and to minimize roads in Hells Canyon.

6.3.4.10 Following any significant human action, revegetation will be undertaken as soon as weather conditions permit (fall: September–October; spring: March–April) in accordance with aesthetic landscape standards, and proper maintenance conducted, or the disturbance will be treated through other BMPs.

6.3.7.1. Except where public safety and project security could be affected, IPC will continue to allow the public to use IPC project roads (though a fee is charged for commercial use).

6.3.7.2. Improvement of roads into and within the canyon would facilitate access of more and larger vehicles and of more people and would therefore increase potential conflicts with wildlife and other natural and cultural resources. Because lands suitable for recreation are limited and because of the importance of the canyon habitat for many wildlife populations, new and improvements to access to and within the canyon should be minimized.

The following HCRMP policy apparently has the same intent as the County's Policy 8—to recognize and preserve the recreational potential of land. Additionally, nearly all lands within the proposed project boundaries in Wallowa County are within the HCNRA, thereby having existing and potential recreational value.

6.3.9.14. Areas within and near the project boundary that are appropriate for developed recreation should be reserved for future recreation development and should be designated *recreation reserve.*

C) The relationship of HCNRA policies 6.3.2.12. and 6.4.1.2. to water quality were discussed above in the section on ***Agricultural Lands***. Policy 6.3.4.10. is directly applicable to water quality in that vegetation and other best management practices hold soil in place, thereby minimizing erosion of soils and transport of other pollutants into water bodies. Allowing the public to continue using IPC-owned and maintained roads (with fees for commercial use), stated in Policy 6.3.7.1, minimizes the need for additional roads for forest purposes, also minimizing the erosion of soils and runoff of other pollutants into water bodies. Minimization of new and improvements to roads to and within Hells Canyon, in Policy 6.3.7.2., is directly related to water quality as described for Policy 6.3.7.1. Policy 6.3.9.14, regarding recreation reserves, has limited, if any, relationship to water quality.

Open Spaces, Scenic and Historic Areas, and Natural Resources

A) Wallowa County's policies on these resources include the following (summarized):

1. Continue agriculture and forest uses to preserve open space.
2. Consider mineral and aggregate and potential hydroelectric power sites as desirable for development, wherever practical.
3. Protect fish and wildlife habitat under the Forest Practices Act and similar provisions.
4. Preserve Wallowa Lake basin moraines as scientific natural areas.
5. Recognize historical sites when they are developed or redeveloped.
6. Oppose extension of, or additional, wilderness area in the county.
7. Establish annual gravel removal sites.
8. Provide for review of any proposed development adjacent to municipal watersheds by the affected town.
9. Provide for review of any development that could alter or detract from scenic views and sites by the public for compatibility.
10. Complete the Goal 5 rule process when information becomes available for 18 sites and resources.
11. Address Goal 5 rule requirements when significant archeological sites are discovered on private lands.
12. Manage sites and resources classified as 2A to preserve original character.

B) Policies 2, 3, 5, and 9 may have some applicability to the proposed project. IPC's HCRMP contains many policies and its federal license application contains many proposed activities that are consistent with the Wallowa County's policies. Since these policies and activities are too numerous to list, a more general discussion is provided. The management direction determined for the HCRMP by the various participants in its development is "to provide for continued human use and opportunities in the Planning Area, while protecting natural and cultural resources." The HCRMP, therefore, contains policies and implementation measures intended to move land uses and the environment in this direction, addressing new development and other human actions; aquatic, botanical, wildlife, and cultural resources; access; public use, information, and safety; and recreation and aesthetics.

As part of its application for relicensing the proposed project with the federal government, the Applicant has proposed PME measures for natural and cultural resources and recreation. These measures include, but are not limited to, acquisition of substantial amounts of land to protect and enhance riparian and upland wildlife operations, to protect fall Chinook salmon spawning and incubation operations, to protect resident fish spawning, measures to improve dissolved oxygen conditions in and downstream of Brownlee Reservoir, measures to improve total dissolved gases below Brownlee and Hells Canyon reservoirs, a cultural resource management plan, and measures to lessen the aesthetic effects of the project on visual resources. Furthermore, the County's policy regarding the desirability of development of potential hydroelectric sites is consistent with the concepts of relicensing and certifying this proposed project.

C) Acquiring land to protect and enhance riparian and upland wildlife habitat is directly related to water quality. Most of the land would be expected to remain in a natural state and, therefore, minimize erosion of soils and transport of other pollutants into water bodies. Protection of riparian vegetation would preserve the natural filtration of runoff provided by wetland areas. Injection of oxygen into Brownlee Reservoir and reduction of total dissolved gases below Hells Canyon Reservoir would directly improve water quality for the benefit of fish resources. The cultural resource management plan would not be expected to affect water quality, nor would measures to lessen aesthetic effects of the proposed project on visual resources.

Air, Water, and Land Resource Quality

A) Wallowa County's air, water, and land resource quality policies include the following (summarized):

1. Assign high priority to maintaining or improving "the above goal."
2. Prohibit partitioning, subdividing, and other development that exceeds the carrying capacity of air, land, or water resources.
3. Cooperate and coordinate with state and federal agencies to meet common resource quality regulations.
4. Insist on compliance with resource quality regulations by state and federal agencies.
5. Notify municipalities of proposed development in their watersheds.
6. Utilize the Wallowa Lake basin water system improvements planning study as a guide for future water development.
7. Require compliance of development within Wallowa County with applicable state and federal environmental rules, regulations, and standards.
8. Cooperate with the ODFW to provide a more complete fish and wildlife inventory.
9. Enable public review of hydroelectric development proposals.

B) Policies 2, 3, 4, 7, 8, and 9 may be applicable to the Applicant's proposed project. In response to Policy 2, IPC's HCRMP sets forth policies intended to avoid development and other human activities that exceed the carrying capacity of land and water resources. Regarding policies 3, 4, and 7, the Applicant has worked and continues to work in developing its application for project relicensing with federal and state agencies to identify measures that will improve water quality and land resources, including measures to be implemented in the draft

Snake River–Hells Canyon TMDL process. Similarly, it has conducted a major effort since 1996 to determine applicable state and federal environmental rules, regulations, and standards (see the section on Citizen Involvement) and to incorporate proposals to comply with those requirements in its federal license application. The proposed PME measures of the license application and the policies stated in the HCRMP demonstrate this effort to comply. In response to Policy 8, during development of its license application, the Applicant developed 58 studies regarding fish and wildlife conditions in the Hells Canyon area. These studies dramatically augment the existing fish and wildlife inventory of this area. The collaborative effort to provide public and agency involvement, described above in the section on Citizen Involvement, enabled broad review of the project, consultation on studies undertaken for its relicensing, and proposed PME measures to mitigate for its presence, in accordance with Policy 9.

C) The HCRMP policies affect water quality both directly and indirectly. Some policies avoid practices (such as sidecasting during road maintenance) that directly contribute pollutants to water bodies. Other policies advocate actions (such as educating the public on ways that visitors can minimize damage to the environment during their visits) that will indirectly decrease pollutants to water bodies. IPC's efforts to work with agencies to define appropriate water standards and targets, studies, and TMDL measures will directly result in future improvements in water quality. Some of the studies conducted regarding fish and wildlife will have an indirect effect on water quality since water quality is a critical element of aquatic habitat and studies on wildlife habitat address riparian systems, which serve to improve water quality. The Applicant's collaborative effort used in the development of the license application indirectly contributes to water quality by identifying agency and public values in the process.

Areas Subject to Natural Disasters and Hazards

A) Wallowa County's policies on areas subject to natural disasters and hazards include the following (summarized):

1. Avoid development of hazardous areas with significant risk of major damage or loss of life.
2. Require flood-proofing of utilities and structures in areas that are likely to be inundated.
3. Utilize floodplains primarily for nonstructural and nonresidential purposes.
4. Utilize the National Flood Insurance Program as the guide for allowing development in floodplain areas.

B) Policies 1, 2, and 3 are relevant to the Applicant's proposed project. The FERC requirements for dam safety are considerable. In addition to having responsibility for day-to-day safety throughout the life of the proposed project, the Applicant must conduct substantial monitoring at various time intervals. When a project is constructed, various geologic studies, including evaluation by outside specialists, are made, and the results are major considerations in deciding whether or not to permit the project. At five-year intervals, a permittee is required to conduct dam safety inspections, which are required to involve technical specialists outside IPC. In the early 1990s, as part of the conduct of the dam safety inspection on the HCC, a seismic network was installed by IPC to monitor seismic activity in the area of the project. Monitoring of the data from that network was conducted between 1991 and 1999, at which time the FERC authorized discontinuing the monitoring. In 1993, an independent report was prepared that evaluated the potential for seismic damage to the project. An independent consultant conducted a dam safety inspection on the HCC this year, and the resulting report will be submitted by the FERC in November 2003.

The HCC provides substantial flood protection to areas downstream of the dams. In accordance with FERC requirements, IPC has prepared an emergency action plan to address unlikely but possible threats of dam failure. Included in the HCRMP is a policy for IPC to minimize the paving of large areas to limit impervious surfaces and, thus, maintain natural absorption, maintaining the flood-carrying capacity in the floodplain area. The hydroelectric use also maintains privately owned lands in open space.

C) Most of the activities described in B) have no relationship to water quality. The HCRMP policy calling for minimization of paving would indirectly affect water quality by conserving areas that provide absorption and thus filtering runoff. The maintenance of open space in the project area also contributes to runoff absorption and filtering in wetland/riparian areas.

Recreational Needs

A) Wallowa County's recreational needs policies include the following (summarized):

1. Incorporate local planning recommendations into state and federal agency plans.
2. Encourage cooperation among private property owners and governmental agencies in closing roads during deer and elk hunting seasons.
3. Assign a high priority to maintenance of the Lostine River and Hurricane Creek access roads.
4. Consider winter recreational development as desirable where economically feasible and environmentally suitable.
5. Protect anadromous fish spawning grounds.
6. Determine developed recreation suitability on basis of location, demand, carrying capacity, recreational fulfillment, environmental effects, economics, and related concerns.
7. Governmental agencies should consider the USFS land use plan, the ODFW plan, the Oregon State Park's six-year plan, and the county land use plan in recreation development.
8. Assign priority for recreation development to private enterprise where economically justifiable and where environmental protection can be assured.
9. Designate Wallowa Mountain Loop Road and the Upper Imnaha area as high priority for improvement and development of recreation facilities.

10. Provide for recreational development in the timber/grazing zone.
11. Pursue funding for two-way trail from Chief Joseph Monument to the Wallowa Lake Lodge.
12. Improve and develop additional public access points to Wallowa Lake and prohibit overnight use of these accesses.
13. Develop convenient access to Wallowa Lake for land-bound lots west of the lake.
14. Encourage development of a destination resort at or near Wallowa Lake.
15. Permit minor improvement of existing public parks where visitation is not increased or neighboring properties impacted.

B) Policy 5 is directly applicable to the Applicant's proposed project. Policies 2, 6, 7, 8, and 15 are indirectly relevant since the practices cannot be applied on IPC's lands in Wallowa County (within the HCNRA). In accordance with Policy 5, the Applicant has proposed to continue protection of fall Chinook salmon spawning and incubation according to the *Idaho Power Fall Chinook Interim Recovery Plan and Study*. The Applicant would consider closing public access on its maintenance roads during deer and elk hunting seasons in conjunction with Policy 2. In the development of its proposed project license application, the Applicant conducted studies that provide information about location, demand, recreational fulfillment, environmental effects, and other recreational issues consistent with the County's Policy 6. Furthermore, the license application includes proposals to conduct an adaptive management plan for recreation that will monitor use and demands on an annual and a six-year basis (see *New License Application: Hells Canyon Hydroelectric Complex*, section E.5.4.4.1.5.). IPC has incorporated many suggestions of local, state, and federal agencies into its proposed recreation improvements and has evaluated these proposals in terms of agency plans (Policy 7). The Applicant's proposals for improvement and development of recreation areas proposed in its federal license application are consistent with the County's Policy 8 since IPC is a private corporation. Actions enhancing recreation in the area contribute to the county economy by further attracting recreationists to the area.

C) The actions described in B) are generally not related to water quality, although recreation planning and activity could indirectly affect water quality in terms of introducing human use, which often involves disturbance of the natural environment and introduction of runoff that carries pollutants into water bodies.

Economic Development

A) Wallowa County's economic development policies include the following (summarized):

1. Maximize retention of land for farm and forest uses.
2. Provide encouragement and support to private recreational developments when compatible with other uses.

3. Coordinate all state and federal plans affecting economy with local needs and provide economic impact statements prior to plan adoption.

4. Expedite permit procedures for economic development, where compatible with other uses and values.

5. Encourage diversification of home-based industry.

6. Consider the revised overall economic development plan as the guide for the county when compatible with this plan.

7. Encourage industries utilizing local materials or having a large segment of market within the county if the location will not adversely affect housing, service costs, or other factors contributing to Wallowa County's desirable lifestyle.

B) Policies 3 and 7 are relevant to the Applicant's proposed project. Policy 2 would be relevant except that all existing and proposed project lands in Wallowa County are within the HCNRA. The FERC process of relicensing the HCC and Oregon's § 401 water-quality certification process provides opportunities for local input. Economics will be considered in the environmental impact statement prepared for the project (Policy 3). Regarding Policy 7, IPC is one of the largest taxpayers, if not *the* largest taxpayer, to Wallowa County, having paid $380,001.81 of the county's $5,319,000.00 tax collected in 2001, or 7%. IPC also provides electrical service to some residents of the county who reside in isolated locations that are uneconomical to service from other systems in the county. Consistency of the Applicant's proposal with recreational policies was discussed in the previous section on recreation.

C) Both the FERC relicensing process and § 401 water-quality certification process have a direct relation to water quality since both processes include study and possible measures to improve water quality. The remainder of activities described in B) are not related to water quality.

Housing

A) Wallowa County's housing policies include the following (summarized):

1. Encourage maximum utilization of vacant land within city limits.

2. Provide a range of housing prices and a variety of housing types and locations.

3. Provide services to city areas before extending them to unincorporated areas.

4. Establish a rural residential zone with a five-acre minimum lot size to facilitate housing demand and variety.

B) Policy 2 may be directly related to the Applicant's proposed project. IPC provides housing for more than half of its HCC employees at Oxbow and Brownlee villages, close to their workplace. This would seem to be consistent with the County's Policy 2.

C) Provision of housing for employees in the proposed project area by the Applicant is not related to water quality.

Public Services and Facilities

A) Wallowa County's public services and facilities policies include the following (summarized):

1. Develop urban uses and densities only where required services and facilities are available.
2. Strictly enforce the solid waste ordinance.
3. Approve rural subdivisions only when all required services are, or can be, made available.
4. Encourage rural residences to locate in areas with required levels of service available.
5. Annex lands to cities only when they are capable of providing desired services and facilities without burdening existing residents.
6. Coordinate planned levels of service within urban growth boundaries.
7. Locate utility lines and similar services within existing transportation right-of-way whenever possible.
8. Give high priority to funding services to the Wallowa Lake basin.

B) Policies 1, 3, and 4 are indirectly applicable to the Applicant' proposed project. IPC's major transmission lines in Wallowa County are not a part of the federal license or § 401 certification applications, making Policy 7 irrelevant to the proposed project. As stated in the previous section, IPC provides electrical service to some residents of the County who reside in isolated locations along IPC's transmission line: locations that are uneconomical to service from other systems in the County. This would seem to be consistent with these policies of the County's plan since the County's intent is to provide necessary services to residents while minimizing the cost of services to existing residents.

C) The provision of electric service by IPC to rural residences removed from other systems is not relevant to water quality.

Transportation

A) Wallowa County's transportation policies include the following (summarized):

1. Improve maintenance on the county and state highway systems.
2. Encourage continued and improved rail transportation of goods.
3. Encourage state and local governments to improve and maintain airport facilities.
4. Encourage the federal government to improve the existing road system and bridges within the HCNRA.
5. Encourage coordinated planning between the county and USFS on road matters.

6. Allow subdivisions only in those areas where winter road maintenance provides year-round access.

7. Consider improved access to the Hells Canyon overview to be desirable.

8. Enforce a 100-foot setback for the entire length of Highway 82 through Wallowa County.

9. Cooperate with the ODOT in implementing the ODOT six-year highway improvement program.

The County's policies are not relevant to the Applicant's proposed project, and the project proposes no policies or activities relevant to these policies.

Energy Conservation

A) Wallowa County's energy conservation policies include the following (summarized):

1. Protect potential hydroelectric sites.

2. Locate rural residential zoning in areas adjacent to towns and where such areas can be easily serviced.

3. Encourage and expedite permit procedures for dwellings using solar energy.

4. Encourage use of forest wastes as an energy source.

5. Prefer renewable energy resources to nonrenewable resources.

6. Encourage development where access and services are available, rather than extending services to new areas, which increases energy costs and consumption.

B) Policies 1, 5, and 6 are applicable to the Applicant's proposed project. IPC's hydroelectric project is an existing project and, therefore, would be expected to warrant County protection at least comparable to potential hydroelectric sites (Policy 1). IPC's policy regarding minimization of development in undeveloped areas and advocating clustering of development instead of dispersal (discussed above in sections on Agricultural Lands and Forest Lands) is consistent with the County's Policy 6. Dispersal of development, as opposed to clustering, requires greater amounts of energy for transportation, as well as higher costs to serve fewer people. Finally, IPC's existing and proposed project generates electric power from water, a renewable resource, as opposed to generation from coal or gas, both of which are nonrenewable resources, and is therefore consistent with Policy 5.

C) Existing hydroelectric projects are related to water quality because of the changes to the natural flow of water that they often cause. The changes can result in both adverse and beneficial effects to water quality. Maintenance of undeveloped areas by consolidating development benefits water quality by maintaining absorption of runoff and minimizing erosion. Generation of electric power from water, a renewable resource, is related to water quality as described above in this paragraph.

Urbanization

A) Wallowa County urbanization policies include the following (summarized):

1. Use urban growth boundaries as guidelines to plan services and annexations.
2. Change urban growth boundaries only after determining that a need for additional urban area exists and urban services can be provided to the area without further financial burden to existing residents.
3. Discourage urban uses from sprawl, which can increase service costs, cause transportation congestion, and cause transition of land away from agriculture and timber production.
4. Reasonably maximize utilization of land within cities before annexation of additional land occurs.

B) These policies are indirectly relevant to the Applicant's proposed project. IPC's HCRMP policies regarding minimization of development in undeveloped areas, clustering of development rather than dispersion, and nonparticipation in road improvements into and within Hells Canyon, as well as the servicing of remote residences with electric power from IPC's system (discussed in preceding sections on Agricultural Lands, Forest Lands, Public Services and Facilities, and Energy Conservation), are consistent with the County urbanization policies. These policies encourage development in existing communities, conserving resource lands for other uses. Servicing residences in remote areas minimizes costs of facilities and services.

C) Policies described in B) are related to water quality in that they preserve open, natural areas for absorption of runoff and minimize soil erosion.

Exhibit 6.1-1

Supporting information for the presence of cold water refugia (CWR) from tributaries and drainages from Hells Canyon Dam downstream to Lewiston, Idaho.

Exhibit 6.1-1
Supporting information for the presence of cold water refugia (CWR) from tributaries and drainages from Hells Canyon Dam downstream to Lewiston, Idaho.

This exhibit summarizes an analysis of the presence of Cold Water Refugia (CWR) to the mainstem Snake River downstream of Hells Canyon Dam to Lewiston, Idaho. The analysis was conducted at two levels: 1) a high-level reconnaissance of the number of perennial and intermittent streams that flow into the Snake River in this area along with a comparison of temperature data collected in 2003 and 2004 from several of the perennial streams relative to the Snake River at RM 202; and 2) a comparison of daily mean temperatures through a diel cycle of a subset of perennial streams to the Snake River relative to the Oregon definition of CWR.

Level One: High Level Reconnaissance

The metric for this high-level comparison was monthly means during the months of May through October. A Geographic Information System (GIS) analysis conducted to itemize the number, name and location of perennial streams that flow into the Snake River from Hells Canyon Dam downstream to Lewiston, Idaho (Figure 1 through Figure 5). A total of 132 perennial (Table 1) and 813 intermittent streams were identified from the National Hydrography Dataset (NHD, http://nhd.usgs.gov/ accessed October 2015). All of these streams have the potential to provide cold water refugia for migrating salmonids. During 2003 and 2004 IPC collected temperature data of surface flows from a subset of the 133 perennial streams. A summary of the data shows that during the summer months of July through September the majority of the perennial streams measured provide potential refugia as defined as cold water that was ≥3°C colder than the mainstem Snake River (Tables 2 and 3). These measurements do not include the potential additional benefit of subsurface flow upwelling into the Snake River at these stream mouths.

Table 1.
Perennial streams that may serve as thermal refugia that enter the Snake River in Hells Canyon between Lower Granite Reservoir and Hells Canyon Dam based on the NHD. Numbers in the Perennial Stream ID correspond to numbers in the plates (Figures 2 through 5) showing location and distribution of the perennial streams in this Exhibit.

Perennial Stream ID	Perennial Stream Name	Snake River Mile	State	Snake Elevation (ft msl)	Headwater Elevation (ft msl)	Length (km)
1	Buffalo Draw	160.6	Idaho	795	3711	5.6
2	Unknown	159.2	Idaho	782	1460	1.0
3	Cook Creek	183.6	Oregon	879	5323	18.9
4	Somers Creek	210.1	Oregon	1101	3983	7.6
5	Willow Creek	227.6	Idaho	1262	3829	1.8

Perennial Stream ID	Perennial Stream Name	Snake River Mile	State	Snake Elevation (ft msl)	Headwater Elevation (ft msl)	Length (km)
6	Rush Creek	231.3	Oregon	1284	4102	5.5
7	Salt Creek	222.5	Oregon	1212	3354	5.7
8	Highrange Creek	206.5	Idaho	1076	4390	6.8
9	Thorn Creek	202.4	Idaho	1037	2085	2.3
10	Camp Creek	209.9	Oregon	1102	4026	4.9
11	Kirkwood Creek	220.5	Idaho	1197	6210	10.6
12	Getta Creek	205.6	Idaho	1063	5189	14.4
13	Big Canyon Creek	210.8	Idaho	1104	4432	8.7
14	West Creek	213.7	Idaho	1115	2754	4.7
15	Kurry Creek	214.4	Idaho	1130	2847	6.2
16	Corral Creek	217.1	Idaho	1162	4624	7.4
17	Tammany Creek	143.7	Idaho	749	1363	11.6
18	Cherry Creek	185.3	Oregon	882	5137	17.7
19	Cottonwood Creek	181.1	Idaho	875	3422	6.4
20	Bernard Creek	235.2	Idaho	1345	6898	7.5
21	Steep Creek	229	Idaho	1270	4975	3.7
22	Tryon Creek	209.5	Oregon	1098	3706	4.5
23	Divide Creek	193.2	Idaho	959	4689	23.9
24	Two Corral Creek	222.3	Oregon	1212	3147	4.0
25	Lookout Creek	208.2	Oregon	1089	2750	3.0
26	Big Canyon	193.7	Oregon	962	1417	0.8
27	Robinson Gulch	198.5	Oregon	999	1831	1.2
28	Saddle Creek	236.2	Oregon	1355	6686	14.0
29	Deep Creek	247.5	Idaho	1527	6794	16.6
30	China Garden Creek	176.1	Idaho	858	4411	7.4
31	Unknown	151.6	Idaho	788	1884	1.4
32	Stud Creek	245.9	Oregon	1477	4843	4.8
33	Tenmile Creek	150.3	Washington	759	2721	20.8
34	Granite Creek	239.6	Idaho	1382	6809	17.7
35	Sand Creek	228	Oregon	1267	3832	5.6

Perennial Stream ID	Perennial Stream Name	Snake River Mile	State	Snake Elevation (ft msl)	Headwater Elevation (ft msl)	Length (km)
36	Sluice Creek	231.8	Oregon	1290	3952	5.5
37	Unknown	149	Idaho	751	1809	3.5
38	Unknown	147.9	Idaho	749	1045	1.0
39	Cache Creek	177.1	Oregon	864	3187	5.6
40	Unknown	166.4	Idaho	805	1542	1.0
41	Jones Creek	208.5	Idaho	1090	3847	4.5
42	Klopton Creek	216.2	Idaho	1163	3878	6.3
43	Captain John Creek	162.4	Idaho	800	3579	9.7
44	Cougar Creek	220.5	Oregon	1198	3785	5.5
45	Corral Creek	175.4	Idaho	853	4485	10.5
46	Temperance Creek	223.8	Oregon	1230	6611	13.3
47	Pleasant Valley Creek	213.6	Oregon	1112	3470	4.2
48	Three Creek	238.1	Idaho	1366	6728	5.1
49	Hells Canyon Creek	246.8	Oregon	1516	4669	4.0
50	Bean Creek	201.7	Oregon	1035	1771	1.3
51	Hominy Creek	223.3	Oregon	1221	5134	7.2
52	Wild Sheep Creek	241.3	Oregon	1402	4845	3.0
53	Unknown	143.5	Washington	750	1681	5.3
54	Roland Creek	203.4	Oregon	1045	1712	1.3
55	Asotin Creek	145.2	Washington	747	1674	22.1
56	Couse Creek	157.6	Washington	780	3610	16.5
57	Unknown	167.5	Idaho	812	1585	1.0
58	Anaconda Creek	172.3	Washington	838	2510	2.0
59	Cave Gulch	177.2	Idaho	865	2570	4.5
60	Unknown	148.6	Idaho	749	1313	1.2
61	Unknown	168.3	Idaho	817	1437	1.7
62	Unknown	163.4	Idaho	794	2958	3.3
63	Brush Creek	244.7	Idaho	1442	5427	2.8
64	Christmas Creek	201	Oregon	1034	1835	1.3
65	Redbird Creek	155.6	Idaho	786	2992	8.2

Perennial Stream ID	Perennial Stream Name	Snake River Mile	State	Snake Elevation (ft msl)	Headwater Elevation (ft msl)	Length (km)
66	Unknown	157.1	Idaho	784	2089	1.2
67	Unknown	153.5	Idaho	815	2127	1.2
68	First Creek	187.1	Idaho	906	2501	2.4
69	Bull Creek	241.2	Oregon	1401	3987	2.8
70	Frenchy Creek	185	Idaho	882	3104	3.3
71	Hat Creek	235.8	Oregon	1350	5587	5.5
72	Big Cougar Creek	179.5	Idaho	869	2202	3.1
73	Muir Creek	218.9	Oregon	1201	3381	3.8
74	Unknown	154	Washington	769	2643	3.8
75	Unknown	154.5	Idaho	775	1978	1.2
76	Garden Creek	178.1	Oregon	865	1629	2.0
77	Dough Creek	170.7	Idaho	830	3124	4.7
78	Unknown	142.4	Idaho	754	1358	1.9
79	Kirby Creek	218.8	Idaho	1200	3815	3.8
80	Copper Creek	205.1	Oregon	1056	3201	2.3
81	Thorn Spring Creek	199.8	Oregon	1014	3927	2.9
82	Cache Creek	239.2	Oregon	1377	4867	3.1
83	Chimney Creek	171	Idaho	833	2838	4.7
84	Billy Creek	164.9	Idaho	800	2020	3.3
85	Sandal Gulch	161.9	Washington	797	2959	4.0
86	Battle Creek	242.2	Oregon	1415	5014	5.1
87	Unknown	147.9	Washington	748	2038	3.0
88	Unknown	147.3	Idaho	753	1685	2.0
89	Durham Creek	218.1	Oregon	1163	1896	1.9
90	Unknown	144	Washington	763	1626	2.7
91	China Creek	192.5	Oregon	955	1358	0.6
92	Fisher Gulch	165.6	Washington	801	3586	10.0
93	Blind Creek	237.1	Idaho	1360	4087	1.8
94	Unknown	164	Idaho	803	3700	4.8
95	Unknown	141.3	Idaho	742	1326	2.9

Perennial Stream ID	Perennial Stream Name	Snake River Mile	State	Snake Elevation (ft msl)	Headwater Elevation (ft msl)	Length (km)
96	Perkins Gulch	164.9	Washington	800	3137	3.8
97	Unknown	163.6	Washington	798	2967	4.1
98	Unknown	153.8	Idaho	768	1444	1.1
99	Birch Creek	196.7	Oregon	989	2188	1.9
100	Schoolhouse Draw	157.3	Washington	781	2883	5.6
101	Unknown	194.4	Oregon	970	1849	1.1
102	Unknown	147.7	Idaho	748	1777	2.9
103	Gilmore Gulch	158.9	Washington	782	2789	3.2
104	Thiessen Canyon	159.5	Idaho	785	2785	3.5
105	Unknown	159.4	Idaho	783	1674	1.4
106	Yreka Creek	228.6	Oregon	1269	2995	1.2
107	Fench Gulch	197.2	Oregon	991	1809	1.2
108	Jim Creek	182.5	Oregon	877	1920	2.6
109	Birch Creek	173.2	Washington	843	2550	3.4
110	Ten Mile Canyon	151.3	Idaho	758	2394	9.2
111	Unknown	159.1	Idaho	780	1845	1.3
112	Bills Creek	233.1	Idaho	1319	4954	3.4
113	Unknown	160.8	Idaho	797	2801	2.0
114	Unknown	146.7	Washington	747	1519	2.1
115	Bar Creek	201.9	Oregon	1034	1759	1.1
116	Unknown	152.3	Idaho	761	1992	1.3
117	Camp Creek	166.1	Idaho	803	3190	3.9
118	Cat Gulch	218.2	Idaho	1167	1928	0.9
119	Unknown	164.2	Idaho	806	1388	1.1
120	Unknown	165.9	Idaho	802	1685	1.5
121	Unknown	168.2	Washington	816	2505	2.3
122	Crowers Canyon	157.6	Idaho	782	2723	4.3
123	Unknown	146.8	Idaho	747	1474	1.6
124	Unknown	169.6	Washington	825	2510	2.1
125	Unknown	153.1	Idaho	762	1536	1.0

Perennial Stream ID	Perennial Stream Name	Snake River Mile	State	Snake Elevation (ft msl)	Headwater Elevation (ft msl)	Length (km)
126	Wolf Creek	203.1	Idaho	1041	4884	24.2
127	Grande Ronde River	168.7	Washington	819	960	13.7
128	Salmon River	188.2	Idaho	904	971	8.1
129	Deep Creek	199.1	Oregon	1003	5525	20.7
130	Sheep Creek	229.4	Idaho	1273	6635	16.4
131	Imnaha River	191.6	Oregon	1018	5326	116.3
132	Dug Creek	198.1	Oregon	997	2511	3.2

Table 2.
Average monthly temperature (AMT) during 2003 of the Snake River measured at approximately RM 202 during the months of May through October compared to the AMT at several perennial streams distributed throughout Hells Canyon (represented as differences relative to the Snake River, a negative value indicates the tributary being colder than the value of the mainstem Snake River).

Year		**2003**					
Month		**5**	**6**	**7**	**8**	**9**	**10**
	RM	**Monthly Mean Temperature (C)**					
Snake River	202	**12.9**	**17.5**	**20.5**	**22.4**	**21.3**	**17.7**
Tributary		**Difference in degrees C from the Snake River**					
Deep	247	-5.5	-8.5	-7.2	-8.9	-10.1	-7.9
Hells Canyon	246.5	-1.5	-2.5	-5.0			
Brush	244.8	-4.3	-8.5	-10.1	-11.5	-11.1	-7.9
Battle	242.3	-2.8	-5.0	-4.6	-6.1	-7.7	-5.6
Granite	239.6	-5.2	-7.1	-6.0	-7.8	-9.4	-7.4
Three Creeks	238	-3.7	-7.1	-8.9	-11.0	-11.0	-7.9
Hat	235.8	-1.1	-4.5	-7.5			
Saddle	236.1	-2.7	-3.5	-2.7	-4.8	-7.2	-5.7
Bernard	235.3	-5.5	-7.7	-6.5	-6.9	-8.3	-6.2
Sluice	231.8	-2.2	-4.9	-6.2	-5.5	-7.6	-5.1
Rush	231.5	-0.5	-4.3	-5.0	-5.4	-6.5	-4.5
Sheep	229.4	-4.7	-7.2	-6.8	-8.7	-9.8	-7.4
Temperance	223.7	-2.9	-2.7	-0.5	-2.7	-5.5	-4.6
Salt	222.6	-0.6	-3.1	-5.3	-7.2	-7.2	-4.0
Kirkwood	220.4	-3.6	-5.5	-4.5	-6.2	-7.8	-6.0
Pittsburg	215.3	-0.2	-3.2	-3.6			
Big Creek	210.8	-0.8	-2.9	-1.9	-2.0		
Somers	210.1	-1.0	-2.4	-1.2	-3.2	-6.3	-5.3
Tryon	209.5	0.0	-1.7	-2.3			
Getta	205.6	-1.0	-1.6	-0.2	-2.8	-6.2	-5.4
Cat	204	0.0	-1.6	-1.5			
Wolf	203	-0.1	-0.2	1.7	-0.7	-5.0	-4.9
Deep	199.1	-2.8	-1.4	0.2	-1.9	-5.6	-5.0
Divide	193.2	0.2	-1.0	0.1	-2.6	-5.9	-4.9
Imnaha	191.7	-2.6	-3.4	0.9	-0.8	-4.3	-5.5
Eureka	191	-1.0	-2.5	-0.3			
Knight	190.4	-0.8	-3.2	-2.8			
Salmon	188.3	-2.2	-3.4	-0.8			-5.7
Grande Ronde	168.7						-9.0

Table 2.
Average monthly temperature (AMT) during 2004 of the Snake River measured at approximately RM 202 during the months of May through October compared to the AMT at several perennial streams distributed throughout Hells Canyon (represented as differences relative to the Snake River, a negative value indicates the tributary being colder than the value of the mainstem Snake River).

Year	**2004**					
Month	**5**	**6**	**7**	**8**	**9**	**10**
	Monthly Mean Temperature (C)					
Snake River	**14.0**	**17.1**	**20.3**	**22.0**	**20.6**	**17.6**
Tributary	**Difference in degrees C from the Snake River**					
Deep	-6.4	-7.5	-7.4	-8.5	-9.8	-9.4
Hells Canyon	-3.9	-3.8	-4.1	-4.7	-4.3	-3.1
Brush	-5.3	-8.3		-11.3	-10.6	-8.4
Battle	-4.7	-4.9	-5.3	-6.2	-7.6	-7.0
Granite	-6.2	-6.7	-6.6	-8.0	-9.5	-9.2
Three Creeks	-5.1	-7.0	-9.1	-10.7	-10.4	-8.6
Hat	-3.5	-4.4	-7.5	-8.0	-8.2	-6.1
Saddle	-4.2	-3.7	-3.2	-5.0	-7.0	-7.4
Bernard	-6.7	-7.4	-6.6	-7.1	-8.5	-8.2
Sluice	-4.1	-4.6	-6.3	-6.6	-7.2	-5.6
Rush	-2.8	-4.0	-4.9	-6.7	-7.1	-6.0
Sheep	-5.8	-7.1	-7.3	-8.7	-9.7	-8.9
Temperance	-4.3	-3.3	-1.5	-3.0	-6.2	-7.1
Salt	-3.3	-2.6	-1.9	-4.2	-6.0	-6.1
Kirkwood	-4.9	-5.1	-4.7	-6.0	-7.7	-7.5
Pittsburg						
Big Creek	-3.2	-4.1	-3.7	-4.5	-6.2	-6.3
Somers	-3.9	-3.7	-2.2	-3.1	-6.3	-7.2
Tryon	-2.2	-4.1	-1.5	-1.9		
Getta	-3.6	-3.6	-1.8	-3.4	-6.5	-7.3
Cat						
Wolf	-2.4	-2.7	0.6	-1.3	-5.2	-6.6
Deep	-4.0	-3.8	-0.2	-2.3	-5.8	-7.1
Divide	-2.3	-2.5	-0.6	-2.7	-5.7	-6.6
Imnaha	-3.1	-2.3	0.6	-0.8	-4.5	-6.4
Eureka	-2.1	-3.1	-3.0			
Knight	-2.2	-3.0	-2.9	-4.5	-6.7	-6.9
Salmon	-2.9	-2.1	1.3	-0.2	-4.3	-2.8
Grande Ronde	-1.1		3.8	0.4	-3.9	-6.4

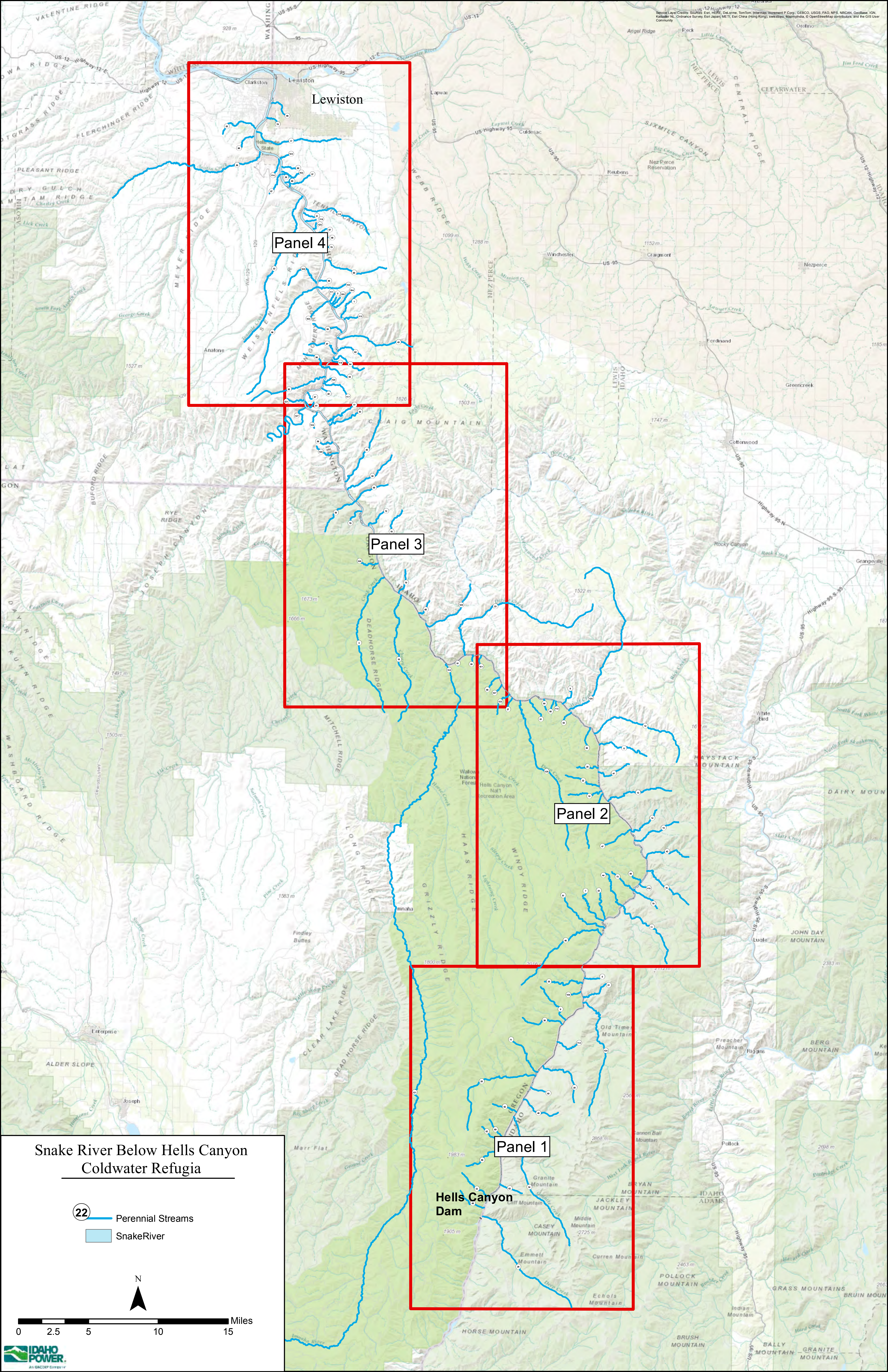
Figure 1.
Vicinity area map and panel references for perennial streams from Hells Canyon Dam downstream to Lewiston, Idaho.

Figure 2.
Panel 1 showing perennial streams flowing into the Snake River below Hells Canyon Dam.

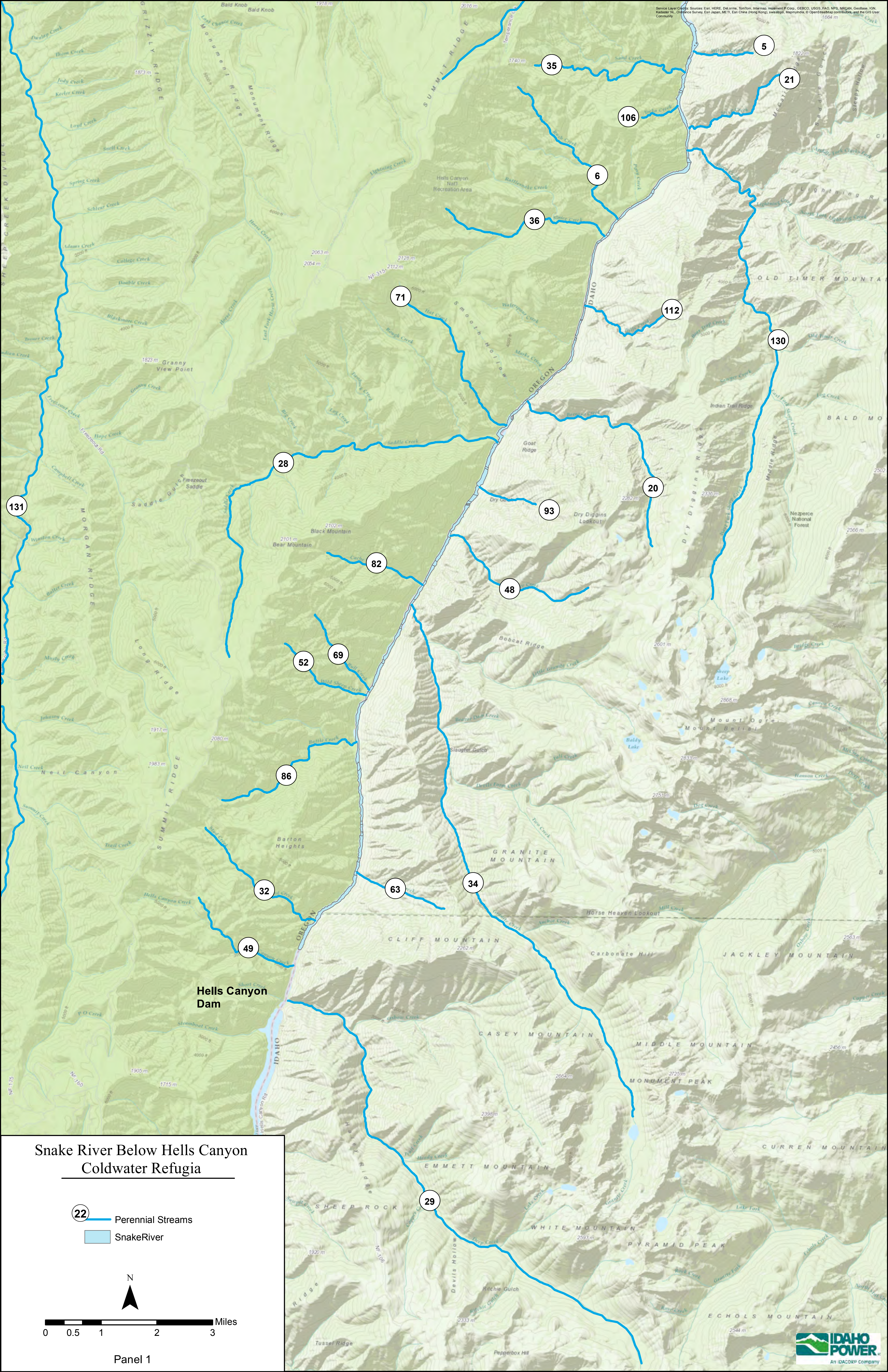
Figure 3.
Panel 2 showing perennial streams flowing into the Snake River below Hells Canyon Dam.

Figure 4.
Panel 3 showing perennial streams flowing into the Snake River below Hells Canyon Dam.

Figure 5.
Panel 4 showing perennial streams flowing into the Snake River below Hells Canyon Dam.

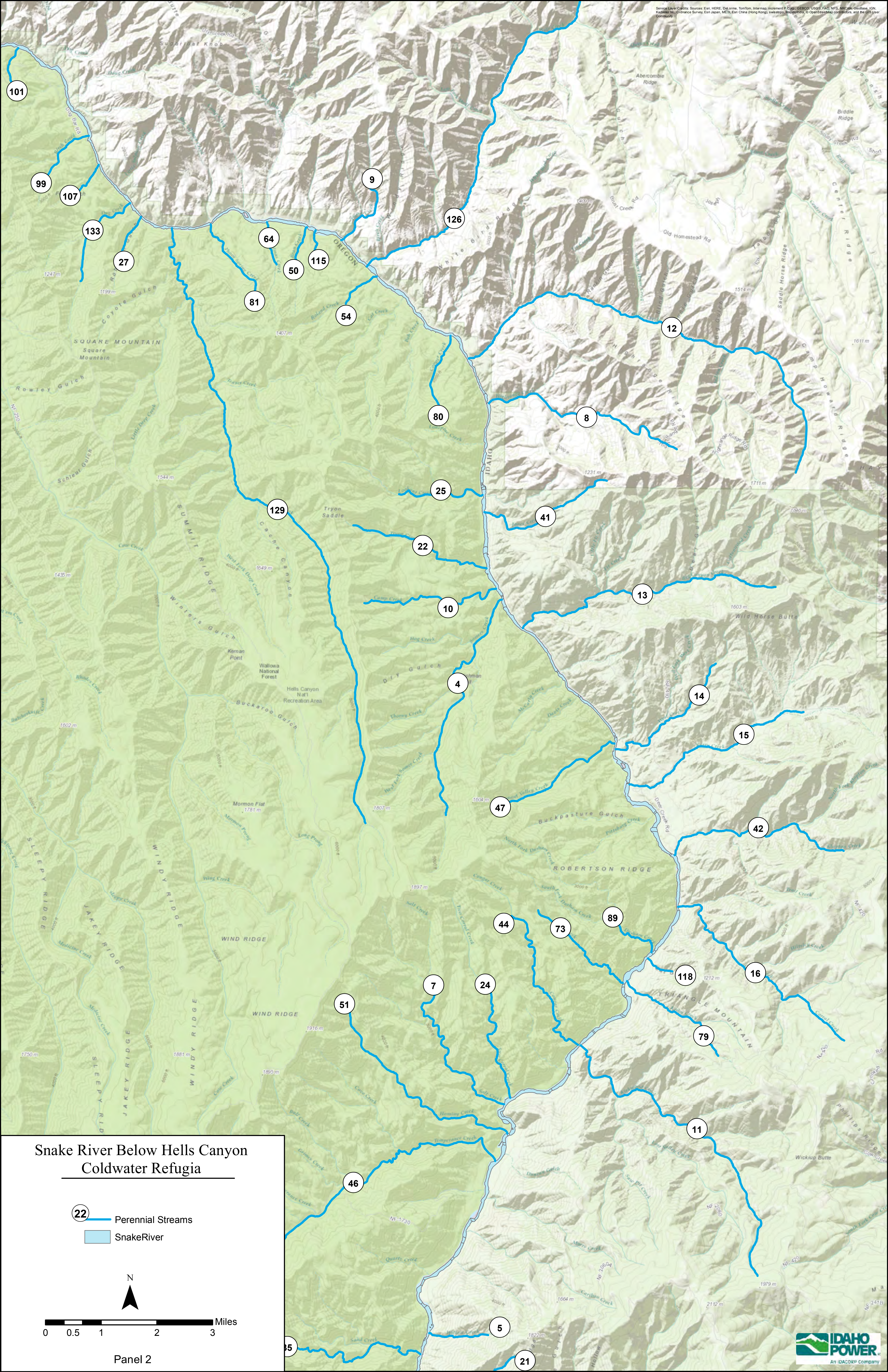


Snake River Below Hells Canyon Coldwater Refugia



Snake River Below Hells Canyon Coldwater Refugia

Panel 1



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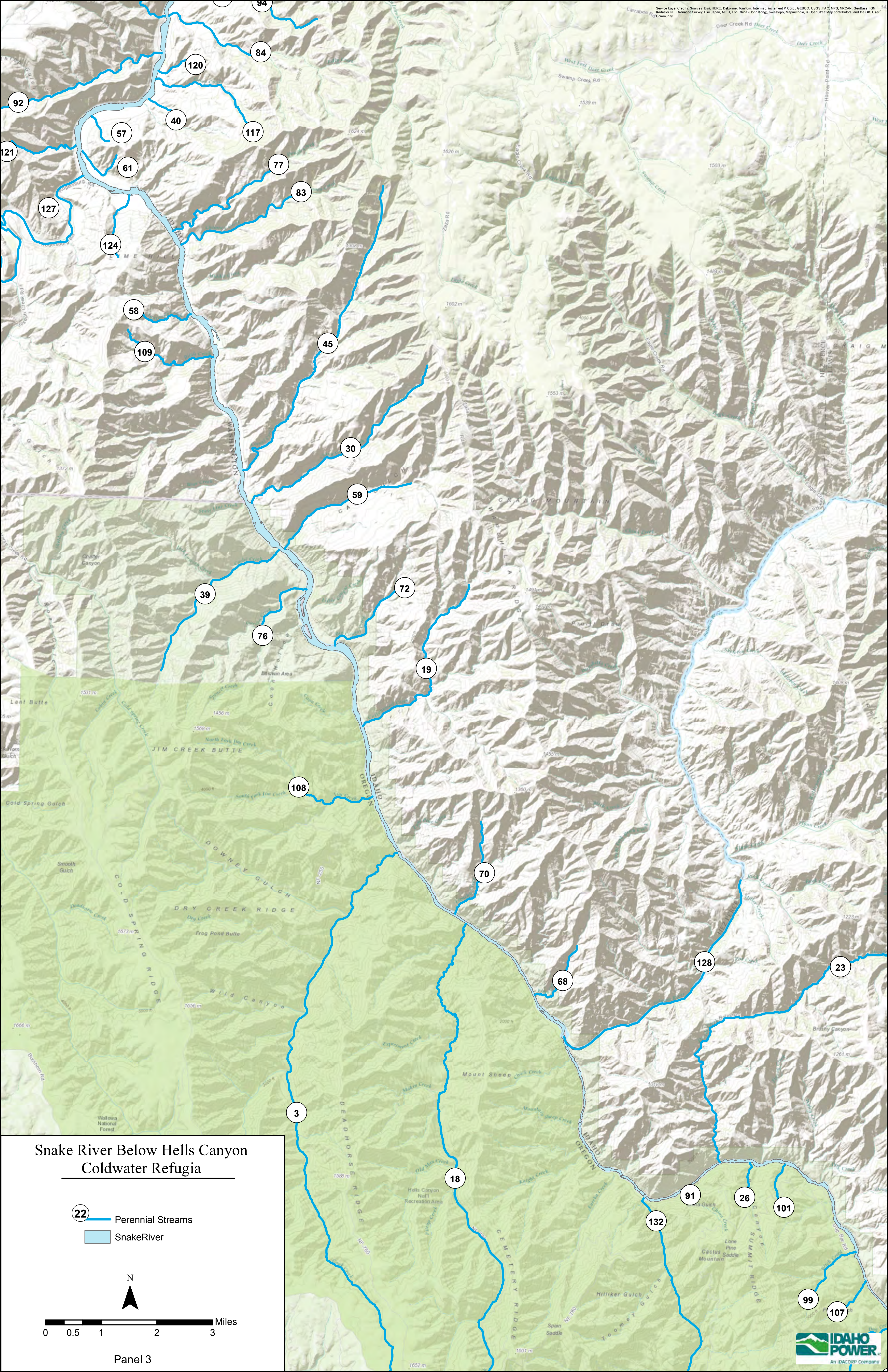
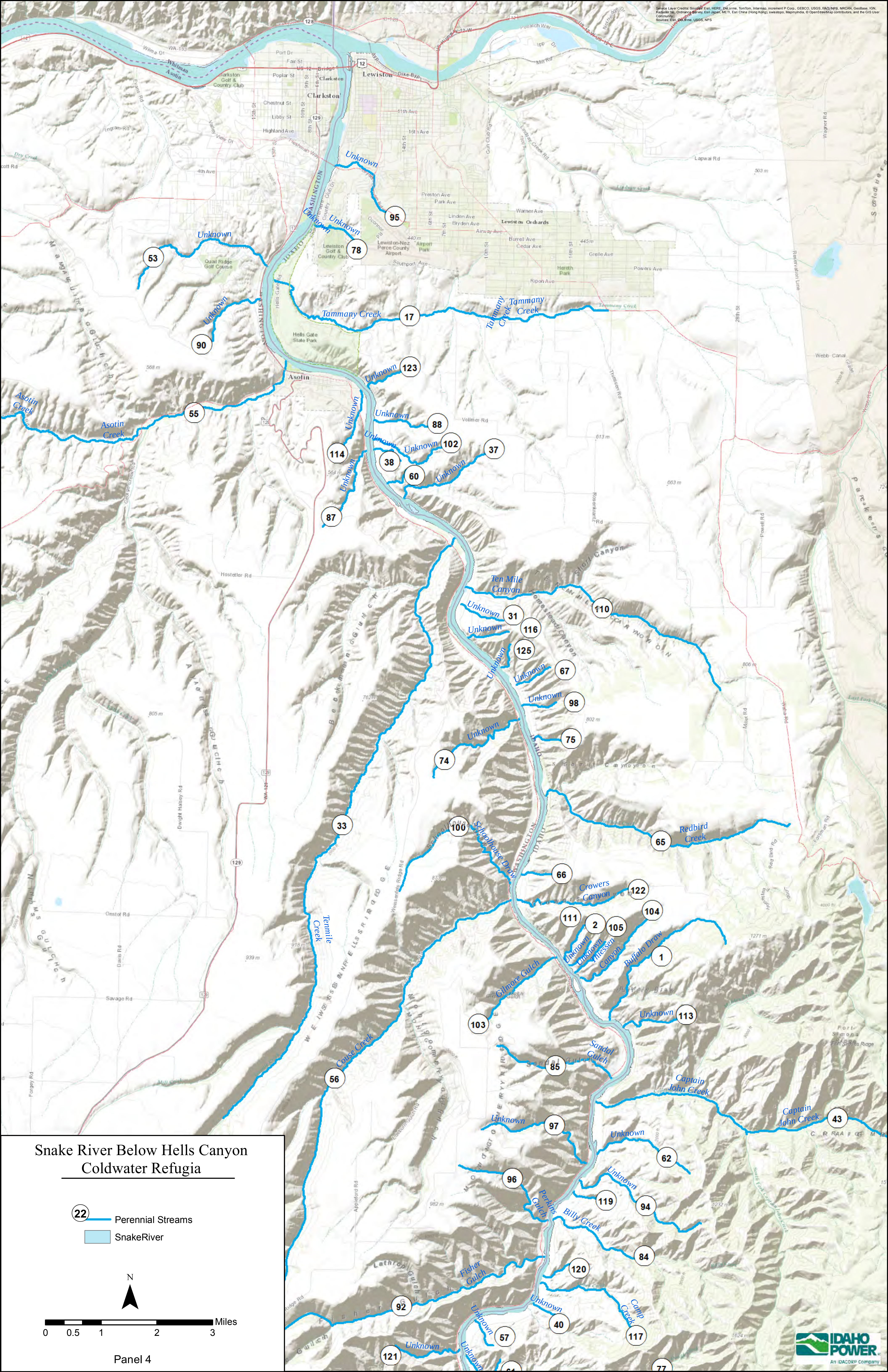


Snake River Below Hells Canyon Coldwater Refugia

Panel 3



Snake River Below Hells Canyon
Coldwater Refugia

Level Two: A comparison of daily temperature metrics to the Snake River relative to CWR

The State of Oregon defines “Cold Water Refugia" (CWR) as “*those portions of a water body where or times during the diel temperature cycle when the water temperature is at least 2 degrees Celsius colder than the daily maximum temperature of the adjacent well-mixed flow of the water body*” (OAR 340-041-0002(10).

The following set of graphs compares daily temperature metrics at several tributaries in Hells Canyon to the daily maximum temperature in the Snake River. The two locations used for comparison to the Snake River because of their general proximity to the tributaries being compared are at River Miles (RM) 202 and RM 247. These two locations in the Snake River had the most complete data set relative to the information available for comparison to the tributaries. Figure 6 demonstrates that generally there is little difference in the daily maximum temperature between these two Snake River locations. There is some downstream warming as would be expected during the time period compared. The RM 202 (Figure 7) location is used as a comparison to tributaries that enter the Snake River between RM 206 and RM 190. The tributaries included in the comparison are Getta Creek (RM 205), Wolf Creek (RM 202), Divide Creek (RM 193) and the Imnaha River (RM 191). The RM 247 location (Figure 8) is used as a comparison to tributaries between RM 247 and RM 220. The tributaries used in this comparison are Deep Creek (RM 247), Granite Creek (RM 239), Sheep Creek (RM 229) Bernard Creek (RM 235) Three Creeks (RM 238), Kirkwood Creek (RM 220) and Temperance Creek (RM 223).

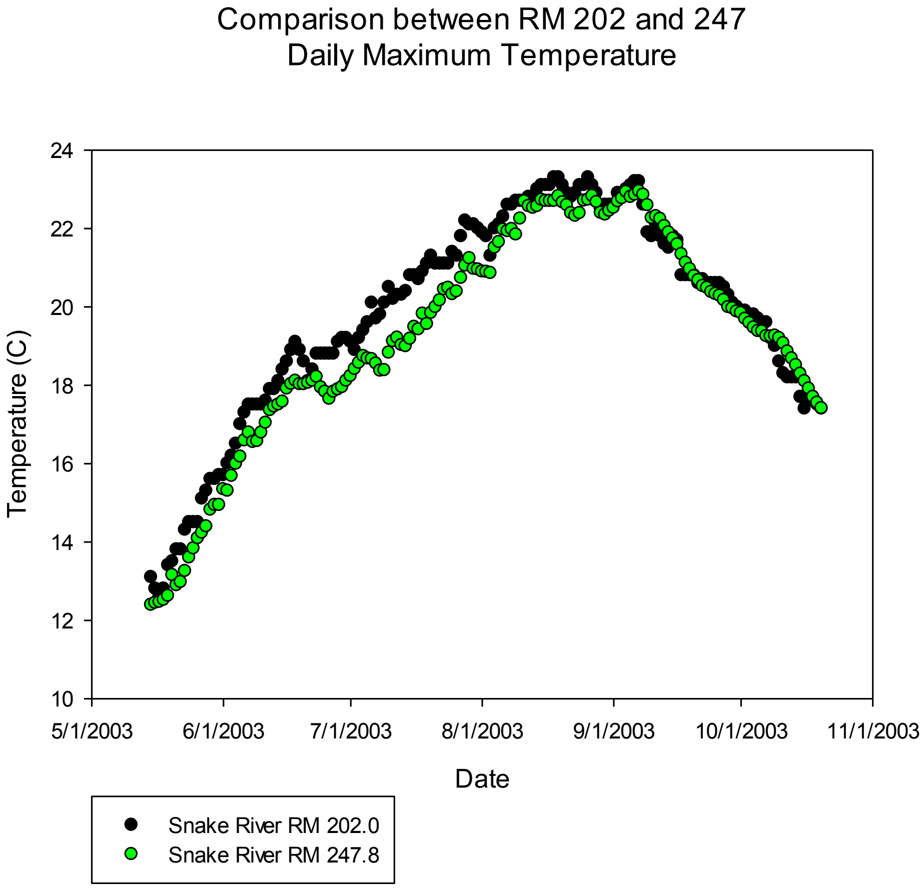
The temperature metrics from the tributaries used for comparison to the Snake River at these locations include daily minimum temperature, daily average temperature and daily maximum temperature. Because the CWR metric references the diel temperature cycle, these metrics offer an indication as to the extent during a diel cycle the tributaries meet the CWR definition. As indicated by the tributaries compared to RM 202 (Figure 7), all of the tributaries provide CWR during at least some portion of the day, with the exception of a few days in the middle of July, where all metrics exceed the -2 °C CWR definition. Generally, by mid-August, the daily average temperatures start to drop below the -2 °C CWR definition which suggests that the majority of the diel cycle is providing thermal refugia. Finally, by around the first of September, all of the tributaries are providing CWR during the entire diel cycle.

The tributaries in Figure 8 demonstrate a much colder pattern relative to the Snake River. All of the tributaries with the exception of Temperance Creek and Kirkwood Creek provide significant CWR during all portions of the diel cycle. Temperance Creek and to a lesser extent Kirkwood Creek show patterns similar to those in the proximity of RM 202. The primary difference for the tributaries that meet the CWR during the entire period is that they originate in high elevation headwaters associated with the Seven Devils Mountains of Idaho. These tributaries are relatively high gradient basins. As such, they originate in a much cooler thermal regime than the lower elevation tributaries that are not directly associated with those higher elevations. Even though Temperance Creek is in this section of river, it is an Oregon tributary, not associated with the elevation or gradient as those on the Idaho side. Kirkwood Creek is somewhat intermediate, because it originates toward the northern end of the Seven Devils Mountains at a slightly lower elevation. There are multiple drainages on the Idaho side of the Snake

River between RM 247 and RM 220 that are associated with this high elevation run-off (see Tables 1 and 2).

Both levels of comparisons demonstrate that overall, perennial tributaries in the Hells Canyon reach of the Snake River provide some level of thermal refugia based on surface water temperature. The component that is not captured in these comparisons is the level of ground water that is contributed through the alluvial fans of these drainages that would not be reflected in the surface flow. Based on the recent literature (Ebersole et al. 2015)[1] many tributaries even with dry channels provide significant cold-water patches in mainstem rivers through hyporheic and groundwater upwelling during the time of year with the warmest water temperatures. It is likely that the subsurface flow associated with the alluvial fans at all of the tributaries contribute to CWR at some level.

Figure 6. A comparison between daily maximum temperatures at RM 202 and RM 247during the period of comparison of various Snake River tributaries to the Snake River relative to cold water refugia.



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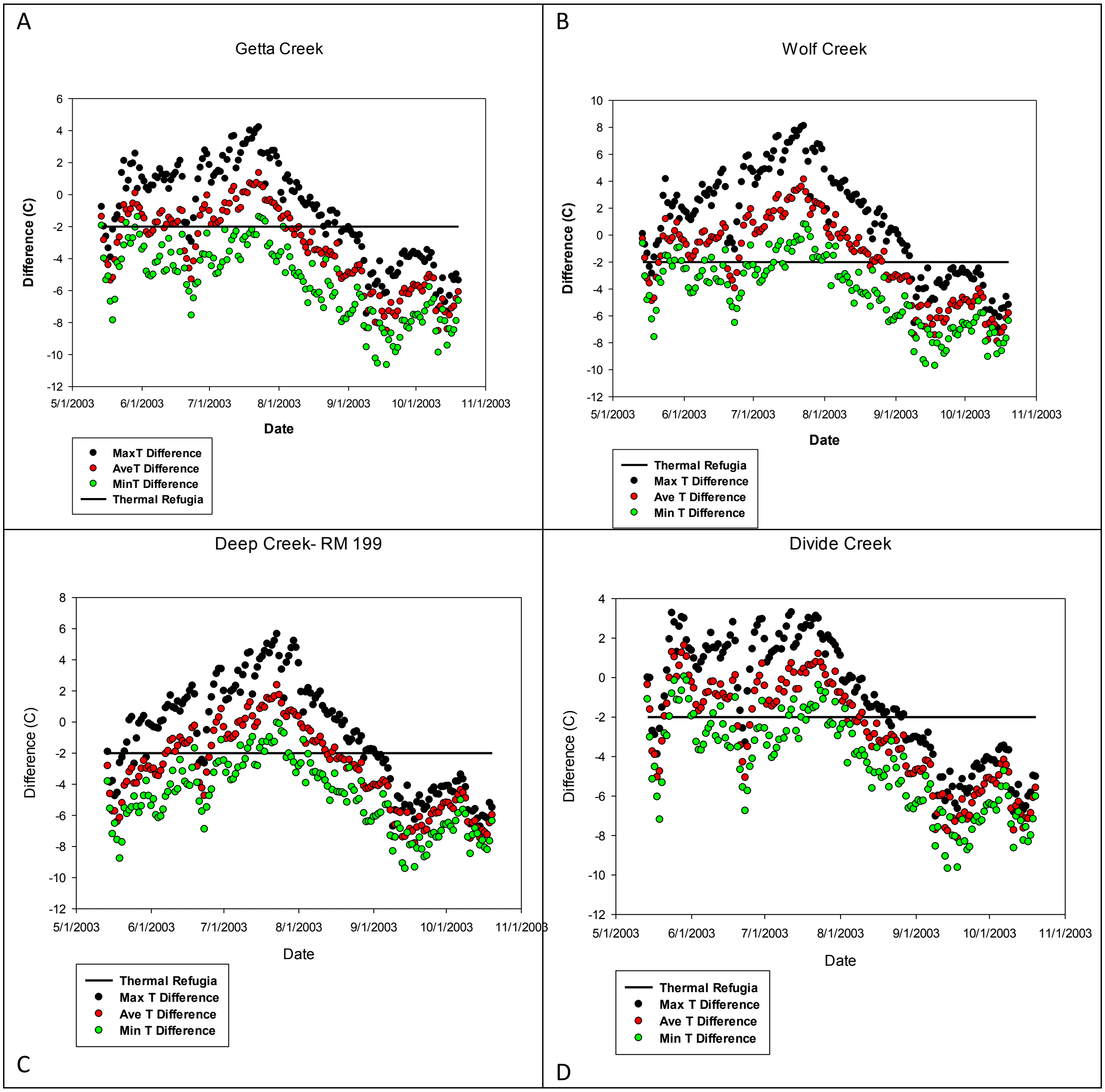
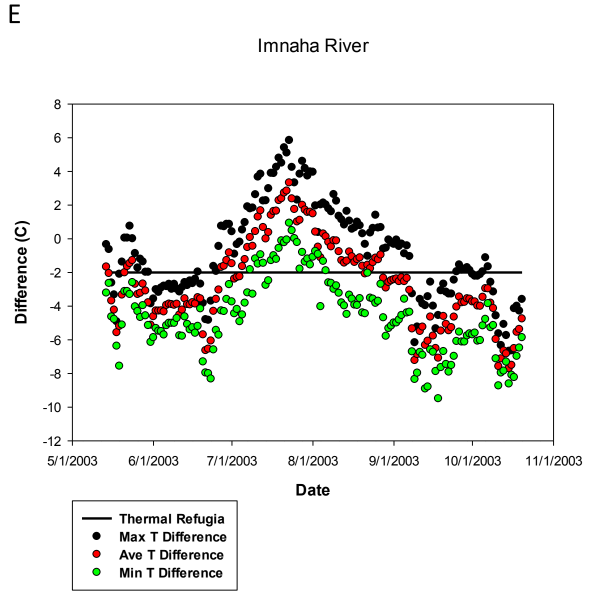
[1] Ebersole, J.L., P.J. Wigington, Jr, S.G. Leibowitz, R.L. Comeleo, and J. VanSickle. 2015. Predicting the occurrence of cold-water patches at intermittent and ephemeral tributary confluences with warm rivers. Freshwater Science 34:111-124.

Figure 7. A comparison (represented by the difference in °C) between the daily maximum temperature in the Snake River at **River Mile (RM) 202** (Graph H) and the corresponding daily maximum, average and minimum temperatures at A. Getta Creek (RM 205), B. Wolf Creek (RM 202), C. Deep Creek (RM 199) D. Divide Creek (RM 193) and the E. Imnaha River (RM 191). A negative value represents the tributary daily maximum temperature being cooler than the corresponding mainstem Snake River.




E
Imnaha River
Difference (C)
8
6
4
2
0
-2
-4
-6
-8
-10
-12
5/1/2003
6/1/2003
7/1/2003
8/1/2003
9/1/2003
10/1/2003
11/1/2003
Date
Thermal Refugia
Max T Difference
Ave T Difference
Min T Difference

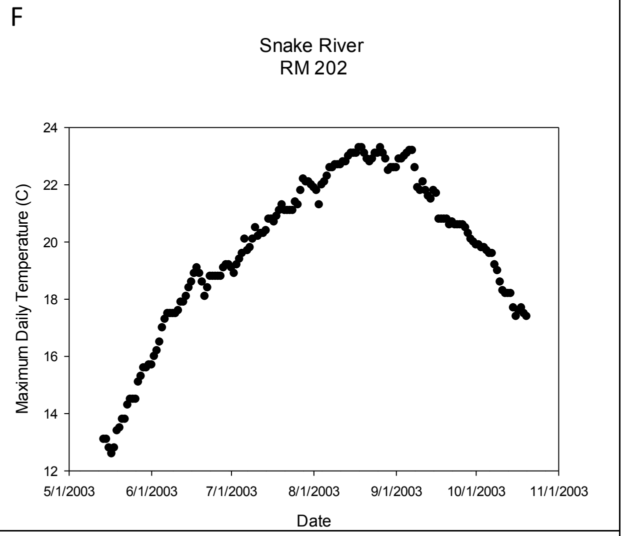
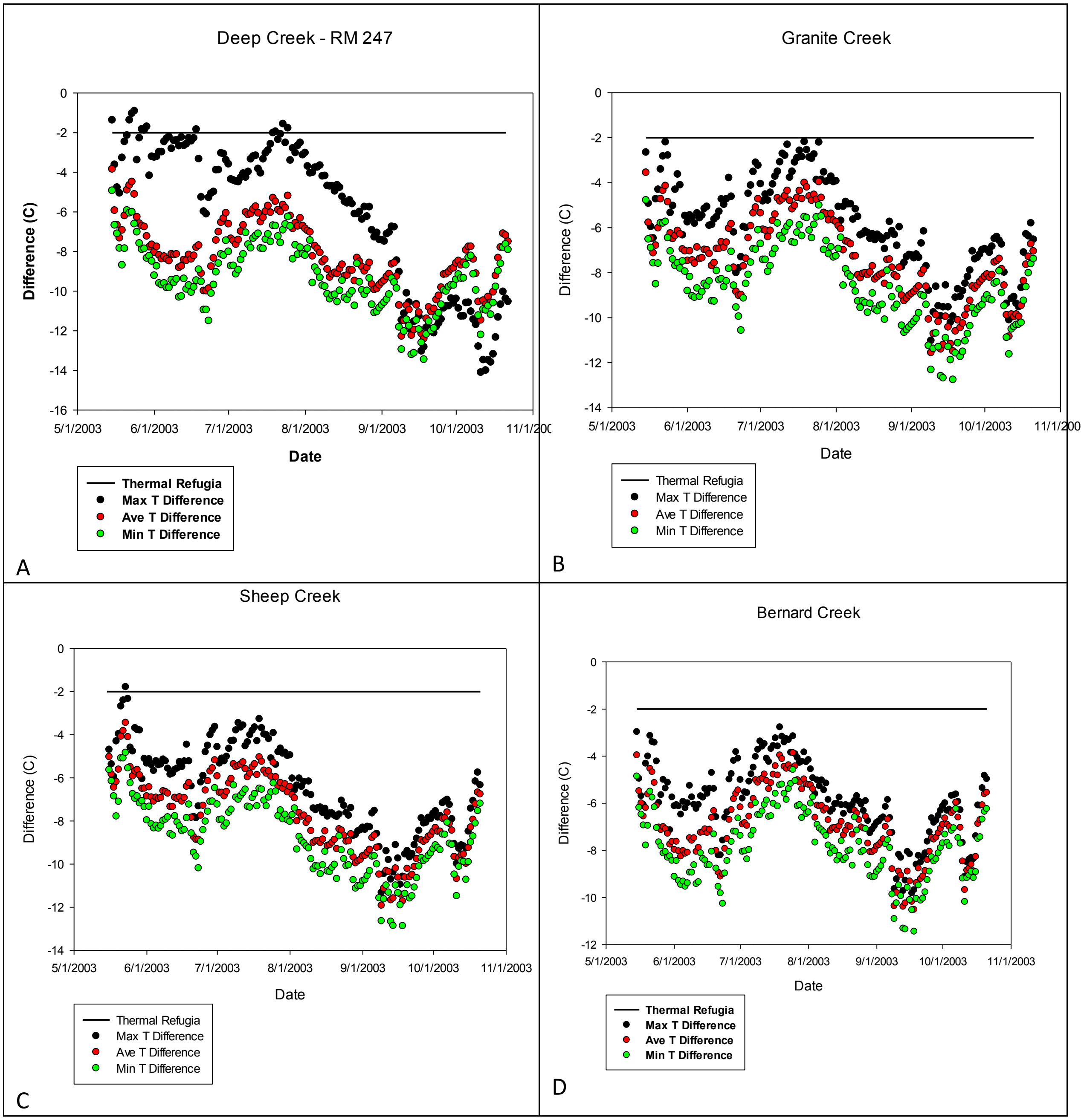
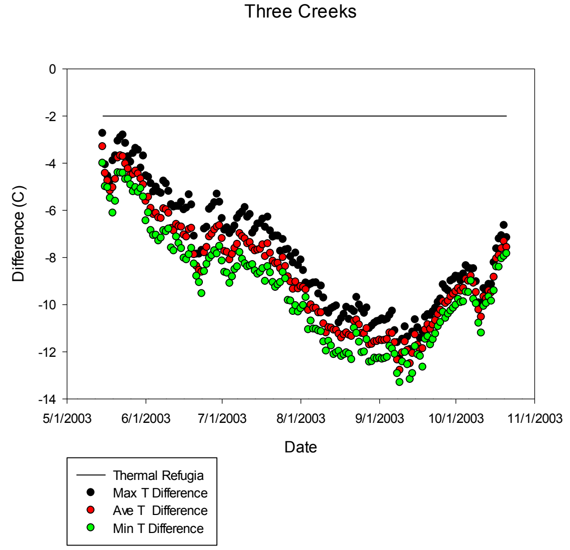
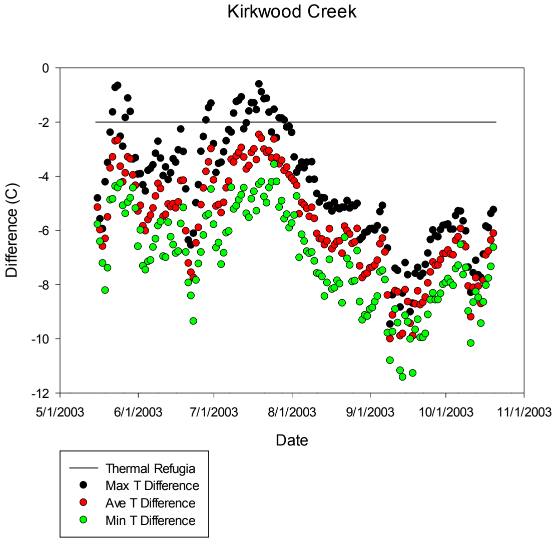

F
Snake River
RM 202
Maximum Daily Temperature (C)
24
22
20
18
16
14
12
5/1/2003
6/1/2003
7/1/2003
8/1/2003
9/1/2003
10/1/2003
11/1/2003
Date

Figure 8. A comparison (represented by the difference in °C) between the daily maximum temperature in the Snake River at Hells Canyon Dam **River Mile (RM) 247.8** (Graph H) and the corresponding daily maximum, average and minimum temperatures at A. Deep Creek (RM 247), B. Granite Creek (RM 239), C. Sheep Creek (RM 229) D. Bernard Creek (RM 235) E. Three Creeks (RM 238), F. Kirkwood Creek (RM 220) and G. Temperance Creek (RM 223). A negative value represents the tributary daily maximum temperature being cooler than the corresponding mainstem Snake River.

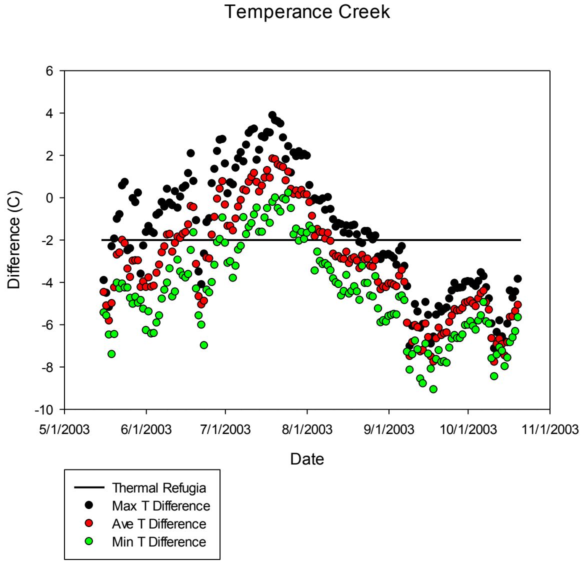



Three Creeks
0
-2
-4
-6
-8
-10
-12
-14
Difference (C)
5/1/2003
6/1/2003
7/1/2003
8/1/2003
9/1/2003
10/1/2003
11/1/2003
Date
Thermal Refugia
● Max T Difference
● Ave T Difference
● Min T Difference

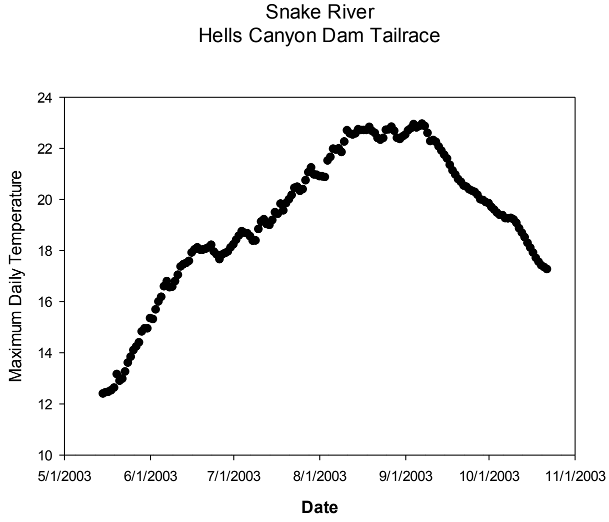
E


Kirkwood Creek
0
-2
-4
-6
-8
-10
-12
Difference (C)
5/1/2003
6/1/2003
7/1/2003
8/1/2003
9/1/2003
10/1/2003
11/1/2003
Date
Thermal Refugia
● Max T Difference
● Ave T Difference
● Min T Difference

F


Temperance Creek
6
4
2
0
-2
-4
-6
-8
-10
Difference (C)
5/1/2003
6/1/2003
7/1/2003
8/1/2003
9/1/2003
10/1/2003
11/1/2003
Date
Thermal Refugia
● Max T Difference
● Ave T Difference
● Min T Difference

G


Snake River
Hells Canyon Dam Tailrace
24
22
20
18
16
14
12
10
Maximum Daily Temperature
5/1/2003
6/1/2003
7/1/2003
8/1/2003
9/1/2003
10/1/2003
11/1/2003
Date

H

Exhibit 6.1-2

HCC inflow and outflow 7-day average maximum (7DAM) temperature data

Exhibit 6.1-2

HCC inflow and outflow 7-day average maximum (7DAM) temperature data

This exhibit presents HCC outflow (Tables 1 through 3) and inflow (Tables 4 through 6) 7-day average maximum (7DAM) temperature data for the period of record. At the inflow, the period of record is 1996 through 2017 while the outflow data spans from 1991 through 2017. The data presented here are the average of the daily maximum temperature of that day and the daily maximum temperature for the six preceding days. Daily maximum temperature is based on temperature data collected frequently throughout the day, typically every 10 minutes or hourly. The primary location for the HCC outflow data is a sensor located in the turbine intake water at Hells Canyon Dam (i.e., HC Penstock) and if data was not available at that location then daily maximum data (used to calculate the 7DAM) were filled in from the next closest location downstream of HC Dam to a maximum of 20 miles downstream (Table 2). If no data was available at any of the locations then the daily maximum temperature was linearly interpolated to fill the gap. If the gap was too large to reasonably fill with linear interpolation then the cells are left blank in Table 1. Table 3 lists more specifically which locations were used and for what dates to fill gaps and the specific dates when interpolation was used for the HCC outflow data.

The primary location for the HCC inflow data (Table 4) is at Brownlee Reservoir inflow (i.e. RM 354.6) and if data was not available at that location then daily maximum data were filled in from the next nearest location from a list of locations extending to 10 miles upstream of RM 345.6 (Table 5). If no data was available at any of the locations then the daily maximum temperature was linearly interpolated to fill the gap. If the gap was too large to reasonably fill with linear interpolation then the cells are left blank in Table 4. Table 5 lists more specifically which locations were used and for what dates to fill gaps and the specific dates when interpolation was used for the HCC inflow data.

Table 1

HCC outflow 7DAM Temperature in °C measured at Hells Canyon Dam.

HCC Outflow 7DAM Temperature (°C)																											
Date	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1/1																											
1/2																											
1/3																											
1/4																											
1/5																											
1/6																											
1/7		5.7	5.3	4.1	4.2	6.2	4.5	4.9	5.3	4.9	4.9	6.0	6.1	5.3	5.8	4.9	4.8	5.5	5.6	4.3	4.9	5.1	6.6	5.3	5.5	5.3	4.6
1/8		5.7	5.2	4.1	4.0	6.1	4.2	4.9	5.1	4.8	4.8	5.9	6.1	5.1	5.7	4.8	4.7	5.4	5.5	4.3	4.7	5.0	6.5	5.2	5.4	5.3	4.5
1/9		5.7	5.0	4.1	3.8	6.0	4.0	5.0	4.7	4.8	4.7	5.8	6.0	4.9	5.6	4.6	4.6	5.3	5.5	4.2	4.7	4.9	6.3	5.2	5.3	5.3	4.4
1/10		5.6	4.9	4.1	3.7	5.9	4.0	5.0	4.4	4.7	4.5	5.7	5.9	4.8	5.5	4.3	4.6	5.2	5.4	4.2	4.7	4.9	6.2	5.1	5.3	5.3	4.3
1/11		5.5	4.8	4.3	3.6	5.8	3.9	5.0	4.0	4.8	4.4	5.6	5.8	4.7	5.4	4.0	4.6	5.1	5.4	4.0	4.7	4.9	6.1	5.0	5.3	5.3	4.2
1/12		5.4	4.6	4.4	3.6	5.7	4.0	5.0	3.8	4.8	4.4	5.5	5.7	4.7	5.4	3.7	4.5	5.1	5.4	3.8	4.7	4.9	6.0	5.0	5.3	5.3	4.1
1/13		5.3	4.4	4.6	3.7	5.7	4.1	4.9	3.6	4.8	4.3	5.4	5.7	4.7	5.4	3.4	4.5	5.1	5.4	3.7	4.6	4.7	6.0	4.9	5.4	5.4	4.1
1/14		5.2	4.1	4.7	3.8	5.7	4.2	4.7	3.6	4.8	4.2	5.3	5.6	4.8	5.4	3.2	4.5	5.1	5.4	3.5	4.5	4.5	5.9	4.8	5.4	5.4	4.1
1/15		5.1	4.0	4.9	3.9	5.6	4.3	4.4	3.5	4.8	4.2	5.2	5.6	4.8	5.3	3.0	4.4	5.0	5.4	3.4	4.3	4.2	5.9	4.8	5.5	5.3	4.1
1/16		5.0	3.8	5.0	3.9	5.5	4.3	4.2	3.6	4.8	4.2	5.0	5.6	4.8	5.3	2.8	4.3	5.0	5.3	3.2	4.2	3.9	5.8	4.7	5.5	5.3	4.0
1/17		4.9	3.7	5.2	3.9	5.3	4.3	4.0	3.7	4.7	4.1	4.9	5.6	4.8	5.3	2.8	4.1	4.9	5.3	3.1	3.9	3.6	5.8	4.6	5.5	5.2	4.0
1/18		4.8	3.5	5.1	3.8	5.0	4.3	3.8	3.8	4.6	4.1	4.8	5.6	4.8	5.3	2.8	4.0	4.9	5.2	3.0	3.7	3.2	5.6	4.5	5.5	5.0	3.9
1/19		4.8	3.3	5.1	3.7	4.6	4.3	3.7	3.8	4.5	4.1	4.7	5.5	4.8	5.3	2.8	3.8	4.8	5.2	3.0	3.6	2.9	5.5	4.2	5.5	4.7	3.9
1/20		4.8	3.1	5.0	3.5	4.3	4.2	3.6	3.9	4.4	4.0	4.6	5.5	4.8	5.3	2.9	3.6	4.7	5.0	3.1	3.5	2.7	5.3	4.0	5.5	4.5	3.8
1/21		4.7	2.9	4.8	3.3	4.0	4.2	3.5	3.9	4.3	4.0	4.5	5.4	4.8	5.3	2.8	3.5	4.6	4.9	3.1	3.4	2.6	5.0	3.7	5.4	4.3	3.7
1/22		4.7	2.8	4.6	3.2	3.7	4.2	3.4	4.0	4.2	4.0	4.4	5.4	4.7	5.3	2.9	3.3	4.5	4.7	3.2	3.3	2.6	4.7	3.5	5.4	4.1	3.5
1/23		4.6	2.7	4.3	3.1	3.4	4.2	3.4	4.0	4.0	3.9	4.4	5.4	4.7	5.2	2.9	3.2	4.3	4.6	3.3	3.2	2.6	4.4	3.2	5.3	4.0	3.3
1/24		4.6	2.6	4.1	3.0	3.3	4.1	3.3	4.0	3.9	3.9	4.4	5.4	4.7	5.3	2.9	3.0	4.0	4.4	3.4	3.2	2.6	4.1	2.9	5.2	3.8	3.1
1/25		4.5	2.5	3.9	2.9	3.2	4.0	3.3	4.0	3.8	3.8	4.4	5.3	4.7	5.3	3.0	2.9	3.6	4.3	3.5	3.0	2.7	3.9	2.6	5.1	3.8	2.8
1/26		4.4	2.5	3.7	2.9	3.2	3.9	3.1	3.9	3.7	3.8	4.4	5.3	4.6	5.3	3.0	2.8	3.3	4.1	3.5	2.9	2.7	3.7	2.5	5.0	3.9	2.6

HCC Outflow 7DAM Temperature (°C)

Date	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1/27		4.4	2.4	3.6	2.9	3.2	3.9	3.0	3.8	3.5	3.7	4.5	5.3	4.5	5.3	3.0	2.6	3.0	3.9	3.5	2.8	2.7	3.6	2.3	4.9	3.9	2.4
1/28		4.4	2.4	3.5	2.9	3.2	3.8	3.0	3.7	3.4	3.6	4.5	5.4	4.5	5.3	3.0	2.5	2.8	3.8	3.4	2.7	2.7	3.4	2.3	4.9	3.9	2.2
1/29		4.3	2.3	3.5	2.9	3.2	3.7	3.0	3.6	3.3	3.5	4.5	5.4	4.5	5.4	3.1	2.4	2.6	3.6	3.4	2.7	2.7	3.3	2.2	4.8	3.8	2.1
1/30		4.3	2.2	3.4	2.9	3.2	3.5	3.1	3.5	3.3	3.3	4.4	5.4	4.4	5.4	3.2	2.2	2.4	3.5	3.3	2.6	2.7	3.2	2.2	4.8	3.8	2.0
1/31		4.2	2.1	3.4	2.9	3.2	3.4	3.1	3.5	3.2	3.2	4.3	5.4	4.3	5.4	3.2	2.1	2.4	3.4	3.2	2.6	2.7	3.0	2.3	4.8	3.8	1.9
2/1		4.1	2.0	3.3	3.0	3.2	3.3	3.2	3.6	3.1	3.0	4.2	5.4	4.1	5.4	3.3	2.1	2.4	3.2	3.2	2.6	2.7	2.9	2.3	4.7	3.7	1.8
2/2		4.0	2.0	3.3	3.0	3.2	3.2	3.2	3.7	3.0	2.9	4.0	5.4	3.9	5.4	3.3	2.0	2.4	3.0	3.1	2.5	2.7	2.8	2.3	4.7	3.6	1.7
2/3		3.9	1.9	3.2	3.1	3.2	3.2	3.3	3.8	3.0	2.7	3.8	5.3	3.7	5.4	3.4	1.9	2.4	2.9	3.1	2.4	2.8	2.8	2.4	4.6	3.5	1.7
2/4		3.8	1.8	3.2	3.2	3.2	3.1	3.3	4.0	3.0	2.6	3.6	5.3	3.4	5.4	3.5	1.8	2.3	2.8	3.1	2.2	2.8	2.7	2.4	4.5	3.4	1.6
2/5		3.7	1.8	3.2	3.3	3.2	3.1	3.4	4.1	3.0	2.5	3.4	5.3	3.2	5.4	3.6	1.8	2.3	2.7	3.1	2.1	2.9	2.7	2.4	4.4	3.3	1.6
2/6		3.7	1.8	3.1	3.4	3.2	3.1	3.4	4.2	3.0	2.4	3.4	5.2	3.0	5.3	3.6	1.8	2.3	2.5	3.2	2.0	2.9	2.7	2.4	4.3	3.3	1.6
2/7		3.7	1.8	3.1	3.5	3.3	3.1	3.5	4.4	3.1	2.3	3.2	5.1	2.8	5.3	3.6	1.8	2.3	2.4	3.2	2.0	2.9	2.6	2.4	4.2	3.3	1.6
2/8		3.7	1.9	3.0	3.6	3.3	3.1	3.5	4.5	3.1	2.3	3.0	5.1	2.7	5.2	3.6	1.8	2.2	2.4	3.2	2.0	2.9	2.6	2.3	4.2	3.2	1.6
2/9		3.7	1.9	2.9	3.6	3.4	3.1	3.6	4.6	3.2	2.3	2.9	5.0	2.6	5.2	3.6	1.9	2.2	2.3	3.3	2.1	2.9	2.6	2.3	4.1	3.2	1.7
2/10		3.7	1.9	2.8	3.6	3.5	3.2	3.7	4.5	3.3	2.2	2.8	4.9	2.6	5.1	3.6	1.9	2.2	2.3	3.3	2.2	2.9	2.6	2.3	4.1	3.3	1.8
2/11		3.7	1.9	2.7	3.6	3.6	3.3	3.8	4.4	3.4	2.2	2.7	4.8	2.6	5.0	3.6	2.0	2.1	2.3	3.3	2.3	3.0	2.5	2.3	4.1	3.3	1.8
2/12		3.7	1.9	2.6	3.6	3.8	3.4	3.9	4.4	3.4	2.2	2.6	4.6	2.6	4.9	3.6	2.1	2.2	2.3	3.3	2.4	3.0	2.5	2.3	4.1	3.3	1.9
2/13		3.6	1.9	2.5	3.6	3.8	3.6	4.1	4.3	3.5	2.2	2.5	4.6	2.6	4.8	3.5	2.2	2.1	2.4	3.3	2.5	3.0	2.4	2.3	4.2	3.4	1.9
2/14		3.6	2.0	2.5	3.6	3.8	3.7	4.2	4.2	3.6	2.2	2.5	4.5	2.6	4.8	3.5	2.3	2.2	2.4	3.3	2.6	3.1	2.4	2.3	4.2	3.4	2.0
2/15		3.6	2.0	2.5	3.6	3.8	3.9	4.4	4.1	3.7	2.2	2.5	4.5	2.6	4.7	3.4	2.4	2.2	2.5	3.4	2.7	3.1	2.5	2.4	4.2	3.5	2.0
2/16		3.6	2.0	2.6	3.5	3.7	4.0	4.6	4.0	3.8	2.3	2.5	4.5	2.6	4.7	3.4	2.5	2.3	2.5	3.5	2.8	3.1	2.6	2.5	4.2	3.6	2.0
2/17		3.6	1.9	2.7	3.5	3.6	4.1	4.8	4.0	4.0	2.3	2.6	4.5	2.6	4.6	3.3	2.6	2.3	2.5	3.5	2.9	3.2	2.7	2.6	4.3	3.7	2.0
2/18		3.7	1.9	2.9	3.5	3.5	4.2	5.1	4.0	4.0	2.4	2.6	4.6	2.6	4.5	3.3	2.7	2.4	2.5	3.6	3.0	3.2	2.8	2.7	4.3	3.7	2.0
2/19		3.7	2.0	3.1	3.5	3.3	4.2	5.3	4.0	4.2	2.5	2.6	4.7	2.6	4.3	3.2	2.7	2.4	2.5	3.7	3.1	3.2	2.9	2.9	4.4	3.7	2.0
2/20		3.7	2.0	3.3	3.6	3.1	4.3	5.4	4.0	4.2	2.6	2.6	4.7	2.6	4.2	3.1	2.8	2.4	2.6	3.7	3.2	3.3	3.0	3.0	4.5	3.8	2.0
2/21		3.8	1.9	3.4	3.7	3.1	4.3	5.6	4.0	4.3	2.7	2.7	4.8	2.6	4.1	3.1	2.8	2.4	2.7	3.8	3.3	3.3	3.0	3.1	4.6	3.8	2.1
2/22		3.8	1.9	3.6	3.8	3.0	4.3	5.8	3.9	4.3	2.8	2.7	4.8	2.6	4.0	3.1	2.8	2.4	2.8	3.9	3.4	3.3	2.9	3.2	4.7	3.8	2.2
2/23		3.8	1.8	3.7	4.0	3.0	4.4	5.9	3.8	4.4	2.8	2.8	4.9	2.7	3.9	3.1	2.8	2.4	2.9	3.9	3.5	3.4	2.8	3.3	4.9	3.9	2.3
2/24		3.8	1.8	3.9	4.2	3.0	4.5	6.1	3.7	4.4	2.9	2.9	5.0	2.7	3.8	3.2	2.9	2.4	3.0	4.0	3.5	3.4	2.6	3.3	5.0	3.9	2.4
2/25		3.9	1.9	3.9	4.4	3.1	4.6	6.2	3.6	4.4	2.9	3.0	5.1	2.8	3.8	3.3	2.8	2.4	3.1	4.0	3.6	3.5	2.5	3.3	5.2	4.0	2.5
2/26		3.9	1.9	3.9	4.6	3.3	4.7	6.3	3.5	4.5	3.0	3.1	5.1	2.9	3.8	3.5	2.8	2.4	3.2	4.1	3.7	3.5	2.5	3.4	5.4	4.0	2.6
2/27		4.0	1.9	3.9	4.8	3.3	4.9	6.4	3.5	4.5	3.1	3.2	5.2	3.0	3.8	3.6	2.8	2.4	3.2	4.2	3.7	3.6	2.4	3.4	5.6	4.1	2.8
2/28		4.1	2.0	3.9	5.0	3.5	5.1	6.4	3.5	4.6	3.1	3.3	5.2	3.0	3.8	3.7	2.8	2.5	3.3	4.3	3.7	3.7	2.4	3.4	5.7	4.2	2.9
3/1		4.2	2.0	3.9	5.1	3.7	5.3	6.4	3.5	4.7	3.2	3.4	5.1	3.1	3.8	3.8	2.8	2.5	3.4	4.3	3.8	3.7	2.5	3.4	5.7	4.3	3.1
3/2		4.5	2.0	3.9	5.2	4.0	5.4	6.4	3.5	4.9	3.2	3.4	5.1	3.2	3.9	3.9	2.7	2.6	3.5	4.4	3.8	3.8	2.6	3.5	5.7	4.4	3.3
3/3		4.8	2.0	3.9	5.3	4.3	5.5	6.4	3.7	5.1	3.3	3.4	5.1	3.2	4.0	3.9	2.7	2.7	3.5	4.6	3.8	3.9	2.6	3.5	5.8	4.6	3.5
3/4		5.1	2.0	4.0	5.3	4.6	5.5	6.4	3.8	5.3	3.3	3.4	5.0	3.3	4.1	3.9	2.8	2.8	3.6	4.7	3.8	4.0	2.7	3.6	5.8	4.8	3.8
3/5		5.3	2.0	4.0	5.3	4.8	5.4	6.3	4.0	5.5	3.3	3.4	4.9	3.4	4.2	3.9	2.8	2.9	3.7	4.8	3.9	4.0	2.8	3.6	5.9	5.0	4.0
3/6		5.6	2.0	4.1	5.3	5.1	5.4	6.3	4.2	5.7	3.4	3.4	4.9	3.5	4.3	3.9	2.9	3.0	3.7	5.0	4.0	4.1	2.9	3.7	6.0	5.3	4.3
3/7		5.8	2.1	4.2	5.3	5.3	5.3	6.4	4.3	5.8	3.4	3.3	4.9	3.5	4.4	3.8	2.9	3.1	3.7	5.2	4.1	4.1	3.1	3.8	6.1	5.6	4.4
3/8		6.0	2.1	4.3	5.2	5.5	5.3	6.4	4.6	6.0	3.4	3.2	5.0	3.6	4.5	3.8	3.0	3.2	3.7	5.4	4.2	4.2	3.2	3.9	6.2	5.8	4.6
3/9		6.2	2.2	4.4	5.2	5.5	5.3	6.4	4.8	6.1	3.5	3.2	5.0	3.6	4.6	3.7	3.1	3.2	3.8	5.5	4.4	4.4	3.3	4.0	6.4	6.0	4.7
3/10		6.3	2.3	4.5	5.2	5.6	5.3	6.4	4.9	6.1	3.5	3.1	5.1	3.7	4.6	3.6	3.3	3.3	3.7	5.6	4.6	4.6	3.4	4.0	6.5	6.2	4.7

HCC Outflow 7DAM Temperature (°C)

Date	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
3/11		6.5	2.5	4.5	5.3	5.5	5.3	6.4	5.0	6.2	3.6	3.1	5.1	3.8	4.7	3.6	3.6	3.4	3.7	5.7	4.8	4.8	3.5	4.1	6.6	6.3	4.7
3/12		6.7	2.6	4.6	5.3	5.5	5.4	6.5	5.1	6.2	3.8	3.1	5.2	3.9	4.8	3.8	3.9	3.4	3.6	5.8	4.9	4.9	3.6	4.2	6.8	6.4	4.8
3/13		6.8	2.7	4.6	5.4	5.4	5.4	6.6	5.3	6.2	4.0	3.1	5.3	4.0	4.9	3.9	4.3	3.5	3.7	6.0	5.0	5.2	3.7	4.4	6.9	6.5	5.0
3/14		7.0	2.8	4.7	5.6	5.4	5.4	6.7	5.4	6.3	4.2	3.2	5.4	4.2	5.0	4.2	4.7	3.6	3.7	6.0	5.1	5.4	3.7	4.6	7.0	6.5	5.2
3/15		7.1	2.9	4.7	5.8	5.5	5.5	6.9	5.6	6.4	4.4	3.4	5.5	4.4	5.1	4.5	5.1	3.7	3.7	6.2	5.2	5.5	3.8	4.9	7.2	6.6	5.4
3/16		7.2	3.0	4.7	6.0	5.6	5.5	7.0	5.8	6.4	4.6	3.5	5.6	4.5	5.3	4.8	5.5	3.8	3.7	6.3	5.3	5.6	3.9	5.2	7.4	6.7	5.7
3/17		7.2	3.2	4.8	6.3	5.7	5.6	7.1	6.0	6.5	4.7	3.6	5.7	4.8	5.5	5.1	5.9	4.1	3.7	6.4	5.3	5.7	4.0	5.5	7.5	6.9	6.1
3/18		7.2	3.4	4.8	6.5	6.0	5.8	7.1	6.2	6.5	4.9	3.7	5.8	5.0	5.6	5.4	6.1	4.4	3.8	6.5	5.4	5.8	4.1	5.7	7.6	7.1	6.5
3/19		7.3	3.5	4.9	6.8	6.3	6.1	7.1	6.3	6.6	5.0	3.8	6.0	5.3	5.7	5.5	6.3	4.7	3.9	6.6	5.4	5.9	4.3	5.9	7.7	7.3	6.8
3/20		7.3	3.7	4.9	7.0	6.7	6.4	7.1	6.5	6.7	5.1	3.9	6.1	5.5	5.9	5.6	6.4	5.1	4.0	6.7	5.6	5.9	4.4	6.2	7.8	7.5	7.2
3/21		7.4	3.9	4.9	7.3	7.1	6.7	7.0	6.7	6.8	5.1	3.9	6.2	5.8	6.0	5.6	6.5	5.4	4.2	6.8	5.7	5.9	4.5	6.4	7.9	7.7	7.6
3/22		7.6	4.1	5.0	7.4	7.5	6.9	6.9	6.8	6.9	5.2	4.0	6.3	6.1	6.1	5.7	6.6	5.7	4.4	6.9	5.9	6.0	4.6	6.6	8.0	7.9	8.0
3/23		7.7	4.2	5.2	7.5	7.7	7.2	6.9	7.1	7.0	5.1	4.1	6.4	6.3	6.1	5.7	6.8	6.0	4.6	7.0	6.0	6.0	4.6	6.8	8.1	8.0	8.4
3/24		7.9	4.3	5.5	7.6	8.0	7.5	6.9	7.3	7.1	5.1	4.2	6.5	6.6	6.1	5.8	6.9	6.2	4.9	7.1	6.2	6.1	4.7	7.0	8.2	8.2	8.8
3/25		8.1	4.6	5.8	7.6	8.2	7.9	7.1	7.4	7.3	5.1	4.4	6.6	6.8	6.1	5.8	7.1	6.3	5.1	7.2	6.4	6.3	4.7	7.3	8.3	8.3	9.1
3/26		8.3	4.8	6.1	7.6	8.3	8.2	7.2	7.7	7.5	5.1	4.6	6.6	7.1	6.1	5.9	7.3	6.4	5.3	7.3	6.7	6.4	4.8	7.4	8.3	8.5	9.3
3/27		8.5	5.1	6.4	7.7	8.4	8.5	7.5	8.0	7.8	5.2	4.7	6.6	7.3	6.1	6.0	7.4	6.5	5.5	7.4	6.9	6.7	4.9	7.5	8.4	8.6	9.4
3/28		8.6	5.5	6.7	7.7	8.4	8.8	7.7	8.1	8.0	5.3	4.9	6.7	7.5	6.3	6.1	7.6	6.6	5.7	7.5	7.0	6.9	5.1	7.6	8.5	8.6	9.5
3/29		8.7	5.8	7.0	7.8	8.5	9.2	7.9	8.2	8.2	5.5	5.1	6.8	7.8	6.5	6.3	7.8	6.7	5.8	7.6	7.1	7.2	5.3	7.7	8.6	8.7	9.6
3/30		8.8	6.2	7.3	7.9	8.5	9.4	8.1	8.3	8.4	5.8	5.2	6.8	8.1	6.7	6.5	7.8	6.9	5.9	7.6	7.2	7.3	5.5	7.7	8.8	8.7	9.6
3/31		8.8	6.7	7.4	8.0	8.6	9.6	8.3	8.4	8.5	6.1	5.4	6.9	8.3	7.0	6.6	7.9	7.0	5.9	7.7	7.3	7.5	5.8	7.8	9.0	8.8	9.5
4/1		8.9	7.0	7.5	8.0	8.7	9.7	8.4	8.5	8.6	6.5	5.5	7.0	8.5	7.2	6.8	8.1	7.0	6.0	7.7	7.4	7.6	6.2	7.8	9.2	8.8	9.5
4/2		9.1	7.3	7.5	8.1	8.7	9.7	8.5	8.6	8.8	6.8	5.7	7.1	8.7	7.2	7.1	8.1	7.1	6.1	7.7	7.5	7.7	6.5	7.8	9.4	8.9	9.5
4/3		9.2	7.5	7.6	8.2	8.7	9.7	8.5	8.6	8.9	7.1	5.9	7.4	9.0	7.3	7.4	8.3	7.2	6.1	7.8	7.6	7.8	6.8	7.9	9.5	8.9	9.5
4/4		9.4	7.8	7.6	8.4	8.6	9.6	8.7	8.7	9.2	7.3	6.1	7.6	9.2	7.3	7.6	8.4	7.3	6.2	7.8	7.7	8.0	7.2	8.0	9.6	8.9	9.5
4/5		9.6	7.9	7.7	8.6	8.5	9.6	8.8	8.7	9.4	7.5	6.4	7.8	9.4	7.4	7.8	8.5	7.3	6.2	7.8	7.8	8.1	7.6	8.1	9.8	8.9	9.5
4/6		9.7	8.1	7.8	8.8	8.5	9.6	8.9	8.6	9.6	7.7	6.7	8.0	9.5	7.5	8.0	8.6	7.4	6.3	7.8	8.0	8.3	7.9	8.1	9.9	9.0	9.4
4/7		9.8	8.2	8.0	9.0	8.4	9.5	9.0	8.6	9.7	7.8	7.0	8.3	9.7	7.5	8.1	8.6	7.4	6.4	7.8	8.1	8.5	8.2	8.2	10.0	9.1	9.5
4/8		9.9	8.3	8.2	9.2	8.4	9.5	9.2	8.6	9.8	7.9	7.2	8.6	9.8	7.6	8.3	8.6	7.5	6.6	7.9	8.2	8.7	8.4	8.4	10.0	9.2	9.6
4/9	8.2	9.9	8.5	8.4	9.3	8.6	9.4	9.4	8.5	9.9	8.0	7.4	8.8	9.8	7.8	8.4	8.8	7.6	6.8	7.9	8.4	8.9	8.5	8.5	10.1	9.3	9.6
4/10	8.2	10.0	8.6	8.6	9.5	8.8	9.4	9.4	8.4	10.0	8.0	7.6	8.9	9.9	7.9	8.5	8.9	7.7	6.9	8.0	8.5	9.1	8.7	8.5	10.2	9.5	9.7
4/11	8.1	10.0	8.8	8.8	9.6	9.0	9.3	9.4	8.3	10.0	8.1	7.9	9.0	10.0	8.0	8.7	9.0	7.8	7.1	8.1	8.6	9.2	8.8	8.7	10.3	9.7	9.7
4/12	8.1	10.1	8.9	8.9	9.6	9.3	9.3	9.5	8.3	10.0	8.2	8.1	9.1	10.1	8.1	8.7	9.3	7.9	7.4	8.2	8.7	9.4	8.8	8.8	10.4	9.9	9.8
4/13	8.0	10.2	9.1	9.0	9.6	9.6	9.2	9.4	8.3	10.1	8.2	8.4	9.3	10.3	8.1	8.8	9.6	8.0	7.7	8.3	8.8	9.5	8.9	9.0	10.4	10.2	10.0
4/14	8.1	10.2	9.3	9.1	9.6	9.9	9.1	9.4	8.4	10.4	8.3	8.8	9.4	10.6	8.2	9.0	9.8	8.1	7.9	8.4	8.9	9.7	9.1	9.1	10.5	10.4	10.1
4/15	8.2	10.2	9.4	9.2	9.6	10.3	9.2	9.4	8.6	10.6	8.4	9.1	9.5	10.8	8.4	9.1	10.1	8.2	8.1	8.6	8.9	9.8	9.2	9.3	10.6	10.6	10.1
4/16	8.2	10.3	9.5	9.4	9.6	10.6	9.3	9.4	8.7	10.8	8.5	9.3	9.5	10.9	8.5	9.2	10.2	8.3	8.3	8.7	8.9	9.9	9.2	9.5	10.6	10.8	10.1
4/17	8.2	10.4	9.6	9.5	9.6	10.9	9.4	9.4	8.9	11.1	8.6	9.5	9.7	11.1	8.6	9.3	10.2	8.5	8.4	8.9	8.8	9.9	9.2	9.7	10.6	11.1	10.2
4/18	8.3	10.4	9.8	9.6	9.7	11.2	9.4	9.4	9.1	11.2	8.8	9.7	9.7	11.2	8.7	9.4	10.3	8.6	8.6	8.9	8.8	10.0	9.2	9.8	10.6	11.4	10.2
4/19	8.4	10.5	9.9	9.7	9.8	11.5	9.5	9.5	9.3	11.5	8.9	9.8	9.8	11.2	8.8	9.6	10.3	8.7	8.7	9.0	8.8	10.1	9.3	10.0	10.7	11.6	10.3
4/20	8.6	10.5	10.0	9.9	9.8	11.7	9.6	9.7	9.6	11.7	9.0	10.0	9.8	11.3	8.9	9.8	10.3	8.8	8.6	9.1	8.8	10.4	9.3	10.1	10.8	11.8	10.3
4/21	8.7	10.6	10.1	9.9	9.8	11.8	9.8	9.8	9.9	12.0	9.1	10.1	9.9	11.3	9.0	10.0	10.3	8.9	8.7	9.2	9.0	10.6	9.4	10.2	10.8	12.0	10.3
4/22	8.8	10.8	10.2	9.9	9.9	11.8	10.0	10.1	10.1	12.1	9.2	10.3	9.9	11.4	9.1	10.2	10.4	9.0	9.0	9.3	9.1	10.9	9.4	10.3	10.9	12.3	10.4

HCC Outflow 7DAM Temperature (°C)

Date	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
4/23	9.0	10.9	10.3	10.0	9.9	11.8	10.3	10.3	10.3	12.3	9.3	10.5	9.9	11.5	9.2	10.3	10.4	9.1	9.2	9.4	9.4	11.2	9.5	10.4	11.0	12.5	10.7
4/24	9.2	11.0	10.4	10.2	9.9	11.7	10.6	10.4	10.6	12.5	9.5	10.6	10.0	11.5	9.4	10.4	10.4	9.2	9.5	9.6	9.7	11.6	9.5	10.5	11.1	12.6	10.9
4/25	9.3	11.1	10.5	10.5	9.9	11.6	10.9	10.6	10.9	12.6	9.6	10.7	10.1	11.6	9.6	10.5	10.4	9.4	9.9	9.7	9.9	11.8	9.7	10.6	11.3	12.7	11.2
4/26	9.5	11.3	10.6	10.7	10.0	11.6	11.2	10.7	11.2	12.7	9.8	10.7	10.2	11.7	9.7	10.6	10.4	9.4	10.3	9.8	10.2	12.0	9.8	10.7	11.4	12.8	11.4
4/27	9.7	11.5	10.7	10.9	10.1	11.5	11.5	10.8	11.3	12.8	10.0	10.7	10.3	11.9	9.9	10.7	10.6	9.5	10.8	9.9	10.3	12.2	9.9	10.8	11.5	12.9	11.6
4/28	9.9	11.6	10.8	11.1	10.3	11.4	11.7	10.9	11.5	12.9	10.1	10.8	10.5	11.9	10.0	10.9	10.6	9.7	11.1	10.0	10.4	12.4	10.0	10.9	11.6	13.0	11.8
4/29	10.1	11.7	10.9	11.3	10.4	11.4	11.9	11.1	11.6	13.0	10.2	10.8	10.6	12.0	10.2	11.1	10.7	9.8	11.4	10.1	10.5	12.6	10.1	11.0	11.7	13.0	12.0
4/30	10.2	11.7	11.0	11.5	10.5	11.3	11.9	11.3	11.6	13.1	10.4	10.8	10.7	12.1	10.3	11.4	10.9	9.9	11.5	10.2	10.5	12.7	10.2	11.1	11.9	12.9	12.1
5/1	10.3	11.8	11.1	11.5	10.6	11.2	11.9	11.5	11.6	13.2	10.4	10.8	10.9	12.2	10.5	11.7	11.1	10.1	11.6	10.2	10.5	13.0	10.5	11.2	12.0	12.9	12.2
5/2	10.5	12.0	11.2	11.5	10.8	11.2	12.0	11.8	11.5	13.3	10.5	11.1	11.0	12.3	10.6	12.1	11.4	10.2	11.7	10.3	10.5	13.2	10.7	11.3	12.1	12.9	12.2
5/3	10.6	12.1	11.3	11.5	10.9	11.2	12.1	12.1	11.5	13.4	10.6	11.2	11.1	12.5	10.7	12.3	11.6	10.3	11.8	10.4	10.6	13.4	10.9	11.4	12.2	12.9	12.3
5/4	10.7	12.2	11.3	11.5	11.0	11.3	12.2	12.5	11.5	13.5	10.7	11.4	11.2	12.6	10.9	12.5	11.7	10.4	11.9	10.5	10.6	13.5	11.0	11.6	12.2	12.9	12.3
5/5	10.8	12.3	11.5	11.7	11.0	11.3	12.2	12.8	11.6	13.6	10.9	11.6	11.3	12.8	11.1	12.8	11.9	10.4	12.0	10.7	10.7	13.7	11.2	11.8	12.3	12.9	12.4
5/6	10.9	12.6	11.6	11.9	11.1	11.5	12.3	13.1	11.6	13.7	11.0	11.7	11.4	12.9	11.2	13.1	12.0	10.6	12.2	10.8	10.9	13.6	11.4	12.0	12.4	13.0	12.5
5/7	11.1	12.8	11.7	12.1	11.2	11.6	12.3	13.4	11.8	13.7	11.1	11.8	11.5	13.1	11.4	13.3	12.1	10.7	12.3	11.0	11.0	13.6	11.6	12.2	12.5	13.3	12.6
5/8	11.2	12.9	11.9	12.4	11.4	11.7	12.3	13.6	11.9	13.7	11.3	11.9	11.6	13.1	11.5	13.5	12.2	10.9	12.4	11.1	11.1	13.5	11.7	12.3	12.6	13.4	12.6
5/9	11.2	13.0	12.0	12.7	11.6	11.8	12.4	13.8	11.9	13.8	11.4	11.8	11.6	13.3	11.7	13.7	12.2	11.1	12.4	11.2	11.1	13.4	11.8	12.5	12.7	13.6	12.8
5/10	11.1	13.1	12.2	13.0	11.7	12.0	12.5	14.0	11.9	13.8	11.4	11.8	11.6	13.4	11.9	13.9	12.3	11.3	12.5	11.3	11.2	13.3	11.8	12.7	12.9	13.9	13.1
5/11	11.1	13.2	12.4	13.2	11.8	12.1	12.8	14.2	11.9	13.8	11.6	11.7	11.7	13.5	12.0	14.0	12.4	11.5	12.5	11.3	11.4	13.2	11.9	12.7	13.0	14.1	13.4
5/12	11.1	13.4	12.6	13.4	11.9	12.4	13.2	14.4	12.0	13.8	11.8	11.6	11.7	13.7	12.1	14.0	12.5	11.7	12.6	11.4	11.5	13.1	12.0	12.8	13.2	14.3	13.7
5/13	11.0	13.5	12.8	13.6	12.0	12.6	13.6	14.5	12.0	13.9	12.0	11.6	11.8	13.8	12.2	14.0	12.7	11.9	12.7	11.4	11.7	13.1	12.0	12.9	13.3	14.5	13.8
5/14	11.0	13.7	13.1	13.7	12.2	12.8	14.0	14.6	12.1	14.0	12.2	11.7	11.9	13.9	12.3	14.1	12.9	12.0	12.8	11.6	12.0	13.2	12.1	12.9	13.4	14.6	14.0
5/15	10.9	13.8	13.3	13.9	12.3	12.9	14.5	14.7	12.2	14.1	12.2	11.7	12.0	14.0	12.5	14.3	13.0	12.0	12.9	11.8	12.3	13.3	12.3	12.9	13.4	14.7	14.1
5/16	11.0	13.9	13.5	14.0	12.3	13.1	14.9	14.8	12.3	14.1	12.4	11.9	12.1	14.1	12.5	14.4	13.2	12.1	13.0	11.9	12.5	13.2	12.5	12.9	13.4	14.7	14.2
5/17	11.2	13.9	13.7	14.1	12.4	13.2	15.3	14.8	12.4	14.2	12.5	12.1	12.3	14.0	12.7	14.5	13.4	12.2	13.2	12.0	12.7	13.3	12.7	12.9	13.5	14.8	14.2
5/18	11.3	13.9	14.0	14.2	12.6	13.2	15.7	14.8	12.5	14.3	12.5	12.3	12.3	14.0	12.8	14.6	13.6	12.3	13.5	12.2	12.9	13.3	12.9	12.9	13.6	14.9	14.1
5/19	11.5	13.8	14.2	14.3	12.8	13.2	16.0	14.8	12.6	14.4	12.5	12.5	12.4	14.0	13.0	14.7	13.7	12.4	13.7	12.4	13.1	13.5	13.1	13.0	13.7	15.0	14.1
5/20	11.6	13.7	14.4	14.4	13.1	13.3	16.3	14.8	12.7	14.5	12.5	12.6	12.6	14.1	13.1	14.8	13.9	12.5	13.8	12.6	13.3	13.7	13.3	13.1	13.8	15.1	14.1
5/21	11.8	13.6	14.6	14.4	13.3	13.4	16.7	14.8	12.8	14.6	12.5	12.9	12.7	14.1	13.3	14.9	14.1	12.7	14.1	12.7	13.4	13.9	13.5	13.2	13.8	15.3	14.2
5/22	11.9	13.6	14.8	14.3	13.5	13.5	17.0	14.8	12.9	14.6	12.7	13.1	12.7	14.2	13.4	15.0	14.3	12.9	14.3	12.7	13.5	14.0	13.8	13.3	13.9	15.4	14.3
5/23	12.0	13.6	15.1	14.2	13.7	13.6	17.3	14.7	13.0	14.7	12.7	13.3	12.9	14.3	13.6	15.2	14.6	13.1	14.4	12.8	13.6	14.3	14.0	13.5	14.0	15.5	14.3
5/24	12.2	13.5	15.4	14.2	14.0	13.8	17.4	14.7	13.2	14.7	12.8	13.4	13.0	14.4	13.8	15.4	14.7	13.2	14.6	12.9	13.7	14.5	14.1	13.7	14.1	15.6	14.3
5/25	12.4	13.6	15.6	14.2	14.1	14.0	17.5	14.6	13.4	14.8	13.0	13.6	13.2	14.5	14.0	15.8	14.7	13.3	14.8	13.1	13.8	14.6	14.2	13.9	14.2	15.7	14.3
5/26	12.5	13.6	15.8	14.2	14.2	14.1	17.5	14.5	13.6	14.8	13.1	13.6	13.4	14.6	14.1	16.0	14.7	13.5	15.0	13.2	13.8	14.7	14.2	14.1	14.3	15.8	14.3
5/27	12.6	13.6	16.0	14.3	14.3	14.2	17.4	14.3	13.8	14.9	13.3	13.7	13.6	14.7	14.3	16.2	14.7	13.6	15.3	13.2	13.8	14.6	14.3	14.2	14.5	15.8	14.4
5/28	12.8	13.6	16.2	14.5	14.4	14.3	17.4	14.1	14.1	15.0	13.6	13.8	13.8	14.8	14.4	16.4	14.6	13.8	15.4	13.3	13.8	14.7	14.4	14.4	14.8	15.9	14.6
5/29	13.0	13.6	16.2	14.8	14.6	14.3	17.3	14.0	14.5	15.2	13.8	13.9	14.0	14.8	14.5	16.6	14.6	14.0	15.7	13.5	13.9	14.7	14.3	14.5	15.0	16.0	14.7
5/30	13.2	13.7	16.3	15.0	14.8	14.4	17.2	14.0	14.8	15.3	14.0	14.0	14.3	14.9	14.6	16.6	14.7	14.1	15.9	13.7	14.0	14.8	14.4	14.8	15.2	16.1	14.9
5/31	13.3	13.7	16.3	15.2	15.0	14.5	17.2	13.9	15.0	15.5	14.3	14.1	14.5	15.0	14.8	16.6	14.8	14.3	16.1	13.8	14.0	14.9	14.4	15.0	15.4	16.2	15.2
6/1	13.4	13.7	16.3	15.5	15.3	14.5	17.1	13.9	15.3	15.6	14.5	14.4	14.7	15.1	14.9	16.6	14.9	14.4	16.3	13.8	14.1	15.0	14.5	15.1	15.7	16.3	15.5
6/2	13.5	13.7	16.4	15.6	15.6	14.5	17.1	13.9	15.6	15.7	14.6	14.7	14.9	15.2	15.1	16.6	15.0	14.5	16.5	13.9	14.2	15.1	14.7	15.3	15.9	16.4	15.8
6/3	13.6	13.7	16.4	15.7	15.8	14.6	17.1	14.0	15.9	15.8	14.7	14.8	15.1	15.3	15.2	16.6	15.1	14.6	16.7	14.0	14.2	15.3	14.8	15.5	16.2	16.6	16.1
6/4	13.7	13.7	16.4	15.7	16.1	14.8	17.1	14.1	16.0	15.8	14.8	15.0	15.3	15.4	15.3	16.6	15.2	14.7	16.9	14.2	14.2	15.4	14.9	15.7	16.3	16.6	16.3

HCC Outflow 7DAM Temperature (°C)

Date	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
6/5	13.8	13.7	16.5	15.8	16.3	15.0	17.1	14.1	16.1	16.0	14.9	15.1	15.5	15.6	15.5	16.7	15.3	14.8	17.1	14.2	14.2	15.5	15.1	15.8	16.5	16.7	16.5
6/6	13.9	13.8	16.5	15.8	16.3	15.2	17.1	14.2	16.2	16.2	15.0	15.1	15.8	15.8	15.6	16.7	15.3	14.9	17.2	14.2	14.1	15.6	15.3	15.9	16.8	16.8	16.7
6/7	14.0	13.8	16.5	15.9	16.3	15.4	17.1	14.3	16.3	16.4	15.1	15.2	16.0	16.0	15.6	16.7	15.4	15.0	17.3	14.2	14.2	15.6	15.5	16.1	17.1	17.0	16.9
6/8	14.1	13.9	16.6	16.0	16.4	15.7	17.1	14.5	16.3	16.6	15.1	15.3	16.2	16.2	15.7	16.7	15.5	15.1	17.4	14.2	14.2	15.6	15.7	16.3	17.3	17.1	17.1
6/9	14.2	14.0	16.6	16.1	16.4	16.0	17.1	14.7	16.3	16.8	15.2	15.3	16.4	16.3	15.7	16.7	15.6	15.2	17.5	14.3	14.2	15.6	15.9	16.5	17.4	17.3	17.2
6/10	14.3	14.0	16.6	16.3	16.5	16.3	17.3	15.0	16.2	17.0	15.2	15.3	16.5	16.4	15.8	16.7	15.7	15.2	17.6	14.4	14.3	15.6	16.2	16.7	17.5	17.4	17.2
6/11	14.4	14.1	16.7	16.3	16.5	16.7	17.4	15.2	16.1	17.3	15.2	15.4	16.7	16.5	15.7	16.8	15.7	15.3	17.6	14.5	14.4	15.5	16.4	16.8	17.6	17.6	17.3
6/12	14.7	14.2	16.6	16.4	16.5	17.0	17.5	15.5	16.0	17.3	15.2	15.4	16.8	16.5	15.7	16.9	15.8	15.3	17.6	14.6	14.6	15.5	16.5	16.9	17.7	17.7	17.4
6/13	15.0	14.2	16.6	16.4	16.7	17.2	17.6	15.8	16.0	17.3	15.0	15.4	16.9	16.5	15.8	17.0	15.9	15.3	17.7	14.8	14.8	15.5	16.6	17.0	17.8	17.9	17.4
6/14	15.2	14.3	16.6	16.4	16.8	17.4	17.6	16.0	16.1	17.3	14.9	15.5	17.0	16.6	15.8	17.0	15.9	15.3	17.8	15.0	15.0	15.6	16.7	17.1	17.8	18.0	17.3
6/15	15.4	14.4	16.6	16.4	16.9	17.6	17.6	16.2	16.1	17.3	14.9	15.7	17.2	16.5	15.9	17.1	16.0	15.4	17.9	15.1	15.2	15.7	16.8	17.1	17.9	18.1	17.2
6/16	15.5	14.5	16.6	16.4	17.0	17.9	17.7	16.4	16.2	17.2	14.9	15.8	17.4	16.6	15.9	17.2	16.1	15.5	18.0	15.2	15.4	15.9	16.9	17.1	17.9	18.1	17.2
6/17	15.7	14.6	16.7	16.4	17.0	18.1	17.8	16.6	16.3	17.2	14.9	16.0	17.6	16.6	16.0	17.3	16.2	15.6	18.1	15.3	15.6	16.0	16.9	17.1	18.0	18.1	17.3
6/18	15.7	14.7	16.7	16.5	16.9	18.2	17.9	16.8	16.5	17.2	15.0	16.2	17.7	16.7	16.1	17.5	16.3	15.8	18.2	15.5	15.7	16.2	17.0	17.1	18.0	18.1	17.3
6/19	15.7	14.8	16.8	16.6	16.9	18.2	18.0	16.9	16.7	17.2	15.0	16.5	17.8	16.8	16.3	17.5	16.6	16.0	18.3	15.7	15.8	16.5	17.0	17.1	18.0	18.1	17.3
6/20	15.8	14.9	16.9	16.6	16.8	18.3	18.2	17.0	16.9	17.2	15.1	16.7	17.9	16.8	16.3	17.7	16.8	16.1	18.4	15.9	16.0	16.7	17.1	17.1	18.1	18.0	17.3
6/21	15.9	14.9	17.0	16.7	16.7	18.3	18.4	17.2	17.2	17.4	15.1	16.9	18.0	16.9	16.4	17.8	17.0	16.3	18.4	16.0	16.1	16.9	17.1	17.0	18.1	18.0	17.3
6/22	16.0	14.9	17.1	16.8	16.7	18.4	18.6	17.3	17.5	17.5	15.1	16.9	18.1	17.0	16.5	17.9	17.1	16.5	18.4	16.2	16.3	17.1	17.2	17.0	18.1	17.9	17.4
6/23	16.0	14.9	17.2	17.0	16.7	18.3	18.7	17.5	17.7	17.5	15.1	17.1	18.1	17.1	16.6	18.1	17.2	16.7	18.4	16.3	16.5	17.4	17.2	17.1	18.1	17.9	17.4
6/24	16.1	15.0	17.2	17.1	16.8	18.2	18.8	17.6	17.9	17.6	15.1	17.1	18.1	17.2	16.7	18.1	17.3	16.8	18.4	16.4	16.7	17.6	17.2	17.2	18.1	18.0	17.4
6/25	16.1	15.1	17.3	17.1	16.9	18.2	18.9	17.7	18.1	17.7	15.2	17.2	18.0	17.3	16.9	18.2	17.4	16.9	18.5	16.5	16.9	17.8	17.2	17.3	18.1	18.2	17.6
6/26	16.2	15.2	17.4	17.2	17.1	18.2	19.1	17.8	18.4	17.8	15.4	17.2	18.0	17.4	17.0	18.4	17.4	17.0	18.5	16.6	17.1	17.9	17.2	17.4	18.1	18.4	17.7
6/27	16.1	15.4	17.6	17.4	17.2	18.2	19.2	17.9	18.5	18.0	15.5	17.2	17.9	17.4	17.3	18.5	17.5	17.1	18.7	16.6	17.3	18.1	17.1	17.7	18.1	18.6	17.8
6/28	16.1	15.7	17.6	17.6	17.4	18.2	19.3	18.0	18.6	18.1	15.6	17.2	17.9	17.5	17.5	18.7	17.6	17.2	18.9	16.8	17.4	18.2	17.1	17.9	18.2	18.8	18.0
6/29	16.1	15.9	17.7	17.7	17.6	18.3	19.5	18.1	18.7	18.2	15.8	17.3	17.9	17.5	17.7	18.7	17.8	17.4	19.0	17.0	17.5	18.2	17.2	18.1	18.3	18.9	18.3
6/30	16.2	16.1	17.8	17.9	17.7	18.4	19.6	18.2	18.8	18.3	16.0	17.4	17.9	17.6	17.9	18.8	17.8	17.5	19.2	17.2	17.6	18.4	17.4	18.2	18.4	19.1	18.6
7/1	16.3	16.2	17.9	17.9	17.8	18.5	19.6	18.3	18.9	18.4	16.1	17.4	17.9	17.6	18.1	18.9	17.9	17.7	19.3	17.3	17.8	18.4	17.6	18.3	18.5	19.2	18.9
7/2	16.4	16.3	18.0	18.0	17.8	18.6	19.6	18.5	18.9	18.5	16.3	17.6	18.0	17.7	18.1	18.9	18.0	17.9	19.5	17.4	18.0	18.6	17.9	18.4	18.6	19.3	19.2
7/3	16.4	16.5	18.0	18.2	17.9	18.7	19.6	18.7	19.0	18.6	16.3	17.7	18.1	17.8	18.2	19.0	18.3	18.0	19.6	17.5	18.2	18.6	18.3	18.5	18.8	19.4	19.5
7/4	16.5	16.7	17.9	18.3	18.0	18.8	19.6	18.9	19.0	18.6	16.5	17.9	18.3	17.9	18.2	19.0	18.4	18.1	19.8	17.7	18.3	18.6	18.6	18.6	19.0	19.4	19.7
7/5	16.6	16.8	18.0	18.2	18.3	18.9	19.6	19.1	19.0	18.8	16.7	18.1	18.4	18.0	18.3	19.1	18.6	18.3	19.9	17.9	18.5	18.7	18.9	18.7	19.2	19.5	20.0
7/6	16.7	17.0	18.1	18.3	18.5	19.0	19.7	19.3	19.0	19.0	16.8	18.1	18.5	18.1	18.4	19.2	18.8	18.4	20.0	17.9	18.7	18.8	19.1	18.9	19.3	19.7	20.2
7/7	16.8	17.3	18.1	18.3	18.7	19.1	19.7	19.4	19.1	19.1	17.0	18.1	18.6	18.3	18.6	19.3	19.0	18.5	20.2	18.1	18.9	18.9	19.3	19.1	19.5	19.8	20.4
7/8	17.0	17.7	18.2	18.5	18.9	19.3	19.8	19.5	19.2	19.3	17.2	18.1	18.6	18.4	18.8	19.5	19.3	18.6	20.3	18.2	19.0	19.0	19.5	19.3	19.7	19.8	20.6
7/9	17.1	18.1	18.3	18.6	19.2	19.4	20.0	19.7	19.2	19.4	17.4	18.1	18.6	18.4	18.9	19.7	19.5	18.7	20.4	18.3	19.2	19.0	19.6	19.4	19.8	19.9	20.7
7/10	17.3	18.4	18.4	18.8	19.5	19.5	20.1	19.8	19.3	19.6	17.6	18.1	18.6	18.5	19.1	20.0	19.6	18.8	20.4	18.3	19.2	19.2	19.6	19.5	19.9	19.9	20.9
7/11	17.4	18.6	18.5	18.9	19.7	19.6	20.2	20.0	19.4	19.7	17.7	18.1	18.7	18.6	19.2	20.2	19.8	18.9	20.5	18.4	19.4	19.4	19.6	19.7	20.0	20.0	21.0
7/12	17.6	18.9	18.6	19.2	19.8	19.6	20.3	20.1	19.6	19.8	17.7	18.1	18.7	18.8	19.3	20.4	20.0	19.0	20.6	18.5	19.5	19.5	19.6	19.8	20.0	20.0	21.2
7/13	17.7	19.1	18.7	19.4	19.9	19.7	20.4	20.3	19.7	19.9	17.9	18.2	18.8	19.0	19.3	20.7	20.1	19.2	20.6	18.6	19.6	19.6	19.7	19.9	20.1	20.0	21.3
7/14	17.9	19.2	18.8	19.5	20.0	19.8	20.5	20.6	19.8	20.0	17.9	18.2	18.8	19.1	19.4	20.9	20.3	19.3	20.7	18.7	19.7	19.8	19.7	20.0	20.1	20.0	21.4
7/15	18.1	19.2	18.9	19.7	20.1	20.0	20.5	20.8	19.9	20.2	18.0	18.3	19.0	19.2	19.4	21.1	20.4	19.5	20.8	18.8	19.8	19.9	19.7	20.0	20.2	19.9	21.5
7/16	18.3	19.2	19.0	19.8	20.1	20.2	20.6	21.0	20.1	20.3	18.1	18.4	19.1	19.5	19.4	21.3	20.5	19.5	20.9	19.0	19.9	20.0	19.8	20.1	20.3	19.9	21.6
7/17	18.4	19.2	19.2	20.0	20.2	20.4	20.7	21.1	20.3	20.4	18.1	18.5	19.2	19.8	19.5	21.5	20.7	19.5	21.0	19.2	20.0	20.2	20.0	20.2	20.3	19.8	21.7

HCC Outflow 7DAM Temperature (°C)

Date	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
7/18	18.6	19.3	19.3	20.0	20.2	20.5	20.7	21.3	20.4	20.5	18.2	18.7	19.3	20.0	19.6	21.6	20.7	19.6	21.1	19.4	20.1	20.3	20.1	20.3	20.4	19.9	21.8
7/19	18.8	19.3	19.4	20.1	20.3	20.7	20.8	21.5	20.5	20.6	18.3	18.8	19.4	20.3	19.6	21.8	20.8	19.8	21.1	19.5	20.3	20.4	20.1	20.4	20.5	20.0	21.9
7/20	19.0	19.3	19.5	20.2	20.4	20.8	20.8	21.6	20.6	20.7	18.3	19.0	19.5	20.5	19.8	21.9	20.9	19.8	21.2	19.7	20.4	20.5	20.3	20.5	20.6	20.1	22.0
7/21	19.1	19.2	19.6	20.3	20.4	20.9	20.9	21.7	20.6	20.7	18.3	19.1	19.6	20.7	19.9	22.1	21.0	19.9	21.3	19.9	20.5	20.6	20.3	20.6	20.7	20.2	22.1
7/22	19.2	19.2	19.7	20.5	20.4	21.0	21.0	21.9	20.6	20.7	18.4	19.3	19.8	20.9	20.1	22.2	21.0	19.9	21.4	20.1	20.6	20.8	20.5	20.6	20.8	20.3	22.1
7/23	19.3	19.2	19.7	20.6	20.5	21.0	21.0	22.1	20.6	20.8	18.5	19.4	19.9	21.0	20.2	22.3	21.1	20.1	21.5	20.1	20.7	20.9	20.6	20.7	21.0	20.4	22.1
7/24	19.3	19.1	19.7	20.8	20.5	21.1	21.1	22.3	20.7	20.9	18.6	19.5	20.0	21.0	20.4	22.4	21.2	20.2	21.7	20.2	20.8	21.0	20.7	20.7	21.2	20.6	22.2
7/25	19.2	19.1	19.7	21.0	20.6	21.2	21.2	22.3	20.8	21.0	18.8	19.6	20.1	21.0	20.5	22.5	21.3	20.3	21.8	20.4	20.9	21.2	20.8	20.8	21.4	20.7	22.3
7/26	19.2	19.0	19.6	21.1	20.7	21.3	21.3	22.4	20.8	21.1	19.0	19.6	20.2	21.0	20.6	22.6	21.4	20.4	21.9	20.5	21.0	21.3	20.9	20.8	21.6	20.8	22.3
7/27	19.1	19.0	19.6	21.2	20.8	21.4	21.5	22.5	20.9	21.1	19.3	19.6	20.4	21.0	20.6	22.6	21.5	20.5	21.9	20.5	21.1	21.4	20.9	20.9	21.8	20.8	22.4
7/28	19.0	19.0	19.6	21.3	20.9	21.5	21.6	22.6	21.1	21.2	19.5	19.6	20.5	21.0	20.7	22.7	21.6	20.7	22.1	20.5	21.2	21.5	21.0	21.0	22.0	20.9	22.5
7/29	18.9	19.0	19.7	21.5	21.0	21.6	21.7	22.7	21.2	21.3	19.7	19.6	20.7	21.0	20.7	22.8	21.6	20.8	22.1	20.5	21.3	21.6	21.0	21.1	22.2	21.0	22.6
7/30	18.8	19.0	19.7	21.6	21.1	21.7	21.8	22.8	21.4	21.4	20.0	19.7	20.8	20.9	20.8	22.8	21.7	20.8	22.2	20.5	21.4	21.7	21.0	21.1	22.3	21.2	22.7
7/31	18.8	19.0	19.8	21.8	21.3	21.8	21.9	22.8	21.5	21.5	20.1	19.7	20.8	20.9	20.8	22.9	21.7	21.0	22.2	20.5	21.5	21.7	20.9	21.3	22.3	21.3	22.8
8/1	18.8	19.0	19.8	21.9	21.4	21.9	21.9	23.0	21.6	21.5	20.2	19.7	20.9	20.9	20.8	22.9	21.8	21.1	22.3	20.5	21.5	21.8	21.0	21.4	22.3	21.3	22.9
8/2	18.9	19.1	19.9	22.1	21.4	22.0	21.9	23.1	21.8	21.6	20.5	19.8	21.0	21.0	20.9	22.9	21.9	21.2	22.3	20.5	21.6	21.8	21.0	21.5	22.4	21.4	23.0
8/3	18.9	19.2	20.0	22.3	21.5	22.0	21.9	23.2	21.9	21.7	20.5	19.9	21.0	21.0	21.0	22.9	22.0	21.3	22.3	20.6	21.7	21.9	21.0	21.6	22.4	21.4	23.2
8/4	19.0	19.4	20.0	22.4	21.5	22.1	22.0	23.3	22.0	21.8	20.6	19.9	21.1	21.1	21.1	22.9	22.1	21.3	22.3	20.8	21.8	22.0	21.1	21.7	22.5	21.4	23.3
8/5	19.1	19.5	20.1	22.5	21.6	22.0	22.0	23.4	22.1	21.8	20.6	20.0	21.1	21.2	21.2	22.8	22.2	21.5	22.3	21.0	21.8	22.1	21.2	21.9	22.6	21.5	23.4
8/6	19.2	19.6	20.2	22.6	21.8	22.0	22.1	23.5	22.1	21.9	20.6	20.0	21.2	21.2	21.4	22.7	22.3	21.6	22.4	21.1	21.9	22.1	21.2	22.0	22.6	21.5	23.5
8/7	19.3	19.8	20.3	22.6	21.9	22.0	22.1	23.5	22.2	22.0	20.6	20.0	21.4	21.3	21.6	22.7	22.3	21.7	22.4	21.3	22.0	22.2	21.3	22.1	22.7	21.5	23.5
8/8	19.3	19.9	20.4	22.6	22.0	22.0	22.2	23.6	22.2	22.1	20.6	20.0	21.5	21.4	21.7	22.7	22.3	21.7	22.5	21.4	22.1	22.2	21.4	22.2	22.8	21.5	23.6
8/9	19.4	20.0	20.5	22.6	22.0	22.0	22.3	23.6	22.2	22.1	20.5	20.2	21.7	21.5	21.8	22.7	22.3	21.7	22.5	21.5	22.2	22.2	21.4	22.3	22.9	21.5	23.6
8/10	19.5	20.1	20.6	22.5	22.1	22.0	22.4	23.7	22.3	22.2	20.6	20.2	21.9	21.6	21.9	22.8	22.3	21.8	22.6	21.5	22.3	22.2	21.5	22.4	23.0	21.5	23.6
8/11	19.6	20.1	20.7	22.5	22.1	22.0	22.5	23.8	22.3	22.3	20.7	20.3	22.0	21.7	21.9	22.8	22.2	21.9	22.6	21.5	22.3	22.2	21.6	22.5	22.9	21.5	23.6
8/12	19.6	20.2	20.8	22.4	22.1	21.9	22.5	23.8	22.3	22.4	20.9	20.3	22.2	21.7	22.0	22.9	22.2	21.9	22.7	21.6	22.4	22.2	21.6	22.5	22.9	21.5	23.5
8/13	19.7	20.2	20.9	22.4	21.9	21.9	22.6	23.8	22.4	22.5	21.0	20.5	22.3	21.8	22.0	23.0	22.3	21.9	22.6	21.7	22.5	22.2	21.7	22.5	22.9	21.5	23.5
8/14	19.8	20.3	21.0	22.3	21.9	21.9	22.6	23.9	22.3	22.5	21.1	20.6	22.4	21.8	22.0	23.0	22.3	21.8	22.6	21.7	22.6	22.2	21.8	22.5	22.9	21.5	23.5
8/15	19.9	20.3	21.1	22.1	21.8	22.0	22.6	23.9	22.3	22.6	21.2	20.8	22.5	21.9	22.1	23.0	22.3	21.9	22.6	21.7	22.6	22.2	21.9	22.5	22.8	21.6	23.5
8/16	20.0	20.4	21.2	22.1	21.7	22.0	22.6	23.9	22.3	22.7	21.4	20.9	22.6	21.9	22.1	23.0	22.3	21.9	22.6	21.7	22.7	22.2	22.0	22.5	22.8	21.6	23.5
8/17	20.0	20.5	21.2	22.0	21.6	22.1	22.6	23.9	22.2	22.7	21.4	21.0	22.7	21.9	22.1	23.0	22.3	21.9	22.5	21.6	22.7	22.2	22.1	22.6	22.8	21.6	23.5
8/18	20.1	20.6	21.3	22.0	21.6	22.1	22.7	24.0	22.2	22.7	21.5	21.1	22.7	21.9	22.1	22.9	22.4	21.9	22.5	21.6	22.7	22.2	22.2	22.6	22.7	21.7	23.4
8/19	20.2	20.7	21.3	21.9	21.5	22.1	22.7	23.9	22.1	22.7	21.5	21.3	22.7	21.9	22.0	22.9	22.4	21.9	22.5	21.5	22.7	22.3	22.2	22.6	22.7	21.7	23.4
8/20	20.3	20.7	21.3	21.9	21.4	22.1	22.7	23.9	22.1	22.7	21.5	21.3	22.7	22.0	22.0	22.9	22.3	21.9	22.5	21.5	22.7	22.3	22.3	22.6	22.7	21.8	23.4
8/21	20.3	20.8	21.3	22.0	21.3	22.1	22.8	23.8	22.1	22.7	21.5	21.3	22.7	22.1	21.9	22.8	22.3	22.0	22.5	21.6	22.7	22.3	22.3	22.7	22.8	21.9	23.4
8/22	20.4	20.9	21.4	22.0	21.3	22.1	22.8	23.7	22.2	22.7	21.5	21.3	22.7	22.2	21.9	22.8	22.3	22.0	22.5	21.6	22.7	22.3	22.4	22.7	22.8	22.0	23.4
8/23	20.4	21.0	21.4	22.1	21.2	22.1	22.8	23.7	22.3	22.6	21.6	21.3	22.6	22.2	21.8	22.9	22.2	22.1	22.5	21.7	22.7	22.4	22.5	22.7	22.8	22.1	23.4
8/24	20.5	21.0	21.4	22.3	21.2	22.0	22.9	23.5	22.4	22.6	21.7	21.2	22.6	22.2	21.8	22.9	22.1	22.1	22.6	21.8	22.7	22.5	22.5	22.7	22.8	22.2	23.5
8/25	20.6	21.1	21.3	22.3	21.2	22.0	22.9	23.4	22.4	22.5	21.7	21.2	22.6	22.3	21.8	22.9	22.1	22.1	22.7	21.9	22.8	22.5	22.5	22.7	22.8	22.2	23.5
8/26	20.6	21.1	21.3	22.4	21.2	22.0	22.8	23.4	22.5	22.5	21.8	21.1	22.5	22.3	21.8	22.8	22.0	22.1	22.7	22.0	22.8	22.5	22.6	22.7	22.8	22.3	23.5
8/27	20.7	21.1	21.3	22.5	21.2	22.0	22.8	23.3	22.6	22.4	21.8	21.0	22.6	22.2	21.8	22.8	21.9	22.1	22.8	22.0	22.9	22.6	22.6	22.7	22.7	22.3	23.5
8/28	20.8	21.1	21.2	22.5	21.3	22.0	22.8	23.3	22.6	22.4	21.8	21.0	22.6	22.1	21.8	22.8	21.9	22.1	22.8	22.0	22.9	22.6	22.6	22.6	22.7	22.3	23.5
8/29	20.9	21.0	21.0	22.5	21.3	22.0	22.8	23.2	22.7	22.4	21.8	20.9	22.6	22.0	21.9	22.8	21.9	22.1	22.8	22.0	23.0	22.7	22.6	22.5	22.6	22.2	23.5

HCC Outflow 7DAM Temperature (°C)

Date	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
8/30	21.0	20.9	21.0	22.5	21.4	22.0	22.8	23.2	22.7	22.3	21.8	20.9	22.6	22.0	21.9	22.7	21.8	22.1	22.8	21.9	23.0	22.6	22.6	22.5	22.6	22.2	23.6
8/31	21.0	20.8	20.9	22.4	21.4	21.9	22.8	23.1	22.7	22.3	21.7	20.9	22.6	22.0	21.9	22.7	21.8	22.0	22.8	21.8	23.1	22.6	22.6	22.4	22.5	22.2	23.6
9/1	21.0	20.7	20.9	22.3	21.4	21.9	22.8	23.1	22.7	22.3	21.7	20.9	22.6	22.0	21.9	22.6	21.8	22.0	22.8	21.7	23.1	22.6	22.6	22.4	22.5	22.2	23.6
9/2	21.0	20.6	20.8	22.3	21.3	21.8	22.7	23.1	22.6	22.2	21.7	21.0	22.6	22.0	21.9	22.5	21.8	21.9	22.8	21.5	23.1	22.6	22.6	22.4	22.5	22.1	23.6
9/3	21.0	20.5	20.8	22.2	21.3	21.8	22.7	23.1	22.6	22.2	21.8	21.0	22.6	22.0	21.9	22.5	21.8	21.8	22.8	21.4	23.1	22.5	22.6	22.4	22.4	22.1	23.5
9/4	21.0	20.5	20.8	22.2	21.3	21.7	22.7	23.0	22.5	22.1	21.8	21.0	22.6	22.0	21.9	22.4	21.9	21.7	22.7	21.3	23.0	22.4	22.7	22.4	22.4	22.1	23.5
9/5	21.1	20.5	20.8	22.1	21.3	21.7	22.7	23.0	22.3	21.9	21.9	21.1	22.6	22.0	21.9	22.3	21.9	21.6	22.7	21.2	22.9	22.4	22.7	22.3	22.3	22.0	23.5
9/6	21.1	20.5	20.7	22.1	21.3	21.6	22.7	22.9	22.1	21.8	21.9	21.1	22.7	22.0	21.9	22.2	22.0	21.5	22.7	21.1	22.8	22.3	22.7	22.3	22.2	22.0	23.5
9/7	21.2	20.6	20.7	22.0	21.2	21.5	22.6	22.9	22.0	21.7	21.8	21.1	22.8	22.0	21.8	22.2	22.1	21.4	22.6	21.0	22.7	22.3	22.7	22.2	22.0	22.0	23.5
9/8	21.2	20.6	20.7	22.0	21.2	21.5	22.6	22.9	21.8	21.5	21.8	21.1	22.8	21.9	21.8	22.1	22.2	21.3	22.6	20.8	22.6	22.3	22.8	22.2	21.9	21.8	23.5
9/9	21.3	20.5	20.7	21.9	21.2	21.4	22.5	22.9	21.7	21.4	21.7	21.1	22.8	21.8	21.8	22.1	22.2	21.3	22.5	20.7	22.6	22.3	22.8	22.1	21.8	21.8	23.4
9/10	21.4	20.5	20.7	21.8	21.2	21.3	22.5	22.8	21.6	21.2	21.6	21.0	22.8	21.7	21.7	22.1	22.2	21.2	22.4	20.6	22.5	22.3	22.8	22.0	21.6	21.6	23.4
9/11	21.4	20.4	20.8	21.7	21.2	21.3	22.4	22.8	21.5	21.1	21.5	21.0	22.7	21.7	21.6	22.1	22.2	21.2	22.3	20.5	22.5	22.2	22.8	22.0	21.5	21.5	23.4
9/12	21.4	20.3	20.8	21.6	21.2	21.2	22.4	22.8	21.4	21.0	21.3	21.0	22.6	21.7	21.6	22.0	22.1	21.1	22.2	20.5	22.5	22.2	22.8	21.9	21.5	21.4	23.3
9/13	21.4	20.2	20.8	21.5	21.1	21.2	22.3	22.7	21.3	20.9	21.2	20.9	22.5	21.7	21.5	22.1	22.0	21.0	22.1	20.4	22.5	22.1	22.8	21.8	21.4	21.3	23.3
9/14	21.4	20.1	20.8	21.3	21.1	21.2	22.3	22.7	21.2	20.8	21.1	20.9	22.3	21.6	21.4	22.0	21.8	20.9	22.0	20.4	22.4	22.1	22.8	21.8	21.4	21.2	23.3
9/15	21.4	20.0	20.7	21.1	21.2	21.2	22.2	22.7	21.1	20.7	21.1	20.8	22.2	21.5	21.3	21.9	21.7	20.8	22.0	20.4	22.3	21.9	22.8	21.7	21.4	21.1	23.2
9/16	21.3	19.9	20.7	21.0	21.2	21.3	22.1	22.6	21.1	20.7	21.0	20.8	22.0	21.4	21.2	21.8	21.6	20.7	22.0	20.3	22.3	21.8	22.9	21.6	21.4	21.0	23.1
9/17	21.3	19.9	20.6	20.9	21.2	21.2	22.0	22.7	21.0	20.6	21.1	20.8	21.9	21.2	21.1	21.7	21.4	20.5	22.0	20.3	22.2	21.7	22.9	21.6	21.4	20.9	23.0
9/18	21.3	19.8	20.5	20.8	21.3	21.2	21.8	22.7	21.0	20.6	21.1	20.8	21.7	21.1	21.0	21.6	21.3	20.4	22.0	20.2	22.1	21.6	23.0	21.5	21.4	20.8	22.9
9/19	21.2	19.7	20.4	20.7	21.3	21.1	21.7	22.7	20.9	20.5	21.2	20.7	21.5	20.9	20.9	21.4	21.2	20.4	22.0	20.1	22.0	21.5	23.0	21.4	21.3	20.7	22.7
9/20	21.2	19.6	20.3	20.6	21.3	20.9	21.4	22.7	20.8	20.4	21.2	20.7	21.3	20.7	20.8	21.2	21.0	20.3	22.0	20.1	21.8	21.4	22.9	21.4	21.3	20.6	22.5
9/21	21.2	19.6	20.2	20.6	21.3	20.7	21.2	22.6	20.7	20.3	21.2	20.6	21.2	20.5	20.7	20.9	20.9	20.3	22.0	20.1	21.8	21.4	22.9	21.4	21.2	20.5	22.2
9/22	21.1	19.5	20.0	20.6	21.3	20.4	21.0	22.5	20.6	20.2	21.2	20.5	21.0	20.4	20.6	20.8	20.8	20.3	21.9	20.0	21.7	21.3	22.8	21.4	21.1	20.4	22.0
9/23	21.0	19.5	19.8	20.5	21.3	20.2	20.9	22.4	20.5	20.0	21.2	20.4	20.8	20.2	20.5	20.6	20.7	20.3	21.8	19.9	21.6	21.3	22.7	21.4	21.0	20.3	21.7
9/24	20.9	19.5	19.7	20.5	21.2	19.9	20.8	22.2	20.4	19.8	21.1	20.3	20.7	20.1	20.3	20.4	20.5	20.3	21.7	19.8	21.5	21.2	22.6	21.4	20.9	20.2	21.4
9/25	20.8	19.5	19.5	20.5	21.1	19.7	20.6	22.0	20.3	19.5	21.0	20.2	20.6	20.0	20.2	20.3	20.3	20.2	21.6	19.7	21.4	21.2	22.4	21.4	20.8	20.0	21.1
9/26	20.7	19.5	19.3	20.5	21.0	19.5	20.5	21.9	20.2	19.2	20.9	20.1	20.5	19.9	20.0	20.1	20.2	20.2	21.5	19.6	21.3	21.1	22.2	21.4	20.7	19.9	20.8
9/27	20.6	19.5	19.1	20.5	20.9	19.3	20.4	21.7	20.1	18.9	20.8	20.0	20.4	19.8	19.9	20.0	20.0	20.1	21.4	19.4	21.3	21.0	22.0	21.3	20.6	19.8	20.6
9/28	20.4	19.5	19.0	20.5	20.7	19.2	20.2	21.6	20.0	18.7	20.7	19.9	20.3	19.7	19.7	19.9	19.8	20.0	21.3	19.4	21.1	20.8	21.8	21.3	20.6	19.7	20.4
9/29	20.4	19.5	18.9	20.5	20.6	19.0	20.0	21.5	19.8	18.4	20.6	19.8	20.2	19.6	19.5	19.7	19.7	19.9	21.2	19.3	21.0	20.7	21.6	21.2	20.5	19.6	20.2
9/30	20.3	19.4	18.8	20.4	20.5	18.9	19.8	21.3	19.6	18.2	20.6	19.7	20.2	19.6	19.3	19.6	19.5	19.8	21.1	19.3	20.9	20.6	21.3	21.0	20.5	19.6	20.1
10/1	20.2	19.3	18.7	20.4	20.3	18.8	19.6	21.2	19.4	18.1	20.5	19.5	20.1	19.5	19.2	19.5	19.4	19.8	21.0	19.4	20.7	20.5	21.1	20.9	20.4	19.5	19.9
10/2	20.2	19.2	18.5	20.4	20.2	18.7	19.5	21.0	19.2	18.0	20.4	19.3	20.0	19.5	19.1	19.3	19.2	19.7	20.8	19.4	20.6	20.4	20.8	20.7	20.3	19.5	19.7
10/3	20.2	19.1	18.4	20.2	20.0	18.5	19.3	20.8	18.9	17.9	20.3	19.2	19.9	19.4	18.9	19.2	19.1	19.6	20.7	19.4	20.5	20.3	20.6	20.6	20.2	19.5	19.4
10/4	20.1	19.1	18.2	20.1	19.9	18.4	19.1	20.5	18.7	18.0	20.2	19.0	19.8	19.4	18.8	19.1	18.9	19.6	20.4	19.5	20.3	20.1	20.3	20.4	20.1	19.4	19.2
10/5	20.0	19.0	18.1	20.0	19.7	18.4	19.0	20.2	18.6	18.0	20.2	18.8	19.7	19.3	18.7	19.0	18.7	19.5	20.2	19.5	20.1	20.0	20.0	20.2	20.0	19.3	18.9
10/6	19.9	18.9	17.9	19.8	19.4	18.3	18.9	19.9	18.4	18.0	20.1	18.6	19.6	19.3	18.5	18.9	18.6	19.4	19.9	19.5	20.0	19.9	19.8	20.1	19.9	19.2	18.6
10/7	19.7	18.9	17.8	19.6	19.2	18.2	18.8	19.6	18.3	18.0	19.9	18.4	19.5	19.2	18.4	18.7	18.4	19.3	19.6	19.4	19.8	19.7	19.5	19.9	19.9	19.1	18.3
10/8	19.5	18.8	17.7	19.4	18.9	18.1	18.6	19.3	18.2	17.9	19.7	18.3	19.4	19.1	18.2	18.6	18.2	19.2	19.2	19.3	19.6	19.4	19.3	19.8	19.8	18.9	18.0
10/9	19.3	18.7	17.6	19.2	18.6	18.0	18.3	19.0	18.1	17.7	19.5	18.1	19.4	19.0	18.0	18.4	18.0	19.0	18.9	19.2	19.3	19.2	19.0	19.7	19.7	18.7	17.7
10/10	19.1	18.6	17.5	19.0	18.4	18.0	18.1	18.8	17.9	17.6	19.3	18.0	19.3	18.9	17.7	18.2	17.8	18.8	18.6	19.1	19.1	18.9	18.7	19.6	19.6	18.5	17.4
10/11	18.9	18.5	17.3	18.9	18.2	17.9	17.9	18.5	17.8	17.4	19.0	17.9	19.3	18.8	17.6	18.1	17.5	18.5	18.3	19.0	18.8	18.6	18.4	19.6	19.5	18.3	17.2

HCC Outflow 7DAM Temperature (°C)

Date	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
10/12	18.7	18.4	17.2	18.7	18.0	17.8	17.6	18.3	17.6	17.2	18.8	17.8	19.2	18.7	17.4	17.9	17.3	18.3	18.0	18.9	18.6	18.4	18.2	19.5	19.4	18.1	17.0
10/13	18.6	18.3	17.1	18.5	17.8	17.7	17.4	18.1	17.5	17.0	18.6	17.7	19.1	18.5	17.2	17.7	17.1	18.0	17.7	18.8	18.4	18.2	17.9	19.4	19.4	18.0	16.8
10/14	18.4	18.2	17.0	18.3	17.7	17.6	17.1	17.9	17.3	16.8	18.4	17.5	19.0	18.4	17.0	17.6	16.9	17.7	17.4	18.7	18.2	18.1	17.7	19.4	19.3	17.8	16.7
10/15	18.3	18.0	16.9	18.1	17.5	17.5	16.8	17.6	17.1	16.7	18.2	17.4	18.8	18.3	16.9	17.4	16.7	17.4	17.0	18.6	18.1	18.0	17.5	19.3	19.2	17.6	16.6
10/16	18.3	17.8	16.8	17.9	17.4	17.4	16.5	17.3	16.9	16.6	18.0	17.2	18.7	18.2	16.8	17.2	16.5	17.1	16.6	18.5	17.9	17.9	17.3	19.2	19.1	17.5	16.5
10/17	18.2	17.6	16.8	17.7	17.2	17.2	16.2	17.0	16.8	16.5	17.9	17.0	18.5	18.0	16.7	17.0	16.4	16.8	16.2	18.4	17.8	17.8	17.1	19.1	19.1	17.4	16.4
10/18	18.1	17.4	16.8	17.5	16.9	17.0	15.9	16.7	16.5	16.4	17.7	16.7	18.3	17.9	16.6	16.9	16.2	16.6	15.9	18.3	17.7	17.7	16.9	18.9	19.0	17.3	16.2
10/19	18.0	17.2	16.7	17.3	16.7	16.9	15.5	16.4	16.3	16.4	17.6	16.5	18.1	17.8	16.6	16.7	16.1	16.4	15.6	18.1	17.6	17.6	16.8	18.7	18.9	17.2	16.1
10/20	17.9	17.0	16.6	17.1	16.5	16.7	15.2	16.0	16.1	16.3	17.4	16.3	17.9	17.7	16.5	16.6	16.0	16.3	15.4	18.0	17.4	17.5	16.6	18.6	18.8	17.0	15.9
10/21	17.8	16.8	16.5	16.9	16.3	16.5	14.9	15.7	15.8	16.3	17.2	16.1	17.8	17.6	16.4	16.5	15.8	16.1	15.2	17.8	17.1	17.5	16.4	18.4	18.8	16.9	15.7
10/22	17.7	16.6	16.5	16.6	16.1	16.3	14.6	15.4	15.6	16.2	17.0	15.9	17.6	17.5	16.3	16.3	15.7	16.0	15.1	17.7	16.9	17.3	16.2	18.2	18.7	16.8	15.5
10/23	17.5	16.5	16.4	16.4	15.9	16.1	14.4	15.1	15.4	16.1	16.9	15.8	17.5	17.4	16.2	16.2	15.6	15.8	15.1	17.5	16.6	17.2	16.0	18.0	18.6	16.7	15.3
10/24	17.4	16.3	16.3	16.2	15.7	15.9	14.2	14.9	15.2	16.0	16.7	15.7	17.4	17.2	16.2	16.1	15.4	15.7	15.1	17.4	16.4	17.0	15.8	17.9	18.5	16.6	15.1
10/25	17.2	16.2	16.2	16.0	15.5	15.7	14.0	14.7	15.1	15.8	16.5	15.7	17.3	17.0	16.1	16.0	15.3	15.6	15.1	17.3	16.1	16.8	15.7	17.7	18.4	16.5	15.0
10/26	17.0	16.1	16.1	15.9	15.2	15.5	13.9	14.5	14.9	15.7	16.4	15.6	17.2	16.9	16.0	15.9	15.1	15.5	15.0	17.2	15.9	16.5	15.6	17.6	18.3	16.3	14.8
10/27	16.8	15.9	16.0	15.8	15.0	15.2	13.7	14.3	14.8	15.4	16.2	15.5	17.0	16.7	15.9	15.7	14.9	15.3	14.9	17.0	15.7	16.3	15.5	17.4	18.2	16.2	14.6
10/28	16.6	15.9	15.9	15.6	14.8	15.0	13.5	14.2	14.7	15.2	16.0	15.4	16.9	16.5	15.8	15.5	14.7	15.1	14.8	16.9	15.5	16.0	15.4	17.3	18.1	16.1	14.5
10/29	16.4	15.8	15.7	15.5	14.6	14.8	13.3	14.0	14.5	15.0	15.8	15.3	16.8	16.3	15.7	15.3	14.5	14.9	14.6	16.8	15.4	15.8	15.3	17.2	17.9	16.0	14.4
10/30	16.1	15.7	15.6	15.4	14.4	14.5	13.2	13.9	14.4	14.8	15.6	15.1	16.7	16.1	15.6	15.0	14.4	14.7	14.4	16.6	15.2	15.5	15.1	17.0	17.8	15.9	14.3
10/31	15.9	15.7	15.5	15.3	14.2	14.4	13.1	13.8	14.3	14.5	15.4	14.9	16.5	15.9	15.5	14.8	14.2	14.5	14.2	16.4	15.1	15.3	15.0	16.9	17.6	15.8	14.1
11/1	15.6	15.6	15.4	15.1	14.0	14.2	12.9	13.7	14.1	14.3	15.2	14.7	16.3	15.7	15.4	14.5	14.0	14.2	13.9	16.2	14.9	15.1	14.8	16.8	17.5	15.7	14.0
11/2	15.4	15.5	15.1	15.0	13.8	14.0	12.8	13.5	14.0	14.1	15.1	14.4	16.0	15.5	15.2	14.3	13.9	14.1	13.7	16.0	14.7	14.9	14.7	16.6	17.3	15.6	13.9
11/3	15.1	15.4	14.9	14.8	13.6	13.9	12.7	13.4	13.8	14.0	14.9	14.1	15.7	15.3	15.1	14.0	13.7	13.9	13.4	15.8	14.4	14.7	14.5	16.4	17.2	15.5	13.7
11/4	14.8	15.3	14.6	14.6	13.4	13.7	12.6	13.2	13.6	13.8	14.8	13.8	15.4	15.1	14.9	13.8	13.6	13.8	13.2	15.6	14.2	14.6	14.3	16.3	17.0	15.4	13.6
11/5	14.5	15.1	14.3	14.3	13.2	13.4	12.5	13.0	13.4	13.7	14.7	13.5	15.1	14.9	14.7	13.5	13.5	13.7	13.0	15.4	14.0	14.5	14.1	16.1	16.8	15.2	13.4
11/6	14.2	14.9	14.0	14.1	13.0	13.2	12.4	12.8	13.2	13.5	14.5	13.2	14.8	14.7	14.5	13.3	13.4	13.6	12.9	15.3	13.8	14.4	13.9	15.9	16.6	15.1	13.2
11/7	13.9	14.7	13.7	13.9	12.8	12.9	12.3	12.6	13.0	13.3	14.3	12.9	14.4	14.5	14.4	13.1	13.2	13.5	12.7	15.2	13.6	14.3	13.7	15.8	16.4	15.0	13.0
11/8	13.6	14.5	13.3	13.7	12.7	12.7	12.2	12.5	12.9	13.2	14.1	12.6	14.1	14.2	14.2	12.9	13.0	13.3	12.6	15.1	13.4	14.2	13.5	15.6	16.2	14.8	12.8
11/9	13.4	14.2	13.2	13.5	12.5	12.4	12.1	12.4	12.7	13.0	13.9	12.3	13.8	14.0	14.0	12.8	12.9	13.2	12.5	15.0	13.2	14.1	13.2	15.4	16.0	14.7	12.6
11/10	13.1	14.0	13.1	13.3	12.2	12.2	12.0	12.3	12.6	12.8	13.7	12.1	13.6	13.8	13.8	12.7	12.7	13.1	12.3	14.9	13.0	13.9	13.0	15.3	15.7	14.5	12.4
11/11	12.9	13.8	13.0	13.1	12.0	11.9	11.9	12.2	12.5	12.7	13.5	11.9	13.3	13.5	13.6	12.6	12.6	12.9	12.2	14.8	12.8	13.8	12.8	15.2	15.5	14.3	12.2
11/12	12.8	13.6	12.7	12.9	11.8	11.7	11.8	12.1	12.4	12.5	13.3	11.7	13.1	13.4	13.5	12.6	12.4	12.7	12.0	14.6	12.6	13.6	12.7	15.0	15.2	14.2	12.0
11/13	12.7	13.4	12.5	12.7	11.6	11.5	11.7	12.1	12.3	12.2	13.1	11.6	12.9	13.2	13.2	12.5	12.2	12.6	11.9	14.4	12.4	13.4	12.5	14.8	15.0	14.1	11.8
11/14	12.6	13.3	12.3	12.5	11.5	11.3	11.5	12.0	12.2	12.1	13.0	11.5	12.7	13.0	13.0	12.5	12.1	12.4	11.8	14.2	12.3	13.2	12.4	14.6	14.8	14.0	11.6
11/15	12.5	13.1	12.1	12.3	11.3	11.1	11.3	12.0	12.1	11.9	12.8	11.4	12.6	12.9	12.8	12.4	12.0	12.3	11.7	13.9	12.1	12.9	12.3	14.4	14.6	13.9	11.5
11/16	12.4	12.9	11.7	12.1	11.1	11.0	11.2	11.9	12.0	11.7	12.7	11.4	12.4	12.7	12.6	12.4	11.9	12.2	11.6	13.7	11.9	12.7	12.2	14.1	14.3	13.8	11.3
11/17	12.3	12.7	11.4	11.9	11.1	10.8	11.0	11.8	11.9	11.6	12.6	11.4	12.3	12.6	12.4	12.3	11.7	12.1	11.4	13.4	11.8	12.5	12.1	13.8	14.1	13.8	11.3
11/18	12.1	12.5	11.0	11.7	11.0	10.7	10.8	11.7	11.9	11.4	12.4	11.4	12.1	12.4	12.2	12.2	11.6	11.9	11.3	13.2	11.6	12.2	12.0	13.5	14.0	13.7	11.2
11/19	11.9	12.4	10.8	11.5	11.0	10.5	10.6	11.5	11.8	11.3	12.3	11.3	12.0	12.3	12.0	12.0	11.5	11.8	11.1	13.0	11.4	12.0	11.9	13.1	13.7	13.6	11.1
11/20	11.7	12.2	10.6	11.3	11.0	10.4	10.4	11.4	11.7	11.1	12.2	11.3	11.9	12.2	11.9	11.9	11.3	11.7	10.9	12.8	11.3	11.8	11.8	12.7	13.5	13.6	11.0
11/21	11.5	12.1	10.3	11.1	11.0	10.3	10.2	11.3	11.5	10.9	12.1	11.2	11.7	12.1	11.7	11.7	11.2	11.6	10.7	12.6	11.1	11.7	11.7	12.3	13.3	13.5	11.0
11/22	11.3	11.9	10.1	10.8	11.0	10.2	10.0	11.2	11.3	10.7	11.9	11.1	11.5	12.0	11.5	11.6	11.1	11.5	10.5	12.5	10.9	11.5	11.6	12.0	13.1	13.4	10.9
11/23	11.0	11.8	9.9	10.6	11.0	10.0	9.9	11.1	11.2	10.5	11.9	11.0	11.3	11.9	11.4	11.5	11.0	11.3	10.3	12.3	10.7	11.4	11.4	11.6	12.9	13.2	10.8

HCC Outflow 7DAM Temperature (°C)

Date	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
11/24	10.8	11.7	9.6	10.4	10.9	9.9	9.7	10.9	11.1	10.3	11.8	10.8	11.1	11.7	11.3	11.3	10.8	11.2	10.1	12.2	10.5	11.3	11.2	11.3	12.6	13.1	10.7
11/25	10.6	11.5	9.2	10.1	10.8	9.8	9.7	10.8	10.9	10.1	11.7	10.6	10.9	11.5	11.1	11.2	10.7	11.0	9.9	12.0	10.3	11.3	11.0	11.0	12.3	12.9	10.6
11/26	10.4	11.4	8.9	9.8	10.8	9.7	9.6	10.6	10.7	9.9	11.6	10.4	10.6	11.3	10.9	11.1	10.6	10.9	9.8	11.8	10.1	11.2	10.8	10.7	12.1	12.8	10.6
11/27	10.1	11.1	8.6	9.5	10.6	9.6	9.6	10.5	10.6	9.7	11.5	10.2	10.4	11.1	10.7	11.0	10.4	10.8	9.6	11.6	9.8	11.1	10.6	10.6	11.8	12.6	10.5
11/28	9.9	10.9	8.3	9.2	10.5	9.4	9.6	10.4	10.5	9.5	11.4	9.9	10.2	10.8	10.6	10.9	10.2	10.6	9.4	11.3	9.7	11.0	10.4	10.5	11.5	12.4	10.4
11/29	9.8	10.6	7.9	9.0	10.4	9.3	9.7	10.2	10.4	9.3	11.2	9.7	9.9	10.6	10.4	10.7	10.0	10.4	9.3	11.0	9.5	10.9	10.2	10.4	11.2	12.2	10.4
11/30	9.6	10.4	7.7	8.7	10.3	9.1	9.6	10.1	10.2	9.1	11.1	9.6	9.7	10.4	10.2	10.6	9.8	10.3	9.1	10.7	9.3	10.8	10.0	10.4	10.9	12.0	10.3
12/1	9.4	10.1	7.5	8.5	10.2	9.0	9.7	10.0	10.1	8.9	10.9	9.4	9.5	10.1	10.1	10.5	9.6	10.2	9.0	10.4	9.2	10.7	9.9	10.4	10.6	11.8	10.1
12/2	9.3	9.8	7.4	8.3	10.2	8.9	9.6	9.9	10.0	8.8	10.6	9.3	9.3	9.9	9.9	10.4	9.4	10.1	8.9	10.1	9.0	10.5	9.7	10.4	10.3	11.7	10.0
12/3	9.1	9.5	7.2	8.2	10.1	8.8	9.6	9.7	9.9	8.7	10.4	9.1	9.2	9.7	9.7	10.2	9.2	9.9	8.7	9.7	8.9	10.4	9.5	10.3	10.0	11.5	9.9
12/4	9.0	9.3	7.0	8.1	10.1	8.7	9.5	9.6	9.8	8.5	10.1	9.0	9.0	9.5	9.5	10.0	9.0	9.9	8.6	9.4	8.8	10.3	9.4	10.3	9.7	11.3	9.7
12/5	8.8	9.0	6.9	8.0	10.0	8.6	9.4	9.5	9.7	8.4	9.9	8.9	8.9	9.3	9.4	9.8	8.8	9.8	8.5	9.2	8.7	10.1	9.2	10.2	9.5	11.1	9.6
12/6	8.7	8.8	6.8	7.8	9.8	8.5	9.2	9.4	9.6	8.2	9.7	8.7	8.8	9.1	9.2	9.6	8.7	9.7	8.4	9.0	8.6	10.1	9.1	10.1	9.3	10.9	9.4
12/7	8.5	8.6	6.7	7.7	9.5	8.3	9.0	9.3	9.6	8.0	9.5	8.6	8.7	8.9	9.0	9.3	8.6	9.6	8.3	8.8	8.5	10.0	8.9	10.0	9.1	10.7	9.2
12/8	8.3	8.4	6.6	7.6	9.3	8.2	8.8	9.2	9.4	7.8	9.3	8.4	8.6	8.7	8.8	9.1	8.5	9.5	8.2	8.6	8.4	9.9	8.7	9.8	8.8	10.4	9.1
12/9	8.2	8.1	6.5	7.6	9.0	8.0	8.6	9.0	9.3	7.7	9.2	8.3	8.5	8.5	8.6	8.8	8.4	9.4	8.0	8.5	8.2	9.8	8.5	9.6	8.7	10.2	9.0
12/10	8.1	8.0	6.5	7.5	8.8	7.8	8.4	8.8	9.1	7.5	9.0	8.1	8.5	8.4	8.4	8.6	8.3	9.3	7.8	8.5	8.0	9.6	8.3	9.5	8.5	9.9	8.8
12/11	8.0	7.8	6.5	7.4	8.5	7.7	8.2	8.6	8.9	7.3	8.8	8.0	8.4	8.2	8.2	8.4	8.2	9.2	7.5	8.4	7.8	9.5	8.1	9.3	8.4	9.7	8.5
12/12	7.9	7.6	6.5	7.4	8.3	7.7	8.0	8.4	8.8	7.1	8.7	7.8	8.3	8.1	7.9	8.3	8.1	9.0	7.2	8.4	7.5	9.3	7.8	9.1	8.4	9.5	8.3
12/13	7.8	7.5	6.6	7.3	8.2	7.6	7.9	8.3	8.6	7.0	8.5	7.7	8.3	8.1	7.7	8.2	8.1	8.9	6.8	8.3	7.2	9.2	7.5	8.9	8.3	9.3	8.1
12/14	7.7	7.3	6.6	7.2	8.1	7.6	7.7	8.1	8.4	6.9	8.4	7.6	8.2	8.0	7.4	8.1	8.0	8.7	6.4	8.3	6.9	9.1	7.2	8.7	8.3	9.0	7.9
12/15	7.6	7.2	6.7	7.1	8.0	7.6	7.5	8.1	8.3	6.8	8.3	7.6	8.1	7.9	7.1	8.1	8.0	8.6	6.0	8.2	6.7	8.9	6.9	8.5	8.4	8.8	7.7
12/16	7.5	7.1	6.8	6.9	8.0	7.6	7.4	8.2	8.1	6.7	8.1	7.5	8.0	7.9	6.8	8.1	7.9	8.3	5.8	8.2	6.5	8.8	6.6	8.4	8.3	8.6	7.5
12/17	7.4	7.0	6.9	6.8	7.9	7.6	7.2	8.3	8.1	6.6	8.0	7.4	7.9	7.9	6.5	8.2	7.8	8.1	5.6	8.1	6.4	8.7	6.4	8.3	8.3	8.4	7.4
12/18	7.2	6.9	6.9	6.8	7.9	7.5	7.1	8.3	8.0	6.5	7.9	7.4	7.8	7.8	6.2	8.2	7.7	7.8	5.5	7.9	6.3	8.6	6.2	8.2	8.2	8.2	7.4
12/19	7.1	6.8	6.8	6.7	7.8	7.4	7.0	8.4	8.0	6.5	7.8	7.4	7.7	7.8	6.0	8.2	7.6	7.5	5.5	7.8	6.3	8.5	6.1	8.1	8.2	7.9	7.3
12/20	7.0	6.7	6.8	6.7	7.8	7.3	6.9	8.4	8.1	6.4	7.7	7.3	7.6	7.8	5.8	8.1	7.5	7.2	5.5	7.6	6.3	8.4	6.0	8.1	8.1	7.7	
12/21	6.9	6.6	6.7	6.6	7.6	7.2	6.8	8.4	8.0	6.4	7.6	7.2	7.5	7.8	5.7	7.9	7.3	7.0	5.6	7.4	6.3	8.2	5.9	8.1	8.0	7.4	
12/22	6.8	6.5	6.5	6.6	7.5	7.1	6.7	8.1	7.9	6.4	7.6	7.1	7.4	7.7	5.6	7.7	7.2	6.7	5.7	7.2	6.2	8.0	5.8	8.0	7.8	7.1	
12/23	6.7	6.4	6.3	6.5	7.4	7.0	6.6	7.7	7.8	6.3	7.5	7.0	7.2	7.7	5.5	7.4	7.1	6.6	5.8	7.1	6.2	7.8	5.8	8.0	7.7	6.8	
12/24	6.6	6.3	6.0	6.4	7.3	6.9	6.5	7.3	7.7	6.2	7.5	6.9	7.1	7.6	5.5	7.2	7.0	6.4	5.8	6.9	6.1	7.6	5.8	7.9	7.6	6.5	
12/25	6.5	6.2	5.7	6.3	7.2	6.7	6.3	7.0	7.6	6.2	7.5	6.8	7.0	7.4	5.5	6.9	7.0	6.3	5.9	6.8	6.0	7.5	5.8	7.8	7.4	6.2	
12/26	6.4	6.1	5.4	6.3	7.0	6.6	6.2	6.7	7.4	6.1	7.4	6.6	6.9	7.3	5.6	6.7	6.9	6.3	5.9	6.7	5.9	7.3	5.7	7.6	7.3	6.0	
12/27	6.4	6.1	5.1	6.1	6.9	6.5	6.0	6.5	7.1	6.0	7.3	6.6	6.8	7.1	5.6	6.5	6.9	6.2	5.8	6.6	5.8	7.3	5.7	7.5	7.1	5.8	
12/28	6.3	5.9	4.8	5.9	6.8	6.4	5.8	6.3	7.0	5.9	7.2	6.5	6.7	6.9	5.7	6.3	6.8	6.1	5.8	6.5	5.7	7.2	5.7	7.3	6.8	5.6	
12/29	6.2	5.9	4.6	5.8	6.7	6.4	5.6	6.2	6.8	5.8	7.1	6.5	6.5	6.8	5.7	6.2	6.7	6.0	5.6	6.4	5.5	7.2	5.6	7.1	6.6	5.5	
12/30	6.1	5.8	4.5	5.6	6.5	6.3	5.5	6.2	6.6	5.7	6.9	6.4	6.4	6.6	5.7	6.1	6.6	6.0	5.5	6.3	5.4	7.1	5.6	7.0	6.4	5.4	
12/31	6.0	5.7	4.3	5.4	6.4	6.2	5.3	6.2	6.4	5.7	6.8	6.4	6.3	6.5	5.7	5.9	6.5	5.9	5.3	6.2	5.3	7.1	5.5	6.8	6.2	5.3	

Table 2
List of alternate Snake River locations referenced by River Mile (RM) used fill in missing data from the temperature dataset measured at Hells Canyon Dam Penstock (RM 247.6).

Snake River_227.5_LC
Snake River_229.7_LB
Snake River_229.8_LB
Snake River_236.3_MC
Snake River_238.5_LC
Snake River_238.6_RB
Snake River_238.9_RB
Snake River_240.9_RB
Snake River_241.3_RC
Snake River_241.4_RB
Snake River_242.8_LB
Snake River_244.3_LB
Snake River_245.8_RC
Snake River_246.4_LB
Snake River_246.6_LB
Snake River_246_LC
Snake River_246_RC
Snake River_247.6_LB
Snake River_247.6_LC
Snake River_247.6_PS1

Table 3
Listing of date ranges, alternate Snake River locations used (referenced by River Mile, RM) and number of samples filled in (N, typically samples every hour or half-hour) when filling gaps in the temperature dataset measured at Hells Canyon Dam Penstock (RM 247.6).

Replaced data for 1991-1998			Replaced data for 1994-1997			Replaced data for 1998-2002			Replaced data for 2003-20017		
Date	Location	N	Date	Location	N	Date	Location	N	Date	Location	N
4/18/1991	Interpolation	0	1/1/1994	Snake River_238.6_RB	20	2/5/1998	Snake River_229.8_LB	20	1/1/2003	Snake River_229.8_LB	48
4/19/1991	Interpolation	0	1/2/1994	Snake River_238.6_RB	20	2/6/1998	Snake River_229.8_LB	20	1/2/2003	Snake River_229.8_LB	48
4/20/1991	Interpolation	0	1/3/1994	Snake River_238.6_RB	20	2/7/1998	Snake River_229.8_LB	20	1/3/2003	Snake River_229.8_LB	48
4/21/1991	Interpolation	0	1/4/1994	Snake River_238.6_RB	20	2/8/1998	Snake River_229.8_LB	20	1/4/2003	Snake River_229.8_LB	48
4/22/1991	Interpolation	0	1/5/1994	Snake River_238.6_RB	21	2/9/1998	Snake River_229.8_LB	20	1/5/2003	Snake River_229.8_LB	48
4/23/1991	Interpolation	0	1/6/1994	Snake River_238.6_RB	20	2/10/1998	Snake River_229.8_LB	20	1/6/2003	Snake River_229.8_LB	48
4/24/1991	Interpolation	0	1/7/1994	Snake River_238.6_RB	20	2/11/1998	Snake River_229.8_LB	20	1/7/2003	Snake River_229.8_LB	48
4/25/1991	Interpolation	0	1/8/1994	Snake River_238.6_RB	20	2/12/1998	Snake River_229.8_LB	20	1/8/2003	Snake River_229.8_LB	48
4/26/1991	Interpolation	0	1/9/1994	Snake River_238.6_RB	20	2/13/1998	Snake River_229.8_LB	20	1/9/2003	Snake River_229.8_LB	48
4/27/1991	Interpolation	0	1/10/1994	Snake River_238.6_RB	20	2/14/1998	Snake River_229.8_LB	20	1/10/2003	Snake River_229.8_LB	48
4/28/1991	Interpolation	0	2/9/1994	Snake River_238.6_RB	20	2/15/1998	Snake River_229.8_LB	20	1/11/2003	Snake River_229.8_LB	48
10/8/1991	Snake River_238.6_RB	24	2/10/1994	Snake River_238.6_RB	20	2/16/1998	Snake River_229.8_LB	20	1/12/2003	Snake River_229.8_LB	48
10/9/1991	Snake River_238.6_RB	24	2/11/1994	Snake River_238.6_RB	20	2/17/1998	Snake River_229.8_LB	20	1/13/2003	Snake River_229.8_LB	48
10/10/1991	Snake River_238.6_RB	24	2/12/1994	Snake River_238.6_RB	20	4/29/1998	Snake River_229.8_LB	20	1/14/2003	Snake River_229.8_LB	47
10/11/1991	Snake River_238.6_RB	24	2/13/1994	Snake River_238.6_RB	20	4/30/1998	Snake River_229.8_LB	20	1/15/2003	Snake River_229.8_LB	48
10/12/1991	Snake River_238.6_RB	23	2/14/1994	Snake River_238.6_RB	20	5/1/1998	Snake River_229.8_LB	20	4/2/2003	Snake River_229.8_LB	48
10/13/1991	Snake River_238.6_RB	24	2/15/1994	Snake River_238.6_RB	20	5/2/1998	Snake River_229.8_LB	20	4/3/2003	Snake River_229.8_LB	48
10/14/1991	Snake River_238.6_RB	24	2/16/1994	Snake River_238.6_RB	20	5/3/1998	Snake River_229.8_LB	20	4/4/2003	Snake River_229.8_LB	48
10/15/1991	Snake River_238.6_RB	24	3/16/1994	Snake River_238.6_RB	20	5/4/1998	Snake River_229.8_LB	20	4/5/2003	Snake River_229.8_LB	48
10/16/1991	Snake River_238.6_RB	24	3/17/1994	Snake River_238.6_RB	20	5/5/1998	Snake River_229.8_LB	20	4/6/2003	Snake River_229.8_LB	46
10/17/1991	Snake River_238.6_RB	24	3/18/1994	Snake River_238.6_RB	20	5/6/1998	Snake River_229.8_LB	20	4/7/2003	Snake River_229.8_LB	48
5/21/1992	Interpolation	0	3/19/1994	Snake River_238.6_RB	20	5/7/1998	Snake River_229.8_LB	20	4/8/2003	Snake River_229.8_LB	48
5/22/1992	Interpolation	0	3/20/1994	Snake River_238.6_RB	20	5/8/1998	Snake River_229.8_LB	20	4/9/2003	Snake River_229.8_LB	48
5/23/1992	Interpolation	0	3/21/1994	Snake River_238.6_RB	20	5/9/1998	Snake River_229.8_LB	20	12/19/2003	Snake River_229.8_LB	48
5/24/1992	Interpolation	0	3/22/1994	Snake River_238.6_RB	20	5/10/1998	Snake River_229.8_LB	20	12/20/2003	Snake River_229.8_LB	48
5/25/1992	Interpolation	0	3/23/1994	Snake River_238.6_RB	20	5/11/1998	Snake River_229.8_LB	20	12/21/2003	Snake River_229.8_LB	48
5/26/1992	Interpolation	0	3/24/1994	Snake River_238.6_RB	20	5/12/1998	Snake River_229.8_LB	20	12/22/2003	Snake River_229.8_LB	48
5/27/1992	Interpolation	0	3/25/1994	Snake River_238.6_RB	20	5/13/1998	Snake River_229.8_LB	20	12/23/2003	Snake River_229.8_LB	48
5/28/1992	Interpolation	0	3/26/1994	Snake River_238.6_RB	20	5/14/1998	Snake River_229.8_LB	20	12/24/2003	Snake River_229.8_LB	48
5/29/1992	Interpolation	0	3/27/1994	Snake River_238.6_RB	20	5/15/1998	Snake River_229.8_LB	20	12/25/2003	Snake River_229.8_LB	48
5/30/1992	Interpolation	0	3/28/1994	Snake River_238.6_RB	20	5/16/1998	Snake River_229.8_LB	20	12/26/2003	Snake River_229.8_LB	48
5/31/1992	Interpolation	0	3/29/1994	Snake River_238.6_RB	20	5/17/1998	Snake River_229.8_LB	20	12/27/2003	Snake River_229.8_LB	48
6/1/1992	Interpolation	0	4/15/1994	Snake River_238.6_RB	20	5/18/1998	Snake River_229.8_LB	20	12/28/2003	Snake River_229.8_LB	48
6/2/1992	Interpolation	0	4/16/1994	Snake River_238.6_RB	20	5/19/1998	Snake River_229.8_LB	20	12/29/2003	Snake River_229.8_LB	48
10/2/1992	Snake River_247.6_LC	144	4/17/1994	Snake River_238.6_RB	20	5/20/1998	Snake River_229.8_LB	20	12/30/2003	Snake River_229.8_LB	48
10/3/1992	Snake River_247.6_LC	144	4/18/1994	Snake River_238.6_RB	20	5/21/1998	Snake River_229.8_LB	20	12/31/2003	Snake River_229.8_LB	48
10/4/1992	Snake River_247.6_LC	144	4/19/1994	Snake River_238.6_RB	20	5/22/1998	Snake River_229.8_LB	20	1/1/2004	Snake River_229.8_LB	48

Replaced data for 1991-1998			Replaced data for 1994-1997			Replaced data for 1998-2002			Replaced data for 2003-20017		
Date	Location	N	Date	Location	N	Date	Location	N	Date	Location	N
10/5/1992	Snake River_247.6_LC	144	4/20/1994	Snake River_238.6_RB	20	5/23/1998	Snake River_229.8_LB	20	1/2/2004	Snake River_229.8_LB	48
10/6/1992	Snake River_247.6_LC	144	6/22/1994	Snake River_238.6_RB	20	5/24/1998	Snake River_229.8_LB	20	1/3/2004	Snake River_229.8_LB	48
10/7/1992	Snake River_247.6_LC	144	6/23/1994	Snake River_238.6_RB	20	5/25/1998	Snake River_229.8_LB	20	1/4/2004	Snake River_229.8_LB	48
10/8/1992	Snake River_247.6_LC	144	6/24/1994	Snake River_238.6_RB	20	5/26/1998	Snake River_229.8_LB	20	1/5/2004	Snake River_229.8_LB	48
10/9/1992	Snake River_247.6_LC	144	6/25/1994	Snake River_238.6_RB	20	3/8/1999	Snake River_246_LC	24	1/6/2004	Snake River_229.8_LB	48
10/10/1992	Snake River_247.6_LC	144	6/26/1994	Snake River_238.6_RB	20	3/9/1999	Snake River_246_LC	24	2/4/2004	Snake River_229.8_LB	48
10/11/1992	Snake River_247.6_LC	144	6/27/1994	Snake River_238.6_RB	20	3/10/1999	Snake River_246_LC	24	2/5/2004	Snake River_229.8_LB	48
10/12/1992	Snake River_247.6_LC	144	6/28/1994	Snake River_238.6_RB	20	3/11/1999	Snake River_246_LC	24	2/6/2004	Snake River_229.8_LB	48
10/13/1992	Snake River_247.6_LC	144	6/29/1994	Snake River_238.6_RB	20	3/12/1999	Snake River_246_LC	24	2/7/2004	Snake River_229.8_LB	48
10/14/1992	Snake River_247.6_LC	144	6/30/1994	Snake River_238.6_RB	20	3/13/1999	Snake River_246_LC	24	2/8/2004	Snake River_229.8_LB	48
10/15/1992	Snake River_247.6_LC	144	7/1/1994	Snake River_238.6_RB	20	3/14/1999	Snake River_246_LC	24	2/9/2004	Snake River_229.8_LB	48
10/16/1992	Snake River_247.6_LC	144	7/2/1994	Snake River_238.6_RB	20	9/16/1999	Snake River_227.5_LC	24	2/10/2004	Snake River_229.8_LB	48
10/17/1992	Snake River_247.6_LC	144	7/3/1994	Snake River_238.6_RB	20	9/17/1999	Snake River_227.5_LC	24	2/11/2004	Snake River_229.8_LB	48
10/18/1992	Snake River_247.6_LC	144	7/4/1994	Snake River_238.6_RB	20	9/18/1999	Snake River_227.5_LC	24	2/12/2004	Snake River_229.8_LB	48
10/19/1992	Snake River_247.6_LC	144	7/5/1994	Snake River_238.6_RB	20	9/19/1999	Snake River_227.5_LC	24	2/13/2004	Snake River_229.8_LB	48
10/20/1992	Snake River_247.6_LC	144	7/6/1994	Snake River_238.6_RB	20	1/1/2000	Snake River_229.8_LB	20	2/14/2004	Snake River_229.8_LB	48
10/21/1992	Snake River_247.6_LC	144	7/7/1994	Snake River_238.6_RB	20	1/2/2000	Snake River_229.8_LB	20	2/15/2004	Snake River_229.8_LB	48
10/22/1992	Snake River_247.6_LC	144	7/8/1994	Snake River_238.6_RB	20	1/3/2000	Snake River_229.8_LB	20	2/16/2004	Snake River_229.8_LB	48
10/23/1992	Snake River_247.6_LC	144	7/9/1994	Snake River_238.6_RB	20	4/7/2000	Snake River_246_LC	24	2/17/2004	Snake River_229.8_LB	48
10/24/1992	Snake River_247.6_LC	144	7/10/1994	Snake River_238.6_RB	20	4/8/2000	Snake River_246_LC	24	3/11/2005	Snake River_229.8_LB	48
10/25/1992	Snake River_247.6_LC	144	7/11/1994	Snake River_238.6_RB	20	4/9/2000	Snake River_246_LC	24	3/12/2005	Snake River_229.8_LB	48
10/26/1992	Snake River_247.6_LC	144	7/27/1994	Snake River_238.6_RB	20	4/10/2000	Snake River_246_LC	24	3/13/2005	Snake River_229.8_LB	48
10/27/1992	Snake River_247.6_LC	144	7/28/1994	Snake River_238.6_RB	20	7/4/2000	Interpolation	0	3/14/2005	Snake River_229.8_LB	48
10/28/1992	Snake River_247.6_LC	144	7/29/1994	Snake River_238.6_RB	20	7/19/2000	Interpolation	0	3/15/2005	Snake River_229.8_LB	48
10/29/1992	Snake River_247.6_LC	144	7/30/1994	Snake River_238.6_RB	20	7/20/2000	Interpolation	0	3/16/2005	Snake River_229.8_LB	48
10/30/1992	Snake River_247.6_LC	144	7/31/1994	Snake River_238.6_RB	20	7/21/2000	Interpolation	0	3/17/2005	Snake River_229.8_LB	48
10/31/1992	Snake River_247.6_LC	144	8/1/1994	Snake River_238.6_RB	20	7/22/2000	Interpolation	0	3/18/2005	Snake River_229.8_LB	48
11/1/1992	Snake River_247.6_LC	144	8/2/1994	Snake River_238.6_RB	20	7/23/2000	Interpolation	0	3/19/2005	Snake River_229.8_LB	48
11/2/1992	Snake River_247.6_LC	144	8/3/1994	Snake River_238.6_RB	20	7/24/2000	Interpolation	0	3/20/2005	Snake River_229.8_LB	48
11/3/1992	Snake River_247.6_LC	144	8/4/1994	Snake River_238.6_RB	20	7/25/2000	Interpolation	0	3/21/2005	Snake River_229.8_LB	48
11/4/1992	Snake River_247.6_LC	144	8/5/1994	Snake River_238.6_RB	20	7/26/2000	Interpolation	0	3/22/2005	Snake River_229.8_LB	48
11/5/1992	Snake River_247.6_LC	144	8/6/1994	Snake River_238.6_RB	20	7/27/2000	Interpolation	0	3/23/2005	Snake River_229.8_LB	48
11/6/1992	Snake River_247.6_LC	144	8/7/1994	Snake River_238.6_RB	20	7/28/2000	Interpolation	0	5/5/2006	Snake River_229.8_LB	48
11/7/1992	Snake River_247.6_LC	144	2/7/1995	Snake River_238.6_RB	20	7/29/2000	Interpolation	0	5/6/2006	Snake River_229.8_LB	48
11/8/1992	Snake River_247.6_LC	144	2/8/1995	Snake River_238.6_RB	20	7/30/2000	Interpolation	0	5/7/2006	Snake River_229.8_LB	48
11/9/1992	Snake River_247.6_LC	144	2/9/1995	Snake River_238.6_RB	20	7/31/2000	Interpolation	0	5/8/2006	Snake River_229.8_LB	48
11/10/1992	Snake River_247.6_LC	144	2/10/1995	Snake River_238.6_RB	20	8/1/2000	Interpolation	0	5/9/2006	Snake River_229.8_LB	48
11/11/1992	Snake River_247.6_LC	144	2/11/1995	Snake River_238.6_RB	20	8/2/2000	Interpolation	0	5/10/2006	Snake River_229.8_LB	48
11/12/1992	Snake River_247.6_LC	144	2/12/1995	Snake River_238.6_RB	20	8/3/2000	Interpolation	0	5/11/2006	Snake River_229.8_LB	48
11/13/1992	Snake River_247.6_LC	144	2/13/1995	Snake River_238.6_RB	20	8/4/2000	Interpolation	0	5/12/2006	Snake River_229.8_LB	48
11/14/1992	Snake River_247.6_LC	144	2/14/1995	Snake River_238.6_RB	20	8/5/2000	Interpolation	0	5/13/2006	Snake River_229.8_LB	48

Replaced data for 1991-1998			Replaced data for 1994-1997			Replaced data for 1998-2002			Replaced data for 2003-20017		
Date	Location	N	Date	Location	N	Date	Location	N	Date	Location	N
11/15/1992	Snake River_247.6_LC	144	2/15/1995	Snake River_238.6_RB	20	8/6/2000	Interpolation	0	5/14/2006	Snake River_229.8_LB	48
1/8/1993	Snake River_247.6_LC	144	2/16/1995	Snake River_238.6_RB	20	8/7/2000	Interpolation	0	5/15/2006	Snake River_229.8_LB	48
1/9/1993	Snake River_247.6_LC	144	2/17/1995	Snake River_238.6_RB	20	8/8/2000	Interpolation	0	5/16/2006	Snake River_229.8_LB	48
1/10/1993	Snake River_247.6_LC	144	2/18/1995	Snake River_238.6_RB	20	1/18/2001	Snake River_229.8_LB	12	9/13/2006	Snake River_229.8_LB	48
1/11/1993	Snake River_247.6_LC	144	2/19/1995	Snake River_238.6_RB	20	1/19/2001	Snake River_229.8_LB	12	9/14/2006	Snake River_229.8_LB	48
1/12/1993	Snake River_247.6_LC	144	2/20/1995	Snake River_238.6_RB	20	1/20/2001	Snake River_229.8_LB	12	9/15/2006	Snake River_229.8_LB	48
1/13/1993	Snake River_247.6_LC	144	2/21/1995	Snake River_238.6_RB	20	1/21/2001	Snake River_229.8_LB	12	9/16/2006	Snake River_229.8_LB	48
1/14/1993	Snake River_247.6_LC	144	2/22/1995	Snake River_238.6_RB	20	1/22/2001	Snake River_229.8_LB	12	9/17/2006	Snake River_229.8_LB	48
1/15/1993	Snake River_247.6_LC	144	2/23/1995	Snake River_238.6_RB	20	1/23/2001	Snake River_229.8_LB	12	9/18/2006	Snake River_229.8_LB	48
1/16/1993	Snake River_247.6_LC	144	2/24/1995	Snake River_238.6_RB	20	1/24/2001	Snake River_229.8_LB	12	9/19/2006	Snake River_229.8_LB	48
1/17/1993	Snake River_247.6_LC	143	2/25/1995	Snake River_238.6_RB	20	1/25/2001	Snake River_229.8_LB	12	9/20/2006	Snake River_229.8_LB	48
1/18/1993	Snake River_247.6_LC	144	2/26/1995	Snake River_238.6_RB	20	1/26/2001	Snake River_229.8_LB	12	9/21/2006	Snake River_229.8_LB	48
1/19/1993	Snake River_247.6_LC	144	2/27/1995	Snake River_238.6_RB	20	1/27/2001	Snake River_229.8_LB	12	9/22/2006	Snake River_229.8_LB	48
1/20/1993	Snake River_247.6_LC	144	2/28/1995	Snake River_238.6_RB	20	1/28/2001	Snake River_229.8_LB	12	9/23/2006	Snake River_229.8_LB	48
1/24/1993	Snake River_247.6_LC	144	3/1/1995	Snake River_238.6_RB	20	1/29/2001	Snake River_229.8_LB	12	9/24/2006	Snake River_229.8_LB	48
1/25/1993	Snake River_247.6_LC	144	3/2/1995	Snake River_238.6_RB	20	1/30/2001	Snake River_229.8_LB	12	9/25/2006	Snake River_229.8_LB	48
2/11/1993	Snake River_247.6_LC	144	3/3/1995	Snake River_238.6_RB	20	1/31/2001	Snake River_229.8_LB	12	1/5/2008	Snake River_229.8_LB	48
2/12/1993	Snake River_247.6_LC	143	3/4/1995	Snake River_238.6_RB	20	2/16/2001	Snake River_229.8_LB	12	1/6/2008	Snake River_229.8_LB	48
2/13/1993	Snake River_247.6_LC	144	3/5/1995	Snake River_238.6_RB	20	2/17/2001	Snake River_229.8_LB	12	1/7/2008	Snake River_229.8_LB	48
2/14/1993	Snake River_247.6_LC	142	3/6/1995	Snake River_238.6_RB	20	2/18/2001	Snake River_229.8_LB	12	1/8/2008	Snake River_229.8_LB	48
2/15/1993	Snake River_247.6_LC	142	7/6/1995	Snake River_238.6_RB	20	2/19/2001	Snake River_229.8_LB	12	1/9/2008	Snake River_229.8_LB	48
2/16/1993	Snake River_247.6_LC	144	7/7/1995	Snake River_238.6_RB	20	2/20/2001	Snake River_229.8_LB	12	1/10/2008	Snake River_229.8_LB	48
2/17/1993	Snake River_247.6_LC	143	7/8/1995	Snake River_238.6_RB	20	2/21/2001	Snake River_229.8_LB	12	1/11/2008	Snake River_229.8_LB	48
2/18/1993	Snake River_247.6_LC	143	7/9/1995	Snake River_238.6_RB	20	2/22/2001	Snake River_229.8_LB	12	1/12/2008	Snake River_229.8_LB	48
2/19/1993	Snake River_247.6_LC	142	7/10/1995	Snake River_238.6_RB	20	9/28/2001	Snake River_229.8_LB	24	1/13/2008	Snake River_229.8_LB	48
2/20/1993	Snake River_247.6_LC	143	7/11/1995	Snake River_238.6_RB	20	9/29/2001	Snake River_229.8_LB	24	1/14/2008	Snake River_229.8_LB	48
2/21/1993	Snake River_247.6_LC	143	7/12/1995	Snake River_238.6_RB	19	9/30/2001	Snake River_229.8_LB	24	1/15/2008	Snake River_229.8_LB	48
2/22/1993	Snake River_247.6_LC	143	7/13/1995	Snake River_238.6_RB	20	10/1/2001	Snake River_229.8_LB	46	8/16/2009	Snake River_244.3_LB	144
2/23/1993	Snake River_247.6_LC	144	7/14/1995	Snake River_238.6_RB	20	10/2/2001	Snake River_229.8_LB	96	8/17/2009	Snake River_244.3_LB	144
2/24/1993	Snake River_247.6_LC	143	7/15/1995	Snake River_238.6_RB	20	10/3/2001	Snake River_229.8_LB	96	8/18/2009	Snake River_244.3_LB	144
2/25/1993	Snake River_247.6_LC	143	7/16/1995	Snake River_238.6_RB	20	10/4/2001	Snake River_229.8_LB	96	11/30/2009	Snake River_244.3_LB	144
2/26/1993	Snake River_247.6_LC	144	7/17/1995	Snake River_238.6_RB	20	10/5/2001	Snake River_229.8_LB	96	12/1/2009	Snake River_244.3_LB	144
2/27/1993	Snake River_247.6_LC	144	1/18/1996	Snake River_229.8_LB	20	10/6/2001	Snake River_229.8_LB	96	1/3/2010	Snake River_229.8_LB	48
2/28/1993	Snake River_247.6_LC	144	1/19/1996	Snake River_229.8_LB	20	10/7/2001	Snake River_229.8_LB	96	1/4/2010	Snake River_229.8_LB	48
3/1/1993	Snake River_247.6_LC	144	1/20/1996	Snake River_229.8_LB	20	10/8/2001	Snake River_229.8_LB	96	1/5/2010	Snake River_229.8_LB	48
3/2/1993	Snake River_247.6_LC	144	1/21/1996	Snake River_229.8_LB	20	10/9/2001	Snake River_229.8_LB	96	1/6/2010	Snake River_229.8_LB	48
3/3/1993	Snake River_247.6_LC	144	1/22/1996	Snake River_229.8_LB	20	10/10/2001	Snake River_229.8_LB	96	4/17/2010	Snake River_244.3_LB	144
3/4/1993	Snake River_247.6_LC	144	1/23/1996	Snake River_229.8_LB	20	10/11/2001	Snake River_229.8_LB	96	4/18/2010	Snake River_244.3_LB	144
3/5/1993	Snake River_247.6_LC	143	1/24/1996	Snake River_229.8_LB	20	10/12/2001	Snake River_229.8_LB	96	4/19/2010	Snake River_244.3_LB	144
3/6/1993	Snake River_247.6_LC	144	1/25/1996	Snake River_229.8_LB	20	10/13/2001	Snake River_229.8_LB	96	4/20/2010	Snake River_244.3_LB	144
3/7/1993	Snake River_247.6_LC	144	1/26/1996	Snake River_229.8_LB	20	10/14/2001	Snake River_229.8_LB	96	4/21/2010	Snake River_244.3_LB	65

Replaced data for 1991-1998			Replaced data for 1994-1997			Replaced data for 1998-2002			Replaced data for 2003-20017		
Date	Location	N	Date	Location	N	Date	Location	N	Date	Location	N
3/8/1993	Snake River_247.6_LC	144	1/27/1996	Snake River_229.8_LB	20	10/15/2001	Snake River_229.8_LB	96	4/22/2010	Snake River_242.8_LB	144
3/9/1993	Snake River_247.6_LC	144	1/28/1996	Snake River_229.8_LB	20	10/16/2001	Snake River_229.8_LB	96	4/23/2010	Snake River_242.8_LB	144
3/10/1993	Snake River_247.6_LC	144	1/29/1996	Snake River_229.8_LB	20	10/17/2001	Snake River_229.8_LB	96	4/24/2010	Snake River_242.8_LB	144
3/11/1993	Snake River_247.6_LC	144	7/30/1996	Interpolation	0	10/18/2001	Snake River_229.8_LB	96	4/25/2010	Snake River_242.8_LB	144
3/12/1993	Snake River_247.6_LC	143	7/31/1996	Interpolation	0	10/19/2001	Snake River_229.8_LB	96	4/26/2010	Snake River_242.8_LB	144
3/13/1993	Snake River_247.6_LC	144	8/1/1996	Interpolation	0	10/20/2001	Snake River_229.8_LB	96	4/27/2010	Snake River_242.8_LB	144
3/14/1993	Snake River_247.6_LC	144	8/2/1996	Interpolation	0	10/21/2001	Snake River_229.8_LB	96	8/2/2010	Snake River_242.8_LB	144
3/15/1993	Snake River_247.6_LC	114	8/3/1996	Interpolation	0	10/22/2001	Snake River_229.8_LB	96	8/3/2010	Snake River_242.8_LB	144
3/16/1993	Interpolation	0	8/4/1996	Interpolation	0	10/23/2001	Snake River_229.8_LB	96	9/3/2010	Snake River_242.8_LB	144
5/4/1993	Interpolation	0	8/5/1996	Interpolation	0	10/24/2001	Snake River_229.8_LB	96	9/4/2010	Snake River_242.8_LB	144
5/5/1993	Interpolation	0	8/6/1996	Interpolation	0	10/25/2001	Snake River_229.8_LB	96	9/5/2010	Snake River_242.8_LB	144
5/6/1993	Interpolation	0	8/7/1996	Interpolation	0	10/26/2001	Snake River_229.8_LB	96	9/6/2010	Snake River_242.8_LB	144
5/7/1993	Interpolation	0	8/8/1996	Interpolation	0	10/27/2001	Snake River_229.8_LB	96	9/7/2010	Snake River_242.8_LB	69
5/8/1993	Interpolation	0	8/9/1996	Interpolation	0	10/28/2001	Snake River_229.8_LB	96	9/8/2010	Snake River_229.8_LB	48
5/9/1993	Interpolation	0	8/10/1996	Interpolation	0	10/29/2001	Snake River_229.8_LB	96	9/9/2010	Snake River_229.8_LB	48
5/10/1993	Interpolation	0	8/11/1996	Interpolation	0	10/30/2001	Snake River_229.8_LB	96	9/10/2010	Snake River_229.8_LB	48
5/11/1993	Interpolation	0	1/8/1997	Snake River_229.8_LB	20	10/31/2001	Snake River_229.8_LB	96	9/11/2010	Snake River_229.8_LB	48
5/25/1993	Interpolation	0	1/9/1997	Snake River_229.8_LB	20	11/1/2001	Snake River_229.8_LB	96	9/12/2010	Snake River_229.8_LB	48
5/26/1993	Interpolation	0	1/10/1997	Snake River_229.8_LB	20	11/2/2001	Snake River_229.8_LB	96	9/13/2010	Snake River_229.8_LB	48
5/27/1993	Interpolation	0	1/11/1997	Snake River_229.8_LB	20	11/3/2001	Snake River_229.8_LB	96	9/14/2010	Snake River_229.8_LB	48
5/28/1993	Interpolation	0	1/12/1997	Snake River_229.8_LB	20	11/4/2001	Snake River_229.8_LB	96	9/15/2010	Snake River_229.8_LB	48
5/29/1993	Interpolation	0	1/13/1997	Snake River_229.8_LB	20	11/5/2001	Snake River_229.8_LB	96	9/16/2010	Snake River_242.8_LB	69
5/30/1993	Interpolation	0	1/14/1997	Snake River_229.8_LB	10	11/6/2001	Snake River_229.8_LB	96	9/17/2010	Snake River_242.8_LB	144
5/31/1993	Interpolation	0	1/15/1997	Interpolation	0	11/7/2001	Snake River_229.8_LB	96	9/18/2010	Snake River_242.8_LB	144
6/1/1993	Interpolation	0	1/16/1997	Interpolation	0	11/8/2001	Snake River_229.8_LB	96	9/19/2010	Snake River_242.8_LB	144
6/2/1993	Interpolation	0	1/17/1997	Interpolation	0	11/9/2001	Snake River_229.8_LB	96	9/20/2010	Snake River_242.8_LB	144
6/3/1993	Interpolation	0	1/18/1997	Interpolation	0	11/10/2001	Snake River_229.8_LB	96	9/21/2010	Snake River_242.8_LB	144
6/4/1993	Interpolation	0	1/19/1997	Interpolation	0	11/11/2001	Snake River_229.8_LB	96	9/22/2010	Snake River_242.8_LB	144
6/5/1993	Interpolation	0	1/20/1997	Interpolation	0	11/12/2001	Snake River_229.8_LB	96	9/23/2010	Snake River_242.8_LB	144
6/6/1993	Interpolation	0	1/21/1997	Interpolation	0	11/13/2001	Snake River_229.8_LB	96	9/24/2010	Snake River_242.8_LB	144
6/7/1993	Interpolation	0	1/22/1997	Interpolation	0	11/14/2001	Snake River_229.8_LB	96	9/25/2010	Snake River_242.8_LB	144
6/8/1993	Interpolation	0	4/2/1997	Interpolation	0	11/15/2001	Snake River_229.8_LB	96	9/26/2010	Snake River_242.8_LB	144
6/9/1993	Interpolation	0	4/3/1997	Interpolation	0	11/16/2001	Snake River_229.8_LB	96	9/27/2010	Snake River_242.8_LB	144
7/8/1993	Interpolation	0	4/4/1997	Interpolation	0	11/17/2001	Snake River_229.8_LB	96	9/28/2010	Snake River_242.8_LB	144
7/9/1993	Interpolation	0	4/5/1997	Interpolation	0	11/18/2001	Snake River_229.8_LB	96	3/18/2013	Snake River_229.8_LB	48
7/10/1993	Interpolation	0	4/6/1997	Interpolation	0	11/19/2001	Snake River_229.8_LB	96	3/19/2013	Snake River_229.8_LB	48
7/11/1993	Interpolation	0	4/7/1997	Interpolation	0	11/20/2001	Snake River_229.8_LB	96	12/7/2014	Snake River_229.8_LB	48
7/12/1993	Interpolation	0	4/8/1997	Interpolation	0	11/21/2001	Snake River_229.8_LB	96	12/8/2014	Snake River_229.8_LB	48
7/13/1993	Interpolation	0	4/9/1997	Interpolation	0	11/22/2001	Snake River_229.8_LB	96	3/12/2015	Snake River_229.8_LB	48
7/14/1993	Interpolation	0	4/10/1997	Snake River_229.8_LB	10	11/23/2001	Snake River_229.8_LB	96	3/13/2015	Snake River_229.8_LB	48
7/15/1993	Interpolation	0	4/11/1997	Snake River_229.8_LB	20	11/24/2001	Snake River_229.8_LB	96	3/14/2015	Snake River_229.8_LB	48

Replaced data for 1991-1998			Replaced data for 1994-1997			Replaced data for 1998-2002			Replaced data for 2003-20017		
Date	Location	N	Date	Location	N	Date	Location	N	Date	Location	N
7/16/1993	Interpolation	0	4/12/1997	Snake River_229.8_LB	20	11/25/2001	Snake River_229.8_LB	96	3/15/2015	Snake River_229.8_LB	48
7/17/1993	Interpolation	0	4/13/1997	Snake River_229.8_LB	20	11/26/2001	Snake River_229.8_LB	96	10/20/2016	Snake River_229.7_LB	96
7/18/1993	Interpolation	0	4/14/1997	Snake River_229.8_LB	20	11/27/2001	Snake River_229.8_LB	96	10/21/2016	Snake River_229.7_LB	96
7/19/1993	Interpolation	0	4/15/1997	Snake River_229.8_LB	20	11/28/2001	Snake River_229.8_LB	96	10/22/2016	Snake River_229.7_LB	96
7/20/1993	Interpolation	0	7/9/1997	Snake River_229.8_LB	9	11/29/2001	Snake River_229.8_LB	96	10/23/2016	Snake River_229.7_LB	96
8/20/1993	Snake River_229.8_LB	20	7/10/1997	Interpolation	0	11/30/2001	Snake River_229.8_LB	96	10/24/2016	Snake River_229.7_LB	88
8/21/1993	Snake River_229.8_LB	20	7/11/1997	Interpolation	0	12/1/2001	Snake River_229.8_LB	96	10/25/2016	Snake River_229.7_LB	62
8/22/1993	Snake River_229.8_LB	20	7/12/1997	Interpolation	0	12/2/2001	Snake River_229.8_LB	96	10/26/2016	Snake River_229.7_LB	96
8/23/1993	Snake River_229.8_LB	20	7/13/1997	Interpolation	0	12/3/2001	Snake River_229.8_LB	96	10/27/2016	Snake River_229.7_LB	96
8/24/1993	Snake River_229.8_LB	20	7/14/1997	Interpolation	0	12/4/2001	Snake River_229.8_LB	96	10/28/2016	Snake River_229.7_LB	96
8/25/1993	Snake River_229.8_LB	20	7/15/1997	Interpolation	0	12/5/2001	Snake River_229.8_LB	96	10/29/2016	Snake River_229.7_LB	96
8/26/1993	Snake River_229.8_LB	20	7/16/1997	Interpolation	0	12/6/2001	Snake River_229.8_LB	96	10/30/2016	Snake River_229.7_LB	96
8/27/1993	Snake River_229.8_LB	20	7/17/1997	Interpolation	0	12/7/2001	Snake River_229.8_LB	96	10/31/2016	Snake River_229.7_LB	96
8/28/1993	Snake River_229.8_LB	20	7/18/1997	Interpolation	0	12/8/2001	Snake River_229.8_LB	96	11/1/2016	Snake River_229.7_LB	96
8/29/1993	Snake River_229.8_LB	20	7/19/1997	Interpolation	0	12/9/2001	Snake River_229.8_LB	96	11/2/2016	Snake River_229.7_LB	96
8/30/1993	Snake River_229.8_LB	20	7/20/1997	Interpolation	0	12/10/2001	Snake River_229.8_LB	96	12/4/2016	Snake River_229.7_LB	96
11/2/1993	Snake River_238.6_RB	20	7/21/1997	Interpolation	0	12/11/2001	Snake River_229.8_LB	96	12/5/2016	Snake River_229.7_LB	96
11/3/1993	Snake River_238.6_RB	20	7/22/1997	Interpolation	0	12/12/2001	Snake River_229.8_LB	96	12/6/2016	Snake River_229.7_LB	96
11/4/1993	Snake River_238.6_RB	20				12/13/2001	Snake River_229.8_LB	96	12/7/2016	Snake River_229.7_LB	96
11/5/1993	Snake River_238.6_RB	20				12/14/2001	Snake River_229.8_LB	96	12/8/2016	Snake River_229.7_LB	96
11/6/1993	Snake River_238.6_RB	20				12/15/2001	Snake River_229.8_LB	96	12/9/2016	Snake River_229.7_LB	96
11/7/1993	Snake River_238.6_RB	20				12/16/2001	Snake River_229.8_LB	96	12/10/2016	Snake River_229.7_LB	96
11/8/1993	Snake River_238.6_RB	20				12/17/2001	Snake River_229.8_LB	96	12/11/2016	Snake River_229.7_LB	96
11/12/1993	Snake River_238.6_RB	20				12/18/2001	Snake River_229.8_LB	96	12/12/2016	Snake River_229.7_LB	96
11/13/1993	Snake River_238.6_RB	20				12/19/2001	Snake River_229.8_LB	96	1/3/2017	Snake River_229.7_LB	96
11/14/1993	Snake River_238.6_RB	20				4/25/2002	Snake River_246_RC	96	1/4/2017	Snake River_229.7_LB	96
11/15/1993	Snake River_238.6_RB	20				4/26/2002	Snake River_246_RC	96	1/5/2017	Snake River_229.7_LB	96
11/16/1993	Snake River_238.6_RB	20				4/27/2002	Snake River_246_RC	96	1/6/2017	Snake River_229.7_LB	96
11/17/1993	Snake River_238.6_RB	20				4/28/2002	Snake River_246_RC	96	1/7/2017	Snake River_229.7_LB	96
11/18/1993	Snake River_238.6_RB	20				4/29/2002	Snake River_246_RC	96	1/8/2017	Snake River_229.7_LB	96
11/19/1993	Snake River_238.6_RB	20				4/30/2002	Snake River_246_RC	96	1/9/2017	Snake River_229.7_LB	96
11/20/1993	Snake River_238.6_RB	20				6/14/2002	Snake River_229.8_LB	96	1/10/2017	Snake River_229.7_LB	96
11/21/1993	Snake River_238.6_RB	20				6/15/2002	Snake River_229.8_LB	96	1/11/2017	Snake River_229.7_LB	96
11/22/1993	Snake River_238.6_RB	20				6/16/2002	Snake River_229.8_LB	96	1/12/2017	Snake River_229.7_LB	96
11/23/1993	Snake River_238.6_RB	20				6/17/2002	Snake River_247.6_LB	85	1/13/2017	Snake River_229.7_LB	96
11/24/1993	Snake River_238.6_RB	20				6/18/2002	Snake River_247.6_LB	144	1/14/2017	Snake River_229.7_LB	96
11/25/1993	Snake River_238.6_RB	20				6/19/2002	Snake River_247.6_LB	144	1/15/2017	Snake River_229.7_LB	96
11/26/1993	Snake River_238.6_RB	20				6/20/2002	Snake River_247.6_LB	144	1/16/2017	Snake River_229.7_LB	96
11/27/1993	Snake River_238.6_RB	20				6/21/2002	Snake River_247.6_LB	144	1/17/2017	Snake River_229.7_LB	96
11/28/1993	Snake River_238.6_RB	20				6/22/2002	Snake River_247.6_LB	144	1/18/2017	Snake River_229.7_LB	96
11/29/1993	Snake River_238.6_RB	20				6/23/2002	Snake River_247.6_LB	144	1/19/2017	Snake River_229.7_LB	96

Replaced data for 1991-1998			Replaced data for 1994-1997			Replaced data for 1998-2002			Replaced data for 2003-20017		
Date	Location	N	Date	Location	N	Date	Location	N	Date	Location	N
11/30/1993	Snake River_238.6_RB	20				6/24/2002	Snake River_247.6_LB	144	1/20/2017	Snake River_229.7_LB	96
12/1/1993	Snake River_238.6_RB	20				6/25/2002	Snake River_247.6_LB	144	1/21/2017	Snake River_229.7_LB	96
12/2/1993	Snake River_238.6_RB	20				6/26/2002	Snake River_247.6_LB	144	1/22/2017	Snake River_229.7_LB	96
12/3/1993	Snake River_238.6_RB	20				12/20/2002	Snake River_229.8_LB	48	1/23/2017	Snake River_229.7_LB	96
12/4/1993	Snake River_238.6_RB	20				12/21/2002	Snake River_229.8_LB	48	1/24/2017	Snake River_229.7_LB	96
12/5/1993	Snake River_238.6_RB	20				12/22/2002	Snake River_229.8_LB	48	1/25/2017	Snake River_229.7_LB	96
12/6/1993	Snake River_238.6_RB	20				12/23/2002	Snake River_229.8_LB	48	11/30/2017	Snake River_229.7_LB	96
12/7/1993	Snake River_238.6_RB	20				12/24/2002	Snake River_229.8_LB	48	12/1/2017	Snake River_229.7_LB	96
12/8/1993	Snake River_238.6_RB	20				12/25/2002	Snake River_229.8_LB	48	12/2/2017	Snake River_229.7_LB	96
12/9/1993	Snake River_238.6_RB	20				12/26/2002	Snake River_229.8_LB	48	12/3/2017	Snake River_229.7_LB	73
12/10/1993	Snake River_238.6_RB	20				12/27/2002	Snake River_229.8_LB	48	12/4/2017	Snake River_229.7_LB	96
12/22/1993	Snake River_238.6_RB	20				12/28/2002	Snake River_229.8_LB	48	12/5/2017	Snake River_229.7_LB	96
12/23/1993	Snake River_238.6_RB	20				12/29/2002	Snake River_229.8_LB	48	12/6/2017	Snake River_229.7_LB	96
12/24/1993	Snake River_238.6_RB	20				12/30/2002	Snake River_229.8_LB	48	12/7/2017	Snake River_229.7_LB	96
12/25/1993	Snake River_238.6_RB	20				12/31/2002	Snake River_229.8_LB	48	12/8/2017	Snake River_229.7_LB	96
12/26/1993	Snake River_238.6_RB	20							12/9/2017	Snake River_229.7_LB	96
12/27/1993	Snake River_238.6_RB	20							12/10/2017	Snake River_229.7_LB	96
12/28/1993	Snake River_238.6_RB	20							12/11/2017	Snake River_229.7_LB	96
12/29/1993	Snake River_238.6_RB	20							12/12/2017	Snake River_229.7_LB	96
12/30/1993	Snake River_238.6_RB	20							12/13/2017	Snake River_229.7_LB	96
12/31/1993	Snake River_238.6_RB	20							12/14/2017	Snake River_229.7_LB	96
									12/15/2017	Snake River_229.7_LB	96
									12/16/2017	Snake River_229.7_LB	96
									12/17/2017	Snake River_229.7_LB	96
									12/18/2017	Snake River_229.7_LB	96
									12/19/2017	Snake River_229.7_LB	68

Table 4
HCC inflow 7DAM Temperature in °C measured at the inflow to Brownlee Reservoir.

HCC Inflow 7DAM Temperature (°C)																					
Date	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1/1																						
1/2																						
1/3																						
1/4																						
1/5																						
1/6																						
1/7		5.9	3.5	3.6	3.2	2.6		4.6	1.7	2.4	4.4	2.8	1.7	2.2	3.4	0.5	3.5	0.4	1.8	1.8	1.0	0.0
1/8		5.7	3.6	3.7	3.3	2.5		4.6	1.5	2.1	4.5	3.0	1.9	2.1	3.3	0.6	3.6	0.2	1.8	2.0	1.5	0.0
1/9		5.6	3.7	3.7	3.4	2.5		4.4	1.4	1.9	4.5	3.2	2.1	2.0	3.1	0.8	3.6	0.1	1.9	2.4	2.0	0.0
1/10		5.5	3.7	3.9	3.5	2.5	3.6	4.1	1.3	1.9	4.4	3.4	2.3	1.8	3.0	1.1	3.7	0.2	2.1	2.8	2.4	0.0
1/11		5.5	3.6	4.0	3.6	2.6	3.6	3.9	1.3	2.1	4.4	3.4	2.4	2.0	3.0	1.2	3.7	0.3	2.3	3.1	2.7	0.0
1/12		5.4	3.6	4.0	3.6	2.7	3.6	3.8	1.4	2.2	4.3	3.3	2.4	2.5	2.9	1.4	3.7	0.4	2.7	3.4	2.9	0.0
1/13		5.2	3.5	4.1	3.7	3.0	3.7	3.8	1.6	2.4	4.3	3.0	2.5	2.9	2.9	1.5	3.5	0.4	3.2	3.6	2.9	0.0
1/14		5.0	3.5	4.1	3.7	3.3	3.6	4.0	1.8	2.5	4.4	2.6	2.5	3.3	3.0	1.6	3.3	0.4	3.5	3.7	2.8	0.0
1/15		4.9	3.6	4.2	3.9	3.6	3.6	4.2	2.0	2.5	4.4	2.2	2.6	3.4	3.1	1.8	3.1	0.4	3.8	3.8	2.7	0.0
1/16		4.7	3.6	4.4	4.0	3.8	3.5	4.5	2.0	2.6	4.3	1.7	2.6	3.4	3.4	2.0	2.9	0.4	3.9	3.9	2.7	0.0
1/17		4.4	3.8	4.5	4.2	3.7	3.3	4.8	2.0	2.6	4.2	1.1	2.5	3.4	3.6	2.3	2.7	0.3	3.9	3.9	2.8	0.0
1/18		4.1	3.9	4.6	4.2	3.6	3.2	4.9	2.0	2.7	4.1	0.7	2.2	3.4	3.8	2.5	2.5	0.1	3.7	4.1	3.0	0.0
1/19		3.9	4.1	4.7	4.2	3.4	3.0	5.0	2.1	2.9	4.1	0.5	2.0	3.1	4.0	2.8	2.5	0.0	3.5	4.1	3.3	0.0
1/20		3.9	4.3	4.8	4.4	3.2	2.9	4.9	2.2	3.1	4.0	0.7	1.7	2.9	4.2	3.1	2.7	0.0	3.3	4.1	3.5	0.0
1/21		3.8	4.4	4.9	4.6	2.9	2.7	4.7	2.4	3.3	3.8	0.9	1.4	2.7	4.4	3.3	2.9	0.0	3.1	4.2	3.7	0.0
1/22		3.7	4.5	5.0	4.7	2.9	2.7	4.6	2.7	3.6	3.7	1.1	1.1	2.5	4.5	3.4	3.1	0.0	3.0	4.2	3.9	0.0
1/23		3.6	4.8	4.9	4.8	2.8	2.6	4.5	2.9	3.8	3.6	1.4	0.9	2.6	4.7	3.5	3.4	0.0	2.9	4.2	4.0	0.0
1/24		3.7	5.0	4.6	4.8	2.8	2.8	4.6	2.9	4.0	3.6	1.7	0.7	2.8	4.8	3.6	3.6	0.0	2.9	4.3	4.2	0.0
1/25		3.7	5.2		5.0	3.0	3.0	4.8	2.8	4.0	3.5	1.9	0.6	3.0	4.9	3.9	3.9	0.0	2.8	4.3	4.3	0.0
1/26		3.7	5.4		5.2	3.1	3.2	5.1	2.8	3.9	3.4	2.0	0.6	3.1	4.9	4.0	4.1	0.0	2.7	4.4	4.3	0.0
1/27		3.7	5.7		5.4	3.1	3.4	5.3	2.7	4.1	3.4	2.0	0.6	3.0	5.0	4.2	4.2	0.0	2.7	4.6	4.3	0.0
1/28		3.8	6.0		5.3	3.0	3.6	5.6	2.7	4.3	3.4	2.0	0.6	2.9	5.1	4.4	4.2	0.0	2.6	4.8	4.3	0.0
1/29		3.8	6.1		5.2	2.7	3.5	5.7	2.8	4.5	3.5	2.0	0.7	2.8	5.3	4.6	4.2	0.0	2.6	5.0	4.2	0.0
1/30		3.9	6.2		5.0	2.5	3.4	5.9	3.0	4.7	3.7	2.0	0.9	2.6	5.4	4.7	4.2	0.0	2.7	5.2	4.2	0.0
1/31		3.8	6.2		4.9	2.4	3.1	6.1	3.3	4.8	3.8	2.1	1.2	2.4	5.5	4.8	4.4	0.0	2.9	5.4	4.1	0.1
2/1		3.9	6.2		4.8	2.1	2.9	6.3	3.5	4.9	4.0	2.2	1.6	2.2	5.5	4.8	4.5	0.1	3.1	5.5	4.0	0.2
2/2		4.0	6.2		4.7	1.9	2.6	6.3	3.7	5.1	4.3	2.2	1.9	2.1	5.6	4.7	4.6	0.6	3.5	5.5	3.9	0.5
2/3		4.1	6.2		4.7	2.0	2.3	6.2	3.8	5.0	4.4	2.2	2.1	2.4	5.5	4.4	4.7	1.0	3.8	5.6	3.9	0.9
2/4		4.2	6.2		4.8	2.2	2.1	6.2	3.8	4.9	4.7	2.4	2.2	2.6	5.4	4.3	4.9	1.5	4.1	5.7	3.9	1.3
2/5		4.3	6.2		5.1	2.6	2.0	6.2	3.9	4.8	4.9	2.7	2.3	2.8	5.3	4.2	4.9	2.1	4.2	5.8	4.0	1.9
2/6		4.3	6.2		5.5	3.1	2.0	5.9	3.8	4.7	4.9	3.1	2.4	3.0	5.4	4.2	4.9	2.7	4.1	6.0	4.0	2.5
2/7		4.2	6.3		5.8	3.4	2.1	5.6	3.8	4.7	4.8	3.4	2.5	3.3	5.5	4.3	4.9	3.3	3.9	6.3	4.1	3.0
2/8		4.2	6.5		6.0	3.4	2.4	5.2	3.9	4.9	4.7	3.8	2.7	3.7	5.7	4.5	4.9	3.8	3.5	6.6	4.3	3.5
2/9		4.2	6.6		6.2	3.4	2.5	4.9	4.0	4.9	4.6	4.4	3.0	4.0	5.8	4.7	4.9	4.1	3.2	7.0	4.6	3.9

HCC Inflow 7DAM Temperature (°C)

Date	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
2/10		4.1	6.5		6.4	3.3	2.8	4.8	4.2	5.0	4.5	5.0	3.3	4.1	5.9	5.0	5.2	4.2	3.0	7.4	4.9	4.1
2/11		4.1	6.4		6.6	3.0	3.0	4.7	4.2	5.0	4.3	5.4	3.6	4.1	6.1	5.1	5.4	4.3	2.9	7.6	5.1	4.3
2/12		4.1	6.4		6.6	2.8	3.2	4.7	4.1	5.1	4.0	5.7	4.0	4.2	6.3	5.2	5.8	4.4	3.1	7.8	5.3	4.4
2/13		4.2	6.4		6.6	2.8	3.4	4.9	4.0	5.3	3.9	5.9	4.4	4.2	6.4	5.2	6.1	4.6	3.4	7.9	5.6	4.4
2/14		4.4	6.3		6.6	2.7	3.5	5.2	3.9	5.4	4.0	6.2	4.6	4.1	6.6	5.2	6.4	4.8	3.8	8.0	5.9	4.4
2/15		4.6	6.1		6.5	2.9	3.4	5.6	3.7	5.4	4.0	6.4	4.7	3.9	6.8	5.3	6.6	5.0	4.3	8.2	6.2	4.4
2/16		4.8	6.0		6.5	3.3	3.4	6.0	3.5	5.4	3.8	6.6	4.8	3.8	7.0	5.5	6.6	5.4	4.7	8.2	6.5	4.4
2/17		5.1	6.0		6.4	3.8	3.4	6.3	3.5	5.4	3.6	6.9	4.8	3.9	7.2	5.7	6.5	5.7	5.0	8.1	6.8	4.5
2/18		5.3	6.1		6.4	4.3	3.5	6.5	3.6	5.4	3.4	7.1	4.8	4.1	7.4	5.8	6.6	6.0	5.3	8.2	7.1	4.7
2/19		5.5	6.2		6.4	4.6	3.6	6.6	3.9	5.3	3.3	7.3	4.7	4.4	7.6	5.9	6.5	6.2	5.5	8.2	7.3	4.8
2/20		5.6	6.3		6.3	4.9	3.8	6.8	4.1	5.2	3.1	7.3	4.7	4.7	7.6	5.9	6.4	6.2	5.7	8.4	7.5	4.9
2/21		5.6	6.5		6.5	5.3	4.1	6.8	4.4	5.3	2.9	7.3	4.7	4.9	7.6	5.9	6.2	6.0	5.8	8.4	7.5	5.0
2/22		5.6	6.6		6.7	5.7	4.5	6.9	4.7	5.5	3.0	7.3	4.8	5.1	7.4	5.9	6.3	5.8	6.1	8.3	7.5	5.2
2/23		5.6	6.6		6.9	6.0	4.9	6.8	5.0	5.8	3.2	7.1	4.8	5.5	7.2	5.8	6.4	5.7	6.3	8.2	7.5	5.2
2/24		5.4	6.7		6.8	6.2	5.2	6.6	5.2	6.2	3.6	6.9	5.0	6.0	7.0	5.8	6.4	5.5	6.6	8.0	7.5	5.1
2/25		5.3	6.6		6.8	6.3	5.4	6.5	5.2	6.6	4.0	6.6	5.5	6.2	6.9	5.7	6.3	5.4	7.1	8.0	7.5	5.0
2/26		5.3	6.6		6.8	6.4	5.4	6.3	5.2	7.1	4.5	6.3	5.8	6.4	6.9	5.4	6.2	5.4	7.5	8.0	7.5	4.8
2/27		5.3	6.4		6.8	6.5	5.3	6.2	5.3	7.5	5.0	6.2	6.1	6.5	6.8	5.2	6.1	5.5	7.9	8.0	7.8	4.7
2/28		5.3	6.3		6.8	6.4	5.2	5.9	5.5	7.6	5.4	6.1	6.4	6.4	6.9	4.9	6.2	5.7	8.4	8.0	8.0	4.7
3/1		5.3	6.2		6.8	6.4	5.0	5.7	5.6	7.8	5.6	6.0	6.8	6.4	7.2	4.9	6.1	5.9	8.7	8.1	8.2	4.7
3/2		5.3	6.2		6.9	6.4	4.7	5.7	5.8	7.9	5.8	5.9	7.2	6.4	7.5	5.0	6.0	6.1	8.9	8.2	8.5	4.8
3/3		5.4	6.2		7.2	6.3	4.5	5.9	5.9	8.1	5.8	5.9	7.3	6.3	7.9	5.1	6.0	6.4	9.0	8.2	8.7	5.0
3/4		5.3	6.3		7.5	6.4	4.4	6.2	6.0	8.3	5.9	6.1	7.2	6.2	8.2	5.4	6.2	6.7	8.8	8.2	9.0	5.4
3/5		5.3	6.4		7.9	6.6	4.5	6.5	6.0	8.6	5.9	6.4	7.1	6.2	8.5	5.8	6.5	6.9	8.7	8.0	9.4	5.7
3/6		5.3	6.4		8.2	6.9	4.9	6.7	6.1	8.9	5.8	6.8	7.2	6.2	8.7	6.3	6.8	7.0	8.7	8.0	9.6	6.0
3/7		5.4	6.4		8.5	7.4	5.1	7.0	6.3	9.3	5.8	7.3	7.2	6.2	9.0	6.7	6.9	7.2	8.7	8.0	9.7	6.0
3/8		5.6	6.3		8.7	7.8	5.3	7.1	6.8	9.8	5.8	7.8	7.2	6.2	9.1	6.8	7.0	7.3	8.7	8.2	9.7	6.0
3/9		5.7	6.3		8.9	8.2	5.4	7.2	7.2	10.2	5.8	8.3	7.3	6.1	9.1	6.8	7.2	7.5	8.8	8.5	9.7	6.2
3/10		5.9	6.3		9.0	8.5	5.5	7.4	7.7	10.7	5.7	8.8	7.5	6.0	8.9	6.8	7.4	7.5	9.0	8.9	9.6	6.4
3/11		6.2	6.6		9.0	8.7	5.6	7.7	8.2	11.1	5.6	9.3	7.9	5.9	8.7	6.9	7.6	7.6	8.9	9.4	9.5	6.5
3/12		6.5	7.0		9.0	8.8	5.8	8.3	8.8	11.4	5.6	9.9	8.2	5.9	8.5	7.0	7.6	8.0	8.8	9.9	9.3	6.7
3/13		6.6	7.5		9.0	8.9	5.8	8.9	9.4	11.5	5.6	10.2	8.5	6.1	8.3	7.1	7.7	8.4	8.8	10.4	9.2	7.0
3/14		6.7	8.1		9.2	8.8	5.9	9.4	9.7	11.4	5.7	10.5	8.7	6.3	8.1	7.3	7.8	8.8	8.9	10.8	9.0	7.5
3/15		6.7	8.6		9.4	8.8	6.0	10.0	9.9	11.3	5.7	10.6	8.6	6.5	8.1	7.5	8.0	9.3	8.9	11.1	9.0	7.9
3/16		6.8	9.1		9.5	8.8	6.3	10.4	10.2	11.0	5.9	10.9	8.6	6.8	8.3	7.6	8.1	9.7	9.0	11.3	8.9	8.3
3/17		7.1	9.4		9.4	8.9	6.5	10.7	10.4	10.6	6.2	11.2	8.5	7.3	8.7	7.6	8.1	10.1	9.1	11.3	8.9	8.6
3/18		7.3	9.3		9.2	9.0	6.5	10.6	10.6	10.2	6.4	11.4	8.4	7.8	9.0	7.7	7.9	10.2	9.3	11.6	9.0	8.9
3/19		7.7	9.2		9.2	9.1	6.5	10.5	10.9	9.8	6.7	11.6	8.2	8.3	9.2	7.7	7.8	10.3	9.5	11.7	9.0	9.1
3/20		8.1	9.1		9.0	9.4	6.6	10.5	11.0	9.7	6.8	11.7	8.1	8.8	9.5	7.7	7.6	10.2	9.6	11.7	9.2	9.2
3/21		8.5	8.9		8.8	9.8	7.0	10.4	11.2	9.7	7.0	11.7	8.1	9.3	9.7	7.6	7.5	10.1	9.6	11.9	9.5	9.3
3/22		8.9	8.8		8.7	10.4	7.5	10.3	11.5	9.7	7.2	11.6	8.3	9.8	9.7	7.7	7.6	9.9	9.7	12.0	9.8	9.4
3/23		9.2	8.7		8.8	11.0	7.9	10.2	11.8	9.9	7.5	11.6	8.3	10.0	9.8	7.8	7.8	9.4	9.7	12.1	10.1	9.4
3/24		9.4	8.7		9.0	11.6	8.2	10.1	12.1	10.1	7.7	11.7	8.5	10.1	9.7	8.1	7.9	9.1	9.8	12.2	10.4	9.3

HCC Inflow 7DAM Temperature (°C)

Date	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
3/25		9.5	8.8		9.3	12.3	8.7	10.0	12.2	10.3	7.9	11.6	8.7	10.1	9.7	8.2	8.2	9.0	10.0	12.0	10.5	9.3
3/26		9.5	8.8		9.6	12.7	9.1	9.9	12.3	10.4	8.0	11.5	8.9	9.9	9.6	8.2	8.6	9.1	10.2	12.0	10.5	9.2
3/27		9.6	8.9		10.0	12.8	9.5	9.7	12.3	10.2	8.1	11.3	9.0	9.7	9.6	8.2	8.9	9.2	10.3	12.2	10.5	9.3
3/28		9.7	9.0		10.3	12.8	9.7	9.5	12.2	10.1	8.2	11.1	8.9	9.3	9.6	8.3	9.3	9.6	10.4	12.4	10.3	9.3
3/29		9.7	9.1		10.3	12.8	9.7	9.4	12.0	9.9	8.3	11.1	8.7	9.1	9.6	8.3	9.4	10.3	10.4	12.7	10.1	9.3
3/30		9.7	9.2		10.2	12.7	9.8	9.5	12.0	9.7	8.3	11.0	8.7	8.8	9.6	8.3	9.4	11.1	10.4	13.0	10.1	9.2
3/31		9.7	9.2		10.3	12.6	10.2	9.8	11.9	9.4	8.4	11.0	8.5	8.7	9.4	8.6	9.5	11.9	10.4	13.5	10.3	9.1
4/1		9.6	9.3		10.4	12.4	10.4	10.2	11.6	9.2	8.4	10.9	8.4	8.5	9.4	9.1	9.5	12.7	10.4	13.8	10.6	9.2
4/2		9.4	9.4		10.6	12.3	10.6	10.6	11.5	9.3	8.5	10.9	8.4	8.5	9.3	9.5	9.5	13.5	10.4	13.9	11.2	9.4
4/3		9.2	9.5		10.9	12.2	10.7	10.8	11.7	9.7	8.7	11.0	8.6	8.4	9.1	9.9	9.5	14.2	10.4	13.7	11.8	9.5
4/4		9.1	9.6		11.2	12.2	10.9	10.8	12.2	9.9	8.7	11.4	8.8	8.5	9.0	10.0	9.5	14.6	10.6	13.4	12.5	9.5
4/5		8.9	9.6		11.5	12.2	11.1	10.9	12.6	10.2	8.6	11.8	9.0	8.7	8.9	10.1	9.6	14.6	11.0	13.2	13.0	9.6
4/6		8.7	9.7		12.0	12.1	11.4	10.7	12.9	10.7	8.7	12.4	9.4	9.2	9.0	10.2	9.6	14.6	11.4	12.9	13.4	9.8
4/7		8.7	9.8		12.2	12.0	11.6	10.5	13.3	11.2	8.7	12.9	9.8	9.7	9.2	9.9	9.5	14.5	11.8	12.6	13.7	10.0
4/8		8.8	9.9		12.4	11.6	11.9	10.4	13.9	11.6	8.8	13.3	10.0	10.3	9.4	9.4	9.6	14.1	12.4	12.4	14.0	10.1
4/9		8.9	10.1		12.4	11.3	12.1	10.5	14.3	11.8	8.9	13.7	10.2	10.9	9.7	9.0	9.8	13.6	13.1	12.5	14.1	10.0
4/10		9.0	10.4		12.4	11.3	12.4	11.0	14.5	11.8	9.0	13.9	10.3	11.4	10.0	8.7	10.1	13.0	13.6	12.8	14.2	9.9
4/11		9.0	10.6		12.5	11.1	12.6	11.8	14.6	12.0	9.0	13.8	10.5	11.9	10.3	8.8	10.4	12.6	14.1	13.1	14.3	10.0
4/12		9.2	10.8		12.7	10.8	12.9	12.5	14.6	12.2	9.2	13.6	10.8	12.1	10.5	8.9	10.6	12.3	14.5	13.2	14.5	10.0
4/13		9.3	10.9		13.0	10.6	13.1	13.1	14.7	12.2	9.4	13.3	11.2	12.3	10.7	9.1	10.8	12.2	14.5	13.3	14.6	10.0
4/14		9.4	11.0		13.2	10.5	13.2	13.5	14.6	11.9	9.7	13.0	11.5	12.4	10.9	9.2	11.1	12.0	14.4	13.5	14.5	10.0
4/15		9.6	11.0		13.3	10.8	13.2	13.6	14.4	11.9	9.9	12.8	11.7	12.1	11.2	9.4	11.2	12.0	14.1	13.5	14.1	10.0
4/16		9.9	11.0		13.4	11.2	12.9	13.6	14.3	12.2	10.0	12.6	11.7	11.7	11.6	9.7	11.3	12.0	13.9	13.5	13.8	10.1
4/17		10.3	11.0		13.5	11.8	12.4	13.5	14.3	12.5	10.0	12.5	11.7	11.6	12.3	10.0	11.2	11.9	13.7	13.6	13.5	10.3
4/18		10.8	10.9		13.5	12.4	11.9	13.2	14.3	12.7	10.1	12.6	11.9	11.6	12.9	10.3	11.3	11.8	13.7	13.8	13.4	10.6
4/19		11.0	11.1		13.5	13.2	11.2	12.9	14.2	12.6	10.3	12.3	11.9	11.8	13.7	10.4	11.5	11.7	13.6	14.2	13.4	10.8
4/20		11.4	11.4		13.6	13.8	10.6	12.9	14.0	12.6	10.4	12.3	11.4	12.0	14.5	10.4	11.9	11.8	13.8	14.6	13.6	11.0
4/21		11.8	11.9		13.9	14.3	10.1	13.2	13.9	12.8	10.5	12.2	10.8	12.4	14.9	10.5	12.4	12.1	14.1	15.2	14.0	11.2
4/22		12.0	12.4		14.1	14.6	9.8	13.4	13.8	13.0	10.6	12.2	10.7	13.1	15.0	10.5	13.0	12.4	14.3	15.9	14.6	11.4
4/23		12.2	12.8		14.3	14.9	9.9	13.6	13.8	13.2	10.8	12.4	10.8	13.9	14.8	10.6	13.6	12.7	14.2	16.4	15.0	11.7
4/24		12.1	13.1		14.4	15.1	10.2	13.7	13.9	13.2	11.2	12.8	10.9	14.1	14.5	10.5	14.2	13.1	14.0	16.6	15.0	11.9
4/25			13.4		14.3	15.5	10.5	13.9	14.2	13.4	11.5	13.3	10.8	14.1	14.2	10.4	14.7	13.7	13.7	16.7	14.8	11.9
4/26			13.4		14.2	16.0	11.1	14.0	14.6	14.2	11.8	14.1	10.9	14.0	13.9	10.4	14.9	14.3	13.4	16.7	14.5	11.9
4/27			13.5		14.3	16.6	11.6	13.8	15.2	15.0	12.1	14.7	11.3	13.8	13.5	10.5	14.7	14.9	13.1	16.6	14.3	11.9
4/28			13.6		14.3	17.4	12.1	13.7	15.7	15.7	12.4	15.5	12.1	13.5	13.1	10.7	14.2	15.5	12.8	16.6	14.0	11.9
4/29			13.8		14.3	17.8	12.7	13.6	15.9	16.0	12.8	16.3	12.7	13.1	12.8	10.7	13.8	16.0	12.7	16.6	13.7	11.9
4/30			14.0		14.3	17.9	13.2	13.5	16.4	16.1	13.1	16.9	12.9	12.9	12.5	10.7	13.4	16.3	13.1	16.8	13.6	11.9
5/1			14.4		14.6	17.7	13.7	13.5	16.7	16.4	13.4	17.4	12.9	12.9	12.3	10.7	13.0	16.4	13.6	17.0	13.9	12.0
5/2			14.9		15.1	17.2	14.3	13.7	17.2	16.7	13.5	17.7	12.9	13.0	12.2	10.8	12.7	16.4	14.3	17.3	14.5	12.1
5/3			15.5		15.5	16.5	14.6	14.1	17.6	16.8	13.6	17.7	13.1	13.1	12.1	11.0	12.4	16.4	15.0	17.9	15.2	12.4
5/4			16.0		15.7	16.0	14.9	14.5	18.0	16.9	13.6	17.5	13.4	13.1	11.9	11.2	12.4	16.3	15.7	18.4	15.7	12.9
5/5			16.3		15.8	15.6	15.2	14.5	18.4	17.1	13.6	16.9	13.5	13.3	11.9	11.4	12.5	16.3	16.3	18.7	16.2	13.4
5/6			16.5		16.0	15.5	15.2	14.6	19.0	17.3	13.7	16.4	13.6	13.3	11.9	11.8	12.5	16.6	16.5	18.7	16.6	13.8

HCC Inflow 7DAM Temperature (°C)

Date	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
5/7			16.8		16.2	15.7	15.1	14.7	19.5	17.5	13.7	16.1	14.0	13.3	12.3	12.2	12.6	17.1	16.4	18.5	17.0	13.8
5/8			17.0		16.2	16.1	14.9	14.7	19.7	17.6	13.7	16.0	14.4	13.4	12.7	12.5	12.9	18.0	16.2	18.1	17.4	13.9
5/9			17.1		16.2	16.6	14.6	14.6	19.6	17.5	13.8	16.3	14.6	13.6	13.1	12.6	13.2	18.8	15.9	17.9	17.5	14.1
5/10			17.1		16.0	17.1	14.5	14.5	19.2	17.0	13.9	16.8	14.6	13.8	13.4	12.7	13.5	19.4	15.5	17.6	17.3	14.3
5/11			17.0		15.7	17.4	14.5	14.5	18.4	16.4	14.2	17.6	14.5	14.2	13.7	12.9	13.8	20.0	15.1	17.3	17.1	14.4
5/12			16.7		15.3	17.6	14.7	14.7	17.7	16.1	14.4	18.5	14.1	14.6	14.1	13.2	14.1	20.5	14.8	17.0	17.0	14.5
5/13			16.4		15.3	17.9	15.1	14.9	17.2	16.1	14.6	19.2	13.8	14.7	14.6	13.5	14.6	20.9	14.9	16.9	17.1	14.3
5/14			16.1		15.4	18.0	15.5	15.3	16.9	16.3	14.9	19.5	13.8	14.9	15.1	13.7	14.9	21.0	15.3	17.2	17.1	14.3
5/15			15.6		15.6	18.0	16.0	15.7	16.6	16.5	15.4	19.6	14.2	15.1	15.6	13.9	15.2	20.9	15.9	17.4	17.0	14.5
5/16			15.1		15.8	17.9	16.5	16.0	16.4	16.6	15.9	19.6	14.7	15.3	16.0	14.0	15.4	20.5	16.3	17.4	16.9	14.4
5/17			14.6		16.0		16.9	16.1	16.4	16.6	16.4	19.7	15.2	15.7	16.6	14.0	15.7	20.2	16.9	17.4	17.1	14.1
5/18			14.4	15.2	16.5		17.4	15.9	16.7	16.8	16.9	19.7	15.7	16.1	17.2	14.0	15.7	19.7	17.6	17.6	17.5	13.7
5/19			14.4	15.3	17.1		17.8	15.8	17.0	16.8	17.2	19.7	16.3	16.6	17.5	13.8	15.8	19.0	17.9	17.8	17.8	13.7
5/20			14.5	15.5	17.7		18.1	15.7	17.2	16.6	17.4	19.7	16.8	17.1	17.6	13.7	15.9	18.5	18.1	18.0	17.9	14.0
5/21			14.4	15.6	18.2		17.9	15.7	17.4	16.2	17.5	19.7	16.8	17.4	17.5	13.7	15.9	18.2	18.1	18.3	17.6	14.5
5/22			14.4	15.7	18.6		17.5	15.8	17.4	15.8	17.4	19.4	16.3	17.7	17.0	13.8	16.0	17.9	18.2	18.6	17.2	14.9
5/23			14.4	15.9	19.0		17.1	16.2	17.4	15.6	17.2	19.0	15.6	18.0	16.3	14.1	15.8	17.5	18.1	19.2	17.0	15.3
5/24			14.7	16.2	19.4		16.8	16.9	17.4	15.9	17.1	18.7	15.1	18.2	15.6	14.3	15.6	17.3	18.1	19.5	16.9	16.0
5/25			14.9	16.6	19.7		16.6	17.7	17.7	16.2	17.0	18.5	14.9	18.2	15.2	14.5	15.5	17.4	18.2	19.9	16.8	16.4
5/26			14.8	16.9	19.7		16.6	18.3	17.9	16.4	16.8	18.5	14.7	18.1	15.1	14.6	15.4	17.6	18.4	20.1	16.7	16.5
5/27			14.4	17.2	19.6		16.7	18.9	17.9	16.9	16.6	18.6	14.7	18.2	15.0	14.5	15.1	17.6	18.5	20.4	16.6	16.5
5/28			14.2	17.4	19.4		17.5	19.4	17.8	17.6	16.2	18.8	14.9	18.6	15.0	14.2	15.0	17.5	18.6	20.7	17.0	16.6
5/29			14.4	17.7	19.1		18.5	19.8	17.6	18.2	16.0	19.3	15.3	19.0	15.1	13.9	15.1	17.5	18.4	21.0	17.4	16.7
5/30			14.4	17.7	18.8		19.4	19.8	17.5	18.7	15.9	19.9	15.9	19.3	15.5	13.7	15.4	17.7	18.2	21.2	17.8	16.8
5/31			14.4	17.5	18.4		20.2	19.5	17.5	19.2	15.9	20.4	16.2	19.6	15.8	13.7	16.0	18.0	17.9	21.4	18.2	17.0
6/1			14.5	17.4	18.0		20.6	19.2	17.3	19.4	16.1	21.0	16.4	19.7	16.1	13.8	16.8	18.2	17.8	21.6	18.5	17.2
6/2			14.8	17.2	18.0		20.6	19.1	17.5	19.4	16.4	21.5	16.6	19.8	16.2	13.9	17.8	18.5	17.9	21.8	18.8	17.5
6/3			15.3	16.9	18.2		20.5	19.0	18.0	19.3	16.8	22.2	16.7	19.8	16.2	14.0	18.8	18.9	18.1	21.9	19.2	17.6
6/4			15.7	16.6	18.7		20.3	18.9	18.7	19.2	17.4	23.0	16.5	19.8	16.2	14.2	19.4	19.4	18.3	21.9	19.8	17.7
6/5			16.0	16.4	19.2		20.2	18.7	19.5	19.1	18.2	23.6	16.4	19.7	16.1	14.6	19.6	20.1	18.8	21.9	20.5	17.7
6/6			16.2	16.3	19.8		20.0	18.6	20.2	18.8	18.7	23.5	16.3	19.4	15.9	14.9	19.4	20.9	19.2	22.1	21.2	17.6
6/7			16.5	16.2	20.6		19.8	18.9	20.7	18.6	19.0	22.8	16.0	19.0	15.9	15.1	19.0	21.6	19.6	22.4	21.8	17.5
6/8			16.7	16.1	21.3		19.4	19.3	20.9	18.3	19.1	22.3	15.8	18.7	15.9	15.2	18.5	22.1	19.9	22.8	22.3	17.5
6/9			16.8	16.1	21.4		19.0	19.7	20.8	18.4	19.2	21.9	15.7	18.6	15.8	15.4	17.8	22.6	20.2	23.4	22.7	17.4
6/10			17.1	16.3	21.2		18.5	20.0	20.3	18.5	19.2	21.2	15.6	18.6	15.9	15.6	17.3	23.1	20.3	24.1	22.9	17.3
6/11			17.4	16.6	20.7		18.1	20.3	19.7	18.4	19.1	20.3	15.6	18.6	16.0	15.7	17.0	23.4	20.4	24.7	22.7	17.1
6/12			17.6	16.9	20.0		18.0	20.5	19.1	18.4	19.0	19.8	15.8	18.7	16.1	15.9	17.1	23.3	20.5	25.0	22.4	16.8
6/13			18.0	17.2	19.5		18.2	20.7	18.9	18.6	18.8	20.1	16.1	18.9	16.5	16.1	17.7	23.0	20.5	25.0	22.0	16.6
6/14			18.2	17.6	19.2		18.7	20.9	18.9	19.0	18.7	20.7	16.6	19.1	16.7	16.4	18.3	22.7	20.5	24.9	21.4	16.5
6/15			18.3	18.3	19.0		19.6	21.0	19.0	19.5	18.5	21.2	17.1	19.2	16.9	16.6	18.8	22.4	20.4	24.6	20.8	16.5
6/16			18.3	18.8	19.2		20.9	21.2	19.2	19.9	18.4	21.6	17.6	19.4	17.1	16.8	19.4	22.3	20.1	24.4	20.1	16.7
6/17	20.0		18.2	19.3	19.5		22.2	21.5	19.8	20.2	18.5	21.8	18.2	19.7	17.0	17.0	20.0	22.3	19.7	24.3	19.7	16.9
6/18	19.1		18.2	19.7	20.1		22.9	21.8	20.3	20.3	18.7	22.2	18.9	19.9	17.1	17.2	20.3	22.5	19.3	24.3	19.5	17.3

HCC Inflow 7DAM Temperature (°C)

Date	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
6/19	18.5		18.3	19.9	20.7		23.1	22.0	20.9	20.5	19.0	22.6	19.5	20.0	17.4	17.2	20.3	22.6	19.0	24.3	19.5	18.1
6/20	18.2		18.3	20.2	21.0		23.1	22.1	21.2	20.8	19.2	22.9	20.0	20.1	17.5	17.3	20.2	22.5	19.1	24.4	19.6	18.9
6/21	18.0		18.4	20.4	21.4		23.0	21.9	21.6	21.2	19.5	23.2	20.4	20.2	17.5	17.5	20.2	22.3	19.4	24.6	20.0	19.5
6/22	18.1		18.6	20.3	21.8		22.7	21.6	22.2	21.7	20.0	23.6	20.7	20.1	17.7	17.9	20.4	22.1	19.8	24.8	20.7	19.9
6/23	18.2		18.9	20.3	22.2		22.5	21.3	22.9	22.0	20.5	23.7	20.9	20.1	18.0	18.3	20.5	21.9	20.3	24.9	21.6	20.2
6/24	18.0		19.3	20.3	22.5		22.7	20.9	23.4	22.5	21.0	24.0	21.0	20.2	18.6	18.7	20.7	21.5	20.9	24.8	22.2	20.5
6/25	18.0	19.7	19.4	20.3	22.7		23.2	20.6	24.0	23.1	21.5	24.1	21.1	20.3	19.1	18.9	20.9	21.0	21.5	25.0	22.7	20.8
6/26	18.3	19.8	19.4	20.2	23.1		24.0	20.6	24.6	23.7	22.1	24.0	21.2	20.4	19.5	19.1	21.3	20.7	21.8	25.3	23.2	20.9
6/27	18.6	19.9	19.2	20.0	23.6		24.8	21.0	25.2	23.9	22.9	24.0	21.4	20.5	20.1	19.2	21.5	21.2	21.8	25.7	23.7	20.9
6/28	18.8	20.0	19.1	19.8	23.9		25.4	21.6	25.6	23.7	23.6	24.0	21.7	20.7	20.7	19.3	21.7	22.0	21.9	26.2	24.2	21.0
6/29	19.1	20.1	19.2	19.9	24.2		25.9	22.4	25.8	23.4	24.0	24.0	22.1	21.2	21.3	19.3	21.7	22.9	22.0	26.8	24.8	21.2
6/30	19.6	20.2	19.5	20.1	24.5		26.2	23.2	25.9	23.5	24.5	24.0	22.7	21.6	21.6	19.2	22.0	23.8	21.9	27.3	25.1	21.5
7/1	20.1	20.1	19.7	20.2	24.9		26.2	23.9	25.8	23.6	24.8	24.2	23.2	21.9	21.9	19.2	22.2	24.9	22.1	27.9	25.6	21.8
7/2	20.9	20.2	20.1	20.3	25.0		26.1	24.4	25.7	23.6	25.1	24.5	23.9	22.0	22.2	19.3	22.4	26.1	22.3	28.4	26.1	22.1
7/3	21.6	20.3	20.7	20.4	25.0		25.9	24.7	25.6	23.5	25.3	24.9	24.6	22.3	22.3	19.7	22.7	27.2	22.9	28.7	26.5	22.6
7/4	22.3	20.5	21.2	20.5	24.6		25.6	25.0	25.4	23.6	25.4	25.3	25.1	22.6	22.3	20.1	23.1	27.9	23.5	28.8	26.6	22.9
7/5	23.0	20.8	21.7	20.6	24.2		25.3	25.1	25.2	24.1	25.4	25.7	25.4	23.1	22.1	20.3	23.5	28.0	24.0	28.8	26.3	23.4
7/6	23.2	21.1	22.0	20.7	23.6		25.3	25.1	25.1	24.6	25.4	26.1	25.4	23.3	21.8	20.7	23.9	27.9	24.6	28.5	25.9	23.9
7/7	23.3	21.4	22.4	20.8	23.1		25.3	25.2	25.1	24.9	25.4	26.5	25.3	23.4	21.9	21.1	24.3	27.7	25.1	28.1	25.5	24.6
7/8	23.4	21.9	22.8	20.8	22.7		25.2	25.2	24.9	25.2	25.3	26.7	25.3	23.4	22.0	21.5	24.6	27.5	25.6	27.7	25.1	25.2
7/9	23.4	22.3	23.2	21.0	22.6		25.3	25.5	24.7	25.4	25.4	27.0	25.3	23.3	22.4	21.6	24.8	27.2	26.0	27.2	24.7	25.8
7/10	23.4	22.4	23.6	21.4	22.7		25.5	25.7	24.5	25.2	25.4	27.2	25.2	23.3	22.9	21.7	25.1	27.0	26.1	26.6	24.3	26.1
7/11	23.4	22.4	24.0	22.1	23.1		25.8	26.0	24.3	25.2	25.5	27.3	24.9	23.2	23.5	21.8	25.6	26.9	26.2	26.2	23.6	26.4
7/12	23.6	22.2	24.4	22.9	23.7		26.4	26.4	24.3	25.3	25.6	27.3	24.7	22.9	24.1	22.0	26.1	26.8	26.5	25.7	23.2	26.5
7/13	24.0	22.2	24.7	23.5	24.5		26.8	26.6	24.4	25.3	25.7	27.2	24.6	22.6	24.5	22.0	26.3	26.6	26.7	25.3	23.1	26.7
7/14	24.4	22.2	24.9	24.0	25.1		27.3	26.7	24.7	25.2	26.0	27.2	24.6	22.6	24.6	22.1	26.4	26.5	26.9	25.1	23.1	26.8
7/15	24.6	22.4	25.2	24.3	25.5		27.6	26.8	25.1	25.1	26.3	27.3	24.7	22.7	24.6	22.2	26.5	26.4	27.0	25.0	23.2	26.8
7/16	24.6	22.7	25.5	24.5	25.6		27.8	27.0	25.4	25.1	26.4	27.4	24.7	23.1	24.7	22.6	26.5	26.3	27.2	24.9	23.2	26.5
7/17	24.6	23.1	25.8	24.6	25.5		28.1	27.2	26.0	25.5	26.6	27.4	24.7	23.6	24.8	22.9	26.4	26.3	27.5	24.7	23.5	26.4
7/18	24.5	23.3	26.2	24.5	25.2		28.1	27.3	26.5	25.7	26.6	27.4	24.8	24.0	24.9	23.2	26.2	26.4	27.7	24.5	24.0	26.3
7/19	24.3	23.4	26.6	24.2	25.0		27.8	27.4	26.6	25.7	26.7	27.3	24.9	24.5	24.8	23.3	26.1	26.7	27.6	24.4	24.6	26.3
7/20	23.9	23.7	26.8	24.0	24.9		27.4	27.6	26.8	25.9	26.8	27.1	25.0	25.1	25.0	23.4	26.1	27.0	27.4	24.6	25.0	26.2
7/21	23.8	24.0	27.0	23.8	24.9		27.1	27.8	26.8	26.0	26.9	26.9	24.9	25.4	25.3	23.5	26.1	27.3	27.1	24.8	25.4	26.0
7/22	23.8	24.1	27.1	23.9	25.0		26.8	28.1	26.7	26.2	27.1	26.8	24.7	25.8	25.4	23.6	26.2	27.4	26.8	24.8	25.7	25.8
7/23	24.1	24.1	27.1	24.1	25.3		26.7	28.3	26.7	26.2	27.3	26.7	24.6	26.0	25.4	23.7	26.3	27.5	26.6	25.0	26.0	25.8
7/24	24.3	24.2	27.0	24.3	25.5		26.6	28.4	26.6	26.4	27.5	26.6	24.4	26.1	25.3	23.7	26.3	27.4	26.2	25.2	26.1	25.8
7/25	24.7	24.5	27.1	24.3	25.9		26.5	28.3	26.5	26.3	27.8	26.4	24.4	26.1	25.3	23.8	26.2	27.3	25.9	25.5	26.4	25.8
7/26	25.2	25.0	27.1	24.4	26.1		26.4	28.0	26.7	26.1	28.1	26.4	24.5	26.2	25.3	23.9	26.2	27.1	25.7	25.6	26.7	25.7
7/27	25.8	25.1	27.2	24.6	26.2		26.3	27.7	26.7	25.8	28.3	26.5	24.5	26.3	25.3	24.0	26.3	26.9	25.6	25.5	27.1	25.7
7/28	26.2	25.1	27.3	25.0	26.1		26.2	27.6	26.7	25.6	28.4	26.7	24.5	26.4	25.4	24.1	26.2	26.7	25.6	25.0	27.4	25.8
7/29	26.4	25.0	27.3	25.2	26.2		26.2	27.5	26.8	25.2	28.3	26.8	24.6	26.4	25.5	24.2	26.2	26.4	25.8	24.7	27.8	25.9
7/30	26.4	24.8	27.3	25.3	26.3		26.2	27.4	26.8	24.9	28.1	26.7	24.5	26.5	25.7	24.3	26.3	26.1	25.8	24.5	28.2	26.1
7/31	26.3	24.6	27.2	25.4	26.5		26.0	27.4	26.7	24.7	27.6	26.6	24.6	26.6	25.9	24.5	26.4	25.8	26.0	24.4	28.5	26.2

HCC Inflow 7DAM Temperature (°C)

Date	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
8/1	26.3	24.4	27.0	25.5	26.6		25.7	27.6	26.8	24.6	26.8	26.6	24.6	26.7	26.0	24.7	26.5	25.6	26.3	24.5	28.4	26.4
8/2	26.0	24.3	26.8	25.6	26.6		25.4	27.8	26.7	24.7	26.2	26.4	24.5	26.9	26.0	25.0	26.4	25.2	26.5	24.7	28.3	26.6
8/3	25.6	24.3	26.5	25.5	26.6		25.2	27.7	26.7	24.7	25.6	26.2	24.4	27.1	26.1	25.3	26.2	25.0	26.6	25.0	27.7	26.7
8/4	24.9	24.3	26.4	25.3	26.6		25.0	27.5	26.7	24.9	25.2	25.9	24.4	27.1	26.2	25.5	26.0	24.8	26.7	25.5	27.1	26.8
8/5	24.2	24.2	26.3	25.0	26.5		24.6	27.2	26.7	25.0	24.9	25.6	24.5	27.1	26.4	25.6	25.8	24.8	26.7	25.8	26.6	26.7
8/6	23.6	24.4	26.2	24.8	26.3		24.0	26.8	26.5	25.2	24.6	25.1	24.7	26.9	26.4	25.7	25.8	24.9	26.7	25.9	26.0	26.5
8/7	23.0	24.7	26.2	24.5	26.2		23.2	26.5	26.3	25.3	24.8	24.9	24.7	26.4	26.2	25.7	25.8	25.0	26.6	25.7	25.5	26.2
8/8	22.6	24.9	26.2	24.2	26.1		22.8	26.2	25.9	25.5	25.1	24.6	24.8	25.5	26.1	25.6	25.9	25.2	26.4	25.5	25.3	25.9
8/9	22.4	24.8	26.1	24.0	26.1		22.5	25.9	25.6	25.7	25.3	24.5	25.0	24.8	25.9	25.5	26.0	25.4	26.3	25.2	24.8	25.7
8/10	22.6	24.7	26.0	23.8	26.1		22.4	26.0	25.3	25.8	25.4	24.3	25.1	24.3	25.7	25.3	26.2	25.5	26.1	24.9	24.6	25.6
8/11	23.0	24.5	25.9	23.6	26.0		22.4	26.0	25.2	25.9	25.3	24.1	25.0	23.9	25.3	25.1	26.3	25.6	26.1	24.8	24.4	25.5
8/12	23.4	24.4	25.8	23.3	25.8		22.4	26.0	25.1	25.9	25.0	24.1	24.9	23.7	24.6	25.0	26.3	25.6	26.0	24.8	24.2	25.5
8/13	24.0	24.2	25.8	23.1	25.7		22.7	25.9	25.2	25.7	24.7	24.2	24.9	23.5	24.2	24.8	26.2	25.5	25.8	24.9	24.1	25.4
8/14	24.4	24.0	25.9	22.9	25.5		23.2	25.7	25.4	25.4	24.4	24.4	25.0	23.5	23.9	24.6	26.0	25.5	25.6	25.1	24.2	25.2
8/15	24.7	23.9	26.0	22.6	25.3		23.7	25.6	25.6	25.1	24.1	24.4	25.0	23.5	23.7	24.3	25.8	25.5	25.4	25.2	24.3	25.1
8/16	24.9	23.8	26.1	22.4	24.9		24.0	25.5	25.8	24.8	23.8	24.3	24.9	23.4	23.6	24.1	25.7	25.6	25.4	25.1	24.6	25.0
8/17	25.0	23.8	25.8	22.3	24.6		24.0	25.3	25.9	24.4	23.4	24.2	24.9	23.2	23.6	23.9	25.5	25.7	25.3	25.0	25.0	24.8
8/18	24.7	23.8	25.4	22.3	24.3		24.0	25.1	25.8	24.1	23.3	24.2	25.1	23.0	23.8	23.8	25.4	25.7	25.2	24.8	25.3	24.6
8/19	24.4	23.8	25.0	22.4	24.0		23.9	25.1	25.7	23.9	23.3	24.0	25.1	22.7	24.2	23.7	25.2	25.8	25.1	24.5	25.4	24.3
8/20	23.9	23.8	24.5	22.6	23.7		23.7	25.0	25.6	24.0	23.3	23.6	24.9	22.7	24.5	23.6	25.1	25.9	25.1	24.2	25.5	24.1
8/21	23.4	23.7	24.1	22.9	23.3		23.2	24.9	25.5	24.1	23.3	23.1	24.6	23.0	24.6	23.6	24.9	25.9	25.1	23.8	25.5	24.0
8/22	22.9	23.6	23.7	23.3	23.0		22.7	24.6	25.3	24.3	23.3	22.9	24.1	23.5	24.6	23.8	24.7	25.8	24.9	23.4	25.3	23.9
8/23	22.5	23.7	23.4	23.6	22.8		22.3	24.4	24.8	24.3	23.2	22.8	23.7	23.9	24.3	23.9	24.5	25.6	24.5	23.1	25.0	23.8
8/24	22.0	23.7	23.2	23.7	22.7		22.0	24.3	24.2	24.2	23.2	22.6	23.4	24.0	23.8	24.0	24.2	25.3	24.1	22.8	24.6	23.7
8/25	21.9	23.7	23.1	23.8	22.7		21.9	24.3	23.5	24.0	23.0	22.5	23.1	24.1	23.5	24.1	23.8	25.1	23.6	22.7	24.1	23.6
8/26	22.1	23.6	23.0	23.9	22.8		21.8	24.2	22.9	23.8	22.7	22.4	22.9	24.2	23.1	24.3	23.4	24.8	23.3	22.7	23.8	23.7
8/27	22.2	23.5	23.0	23.9	23.0		21.7	24.0	22.2	23.6	22.6	22.6	22.5	24.1	22.7	24.4	23.2	24.5	23.1	22.8	23.5	23.8
8/28	22.2	23.3	22.9	23.9	23.0		21.8	23.9	21.6	23.4	22.5	22.7	22.3	23.9	22.1	24.5	23.0	24.4	23.1	22.8	23.2	23.9
8/29	22.2	23.1	22.8	23.9	23.0		21.9	23.8	21.3	23.2	22.3	22.7	22.3	23.7	21.4	24.4	22.8	24.4	23.2	22.9	23.0	24.1
8/30	22.4	22.8	22.8	23.9	22.8		22.0	23.8	21.4	22.8	22.1	22.8	22.4	23.5	20.9	24.4	22.6	24.5	23.3	22.9	22.9	24.3
8/31	22.4	22.6	22.9	23.7	22.6		22.1	23.7	21.7	22.5	21.9	23.0	22.2	23.6	20.6	24.2	22.4	24.6	23.3	22.8	22.8	24.3
9/1	22.4	22.4	23.0	23.2	22.1		22.1	23.3	22.0	22.3	21.7	23.1	21.5	23.6	20.2	23.7	22.4	24.7	23.2	22.7	22.7	24.2
9/2	22.1	22.3	23.2	22.5	21.5		22.0	23.1	22.2	22.2	21.5	23.4	20.9	23.5	19.8	23.2	22.3	24.7	23.0	22.5	22.6	24.2
9/3	21.9	22.1	23.4	21.6	20.8		22.0	23.0	22.1	22.1	21.2	23.7	20.5	23.5	19.7	22.7	22.1	24.7	22.8	22.2	22.4	24.1
9/4	21.7	22.1	23.5	20.9	20.1		21.9	23.0	21.7	21.9	21.0	23.9	20.1	23.5	19.9	22.2	21.9	24.6	22.4	21.7	22.0	24.2
9/5	21.2	22.2	23.5	20.4	19.6		21.7	23.1	21.3	21.6	20.9	23.9	19.6	23.4	20.2	21.7	21.8	24.4	22.0	21.1	21.6	24.1
9/6	20.6	22.2	23.5	19.8	19.1		21.4	23.2	20.9	21.6	21.0	23.6	19.3	23.2	20.2	21.4	21.7	24.2	21.7	20.6	21.1	23.8
9/7	20.1	22.3	23.6	19.4	18.7		21.1	23.3	20.4	21.7	21.3	23.3	19.1	22.9	20.1	21.3	21.6	24.0	21.5	20.2	20.7	23.5
9/8	19.7	22.3	23.7	19.3	18.4		20.8	23.5	20.0	21.8	21.6	22.8	19.4	22.4	20.0	21.4	21.5	23.7	21.4	19.8	20.3	23.4
9/9	19.6	22.3	23.7	19.2	18.1		20.5	23.2	19.7	21.8	21.8	22.2	19.7	21.9	19.6	21.5	21.6	23.5	21.2	19.6	20.0	23.3
9/10	19.6	22.3	23.4	19.3	18.0		20.2	22.5	19.9	21.4	22.0	21.5	19.9	21.5	19.1	21.6	21.6	23.3	21.1	19.5	19.8	23.3
9/11	19.9	22.1	23.1	19.3	18.0		20.1	21.9	20.2	20.9	22.0	20.9	19.9	21.2	18.6	21.8	21.5	23.2	20.8	19.7	19.6	23.2
9/12	20.3	21.9	22.9	19.2	18.1		20.1	21.2	20.4	20.5	21.9	20.5	19.9	21.0	18.3	22.0	21.2	23.1	20.5	20.2	19.5	23.1

HCC Inflow 7DAM Temperature (°C)

Date	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
9/13	20.7	21.6	22.7	19.1	18.4		20.2	20.4	20.4	20.1	21.7	20.3	19.8	21.0	18.3	22.1	20.9	23.0	20.1	20.7	19.5	23.1
9/14	21.0	21.4	22.4	19.1	18.8		20.4	19.6	20.3	19.7	21.4	20.2	19.7	21.1	18.5	22.2	20.6	23.1	19.7	21.1	19.4	23.3
9/15	21.1	21.2	22.2	19.1	19.2		20.6	18.9	19.9	19.3	21.0	20.2	19.6	21.2	18.8	22.2	20.3	23.2	19.4	21.1	19.2	22.9
9/16	20.9	20.8	22.1	19.2	19.7		20.8	18.5	19.6	18.9	20.3	20.3	19.6	21.5	19.2	22.1	19.9	23.4	19.3	20.9	18.9	22.2
9/17	20.3	20.4	22.2	19.2	20.3		20.8	18.3	19.1	18.9	19.6	20.3	19.6	21.7	19.6	21.9	19.7	23.4	19.4	20.5	18.7	21.4
9/18	19.4	19.8	22.3	19.3	20.8		20.6	18.0	18.6	18.9	18.9	20.2	19.7	21.7	20.0	21.6	19.6	23.1	19.6	20.0	18.6	20.6
9/19	18.7	19.4	22.0	19.4	21.0		20.4	17.7	18.1	18.9	18.2	19.9	19.8	21.7	20.1	21.3	19.6	22.5	20.0	19.5	18.7	19.7
9/20	18.0	19.1	21.6	19.5	20.9		20.0	17.6	17.6	18.8	17.4	19.4	19.8	21.5	20.1	21.0	19.6	22.0	20.5	19.1	18.8	18.7
9/21	17.5	18.7	21.1	19.5	20.6		19.6	17.5	17.3	18.7	16.8	19.0	19.5	21.1	20.0	20.7	19.5	21.3	20.8	18.8	18.8	17.6
9/22	16.9	18.4	20.6	19.5	20.1		19.1	17.5	17.1	18.6	16.3	18.5	19.2	20.6	19.7	20.4	19.2	20.6	21.1	18.8	18.8	17.0
9/23	16.5	18.3	20.1	19.5	19.3		18.6	17.5	17.0	18.3	16.2	17.9	18.8	20.2	19.4	20.2	18.8	19.7	21.1	19.0	18.6	16.6
9/24	16.3	18.4	19.6	19.4	18.4		18.4	17.7	17.1	17.9	16.1	17.4	18.4	19.8	19.2	20.2	18.3	19.0	21.1	19.3	18.5	16.2
9/25	16.2	18.6	19.1	19.3	17.5		18.2	17.9	17.2	17.5	16.0	17.0	18.0	19.5	18.9	20.1	18.1	18.4	21.0	19.5	18.2	15.9
9/26	15.9	18.7	18.8	19.1	16.8		17.9	18.2	17.4	17.1	16.1	16.8	17.8	19.3	18.7	20.0	17.9	17.8	20.8	19.6	17.8	15.9
9/27	15.7	18.7	18.6	18.6	16.2		17.6	18.5	17.8	16.8	16.3	16.7	17.6	19.1	18.7	19.8	17.8	17.2	20.5	19.7	17.6	16.0
9/28	15.6	18.5	18.6	17.9	15.8		17.5	18.7	18.2	16.5	16.4	16.6	17.5	19.2	18.7	19.7	17.8	16.6	20.1	19.6	17.5	16.2
9/29	15.7	18.3	18.7	17.2	15.7		17.3	18.9	18.6	16.3	16.6	16.2	17.6	19.2	18.8	19.5	17.9	16.1	19.6	19.5	17.6	16.5
9/30	15.9	18.1	18.7	16.6	15.9		17.0	19.0	18.8	16.2	16.9	15.9	17.8	18.8	19.0	19.2	18.2	15.8	19.1	19.3	18.0	16.7
10/1	16.2	17.9	18.6	16.1	16.4		16.5	19.1	18.9	16.3	17.0	15.6	18.0	18.1	19.0	19.1	18.5	15.5	18.5	19.1	18.3	16.9
10/2	16.4	17.7	18.6	15.6	16.7		15.9	19.2	18.8	16.3	17.1	15.3	18.2	17.3	19.1	19.1	18.6	15.2	18.0	18.9	18.5	16.8
10/3	16.7	17.5	18.5	15.2	16.8		15.3	19.3	18.7	16.2	17.0	14.9	18.2	16.4	19.1	19.0	18.5	15.0	17.6	18.6	18.4	16.5
10/4	16.9	17.3	18.2	15.1	16.8		14.9	19.3	18.6	16.0	16.9	14.6	18.1	15.4	19.1	18.9	18.1	14.8	17.2	18.4	18.2	16.0
10/5	17.0	17.1	17.7	15.1	16.6		14.6	19.3	18.3	15.7	16.8	14.1	17.9	14.4	18.9	18.8	17.7	14.5	17.1	18.2	17.7	15.5
10/6	17.1	16.9	17.1	15.2	16.2		14.5	19.3	18.0	15.2	16.6	13.8	17.7	13.7	18.5	18.4	17.1	14.3	17.1	18.0	17.2	15.0
10/7	17.1	16.4	16.5	15.2	15.8		14.6	19.4	17.8	14.8	16.4	13.5	17.5	13.2	18.2	17.8	16.3	14.0	17.3	17.8	16.6	14.6
10/8	17.2	15.9	16.1	15.1	15.3		14.8	19.3	17.6	14.5	16.1	13.5	17.0	13.1	18.0	17.3	15.5	13.8	17.5	17.7	16.1	14.2
10/9	17.3	15.3	15.7	15.1	14.7		15.1	19.2	17.4	14.4	15.8	13.6	16.5	13.1	17.6	16.6	14.8	13.6	17.7	17.7	15.7	13.9
10/10	17.3	14.8	15.3	15.1	14.3		15.5	18.7	17.1	14.4	15.5	13.6	15.8	12.9	17.3	16.0	14.3	13.4	17.8	17.9	15.5	13.7
10/11	17.4	14.3	15.0	15.2	13.9		15.4	18.1	16.7	14.3	15.1	13.5	14.8	12.7	17.1	15.5	14.1	13.4	17.8	17.9	15.4	13.5
10/12	17.4	13.8	14.8	15.3	13.7		15.1	17.3	16.3	14.3	14.7	13.5	13.8	12.4	16.8	15.1	14.1	13.3	17.7	18.0	15.4	13.4
10/13	17.2	13.3	14.7	15.4	13.5		14.6	16.5	15.9	14.4	14.4	13.6	12.8	12.0	16.5	15.0	14.3	13.2	17.4	17.8	15.3	13.1
10/14	16.9	13.0	14.5	15.4	13.3		14.0	15.7	15.6	14.4	14.1	13.7	12.0	11.8	16.1	15.1	14.6	13.1	17.1	17.7	15.0	12.7
10/15	16.4	12.9	14.2	15.3	13.2		13.4	15.0	15.4	14.4	13.9	13.7	11.5	11.6	15.8	15.1	14.9	12.9	16.6	17.5	14.7	12.3
10/16	15.8	12.8	13.7	14.9	13.0		12.9	14.2	15.2	14.3	13.6	13.6	11.2	11.7	15.6	15.1	15.3	12.7	16.0	17.3	14.4	12.0
10/17	15.1	12.7	13.2	14.4	12.9		12.5	13.9	15.0	14.3	13.5	13.5	11.3	11.9	15.3	15.0	15.4	12.5	15.4	16.9	14.1	11.8
10/18	14.3	12.6	12.8	13.7	12.7		12.3	13.9	15.0	14.3	13.3	13.4	11.6	12.3	15.0	14.8	15.3	12.4	15.0	16.7	13.8	11.5
10/19	13.4	12.7	12.5	13.2	12.6		12.3	14.0	14.7	14.3	13.1	13.0	12.2	12.8	14.8	14.7	15.1	12.2	14.7	16.6	13.5	11.4
10/20	12.4	12.7	12.3	12.6	12.5		12.4	14.1	14.4	14.4	12.9	12.6	12.7	13.2	14.6	14.5	14.8	12.1	14.5	16.4	13.3	11.4
10/21	11.6	12.6	12.0	12.2	12.3		12.6	14.3	14.1	14.3	12.7	12.2	13.0	13.6	14.4	14.4	14.3	12.2	14.4	16.2	13.3	11.4
10/22	10.9	12.5	11.8	11.8	12.2		12.8	14.5	13.7	14.2	12.4	11.9	13.0	13.5	14.3	14.2	13.8	12.2	14.3	16.0	13.2	11.4
10/23	10.4	12.3	11.8	11.8	12.1		12.9	14.8	13.3	14.0	12.3	11.7	12.7	13.3	14.1	14.1	13.0	12.3	14.2	15.7	13.2	11.4
10/24	10.2	12.0	12.0	11.8	11.9		12.8	14.7	12.8	13.8	12.1	11.5	12.3	13.1	13.9	14.1	12.4	12.3	14.2	15.5	13.2	11.4
10/25	10.2	11.7	12.1	11.9	11.8		12.6	14.4	12.3	13.6	11.9	11.5	11.9	12.9	13.6	13.9	11.8	12.3	14.2	15.1	13.2	11.4

HCC Inflow 7DAM Temperature (°C)

Date	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
10/26	10.2	11.2	12.2	11.8	11.8		12.3	14.0	12.0	13.4	11.6	11.5	11.5	12.5	13.2	13.6	11.4	12.3	14.0	14.8	13.3	11.5
10/27	10.1	10.9	12.2	11.7	11.8		12.0	13.7	11.7	13.2	11.2	11.4	11.1	12.2	12.8	13.2	10.8	12.3	13.8	14.5	13.3	11.5
10/28	10.0	10.6	12.2	11.6	11.8		11.6	13.4	11.4	13.0	10.9	11.2	10.8	11.8	12.5	12.6	10.4	12.1	13.4	14.2	13.4	11.6
10/29	9.9	10.3	12.2	11.4	11.8		11.2	13.2	11.2	12.8	10.6	11.1	10.6	11.2	12.1	12.3	10.1	11.8	13.1	13.9	13.4	11.8
10/30	9.8	10.2	11.9	11.3	11.7		10.7	12.7	11.1	12.6	10.3	11.1	10.6	10.6	11.7	11.9	10.2	11.6	13.0	13.6	13.3	11.9
10/31	9.6	10.1	11.6	11.1	11.7		10.0	12.3	10.9	12.4	9.9	10.9	10.7	10.1	11.5	11.6	10.3	11.3	12.8	13.2	13.2	11.9
11/1	9.4	10.2	11.3	10.9	11.5		9.3	11.7	10.6	12.1	9.5	10.7	10.7	9.8	11.4	11.4	10.6	11.0	12.6	13.0	13.0	11.7
11/2	9.2	10.3	11.0	10.6	11.2		8.5	11.0	10.4	11.8	8.9	10.5	10.8	9.6	11.5	11.2	10.9	10.7	12.2	12.7	12.7	11.5
11/3	9.2	10.3	10.6	10.4	10.8		7.8	10.3	10.2	11.5	8.5	10.4	10.8	9.4	11.7	10.9	11.2	10.3	12.0	12.5	12.5	11.2
11/4	9.2	10.2	10.4	10.2	10.4		7.1	9.4	9.9	11.2	8.4	10.3	10.8	9.3	11.7	10.5	11.5	10.0	11.8	12.0	12.2	10.9
11/5	9.1	10.2	10.2	10.1	10.0		6.5	8.5	9.5	10.8	8.4	10.1	10.7	9.4	11.8	9.9	11.7	9.7	11.7	11.5	11.9	10.5
11/6	8.8	10.1	10.1	10.1	9.7		6.0	7.7	9.1	10.4	8.6	9.7	10.4	9.5	11.9	9.3	11.7	9.4	11.5	11.1	11.7	10.1
11/7	8.5	10.0	10.0	10.1	9.4		6.0	7.1	8.9	10.1	9.1	9.4	10.2	9.5	11.8	8.8	11.6	9.2	11.4	10.6	11.5	9.8
11/8	8.4	10.0	9.8	10.1	9.2		6.2	6.9	8.7	9.9	9.7	9.3	10.0	9.4	11.5	8.3	11.3	9.0	11.3	10.1	11.3	9.4
11/9	8.4	10.0	9.5	10.2	8.8		6.6	6.8	8.5	9.6	10.3	9.1	9.8	9.2	11.2	7.9	11.0	9.0	11.3	9.7	11.2	9.2
11/10	8.3	10.0	9.2	10.2	8.5		7.0	6.9	8.4	9.3	10.6	9.0	9.6	9.1	10.8	7.7	10.7	9.0	11.2	9.2	11.1	8.9
11/11	8.2	10.0	8.8	10.2	8.1		7.3	7.1	8.4	9.1	10.5	9.0	9.4	9.1	10.3	7.7	10.2	9.0	11.0	9.0	11.1	8.7
11/12	8.2	9.8	8.6	10.3	7.7		7.7	7.4	8.5	8.9	10.2	9.0	9.4	9.0	9.9	7.6	9.5	9.1	10.5	8.8	11.1	8.6
11/13	8.3	9.6	8.4	10.2	7.3		8.0	7.7	8.6	8.8	9.7	8.9	9.6	8.9	9.5	7.6	8.9	9.2	9.7	8.7	11.1	8.5
11/14	8.4	9.3	8.3	10.2	6.9		8.2	7.8	8.8	8.6	9.1	8.7	9.7	8.8	9.0	7.5	8.3	9.3	8.6	8.7	11.0	8.5
11/15	8.4	8.9	8.3	10.0	6.5		8.2	7.8	8.9	8.3	8.5	8.5	9.7	8.5	8.8	7.5	8.0	9.2	7.4	8.6	11.0	8.5
11/16	8.4	8.5	8.5	9.8	6.2		8.1	7.9	9.0	8.0	8.0	8.2	9.5	8.1	8.7	7.5	7.9	9.0	6.3	8.5	10.9	8.5
11/17	8.3	8.2	8.7	9.6	5.9		7.9	7.9	9.1	7.6	7.8	8.1	9.3	7.8	8.6	7.4	7.8	8.8	5.2	8.2	10.7	8.6
11/18	8.2	8.0	8.8	9.3	5.5		7.6	7.7	9.0	7.3	7.7	8.1	9.1	7.5	8.5	7.3	8.0	8.6	4.1	8.0	10.4	8.4
11/19	8.3	7.9	8.8	9.0	5.2		7.5	7.6	8.8	7.0	7.8	8.1	8.8	7.2	8.4	7.2	8.2	8.4	3.2	7.8	9.9	8.2
11/20	8.4	7.8	8.7	8.6	4.9		7.4	7.6	8.5	6.7	7.9	8.1	8.4	6.8	8.3	6.9	8.6	8.3	2.7	7.5	9.4	7.9
11/21	8.3	7.8	8.5	8.3	4.6		7.3	7.7	8.0	6.4	8.1	8.1	8.1	6.5	8.2	6.6	8.9	8.0	2.6	7.1	8.9	7.8
11/22	8.2	7.7	8.5	8.0	4.4		7.2	7.6	7.5	6.2	8.4	7.9	7.9	6.4	7.9	6.4	8.9	7.6	2.7	6.7	8.4	7.8
11/23	8.2	7.6	8.4	7.8	4.2		7.3	7.2	7.0	5.9	8.5	7.6	7.6	6.2	7.4	6.3	8.8	7.1	2.9	6.3	8.0	8.0
11/24	8.2	7.5	8.2	7.5	4.0		7.4	6.7	6.6	5.8	8.5	7.2	7.3	6.0	6.7	6.2	8.6	6.6	3.3	6.0	7.7	8.1
11/25	8.3	7.5	8.1	7.4	4.0		7.5	6.2	6.3	5.5	8.3	6.7	7.0	5.7	5.9	6.3	8.4	6.2	3.8	5.8	7.6	8.3
11/26	8.1	7.3	8.1	7.4	4.0		7.3	5.5	6.1	5.3	8.1	6.1	6.8	5.4	5.1	6.3	8.2	5.7	4.5	5.5	7.5	8.5
11/27	7.8	7.2	8.2	7.5	4.1		7.0	5.0	6.0	5.0	7.7	5.6	6.5	5.2	4.4	6.3	7.7	5.3	5.2	5.2	7.3	8.6
11/28	7.7	7.1	8.2	7.5	4.3		6.6	4.6	6.0	4.7	7.2	5.2	6.2	5.0	3.8	6.3	7.2	4.9	5.7	4.8	7.2	8.5
11/29	7.5	7.1	8.2	7.5	4.3		6.1	4.4	5.9	4.5	6.4	5.0	6.2	4.9	3.3	6.3	6.8	4.9	6.1	4.4	7.1	8.3
11/30	7.3	7.0	8.2	7.7	4.5		5.7	4.6	5.6	4.3	5.6	4.9	6.3	4.7	2.7	6.2	6.7	5.0	6.4	4.1	6.9	7.8
12/1	7.0	6.9	8.2	7.9	4.6		5.2	4.9	5.2	4.0	4.9	4.8	6.5	4.7	2.4	6.0	6.7	5.1	6.3	3.7	6.7	7.3
12/2	6.8	6.7	8.3	7.9	4.7		4.9	5.5	4.8	3.9	4.3	4.6	6.8	4.5	2.4	5.8	6.8	5.4	6.1	3.2	6.5	6.9
12/3	6.6	6.5	8.3	7.6	4.7		4.7	5.9	4.3	3.8	3.8	4.5	7.0	4.4	2.6	5.5	6.9	5.5	5.9	2.8	6.3	6.6
12/4	6.4	6.2	8.2	7.2	4.5		4.6	6.4	3.9	3.7	3.4	4.6	7.3	4.1	2.7	5.3	7.0	5.5	5.7	2.6	6.2	6.3
12/5	6.1	5.9	7.9	6.8	4.4		4.5	6.7	3.5	3.6	3.0	4.7	7.4	3.8	2.9	5.1	7.4	5.2	5.7	2.7	6.0	6.0
12/6	6.0	5.5	7.4	6.4	4.3		4.5	6.9	3.3	3.4	2.8	4.9	7.2	3.4	3.1	4.8	7.6	4.6	5.7	2.8	5.7	5.7
12/7	5.9	5.3	6.9	5.9	4.2		4.4	7.0	3.5	3.2	2.7	5.2	6.9	2.9	3.4	4.4	7.6	4.1	5.8	3.1	5.3	5.4

HCC Inflow 7DAM Temperature (°C)

Date	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
12/8	5.7	5.1	6.6	5.5	4.0		4.3	6.9	3.7	2.9	2.7	5.3	6.6	2.3	3.7	4.0	7.4	3.2	6.1	3.5	4.7	5.2
12/9	5.6	4.9	6.2	5.1	4.0		4.3	6.6	4.0	2.5	2.7	5.4	6.2	1.8	3.9	3.7	7.0	2.3	6.5	4.1	4.1	4.9
12/10	5.6	4.8	5.7	4.8	4.0		4.2	6.3	4.4	1.9	2.8	5.3	5.8	1.2	3.9	3.5	6.7	1.5	6.9	4.6	3.6	4.7
12/11	5.7	4.7	5.2	4.7	4.0		4.2	6.0	4.8	1.3	2.9	4.9	5.4	0.7	3.9	3.2	6.5	0.8	7.1	5.1	3.2	4.5
12/12	5.7	4.5	5.0	4.7	3.9		4.3	5.9	5.3	0.9	3.2	4.5	5.1	0.4	3.9	3.0	6.2	0.4	7.2	5.3	2.9	4.3
12/13	5.7	4.4	5.0	4.7	4.0		4.6	5.7	5.8	0.6	3.5	4.0	4.8	0.2	4.1	2.8	5.9	0.2	7.2	5.5	2.7	4.2
12/14	5.6	4.2	4.9	4.7	4.0		5.0	5.6	6.0	0.3	3.9	3.5	4.7	0.2	4.2	2.7	5.7	0.1	7.2	5.5	2.6	4.1
12/15	5.5	3.9	4.7	4.7	4.1		5.4	5.5	6.1	0.1	4.3	3.1	4.4	0.3	4.2	2.7	5.7	0.3	7.0	5.3	2.7	4.0
12/16	5.5	3.8	4.5	4.7	4.2		5.8	5.4	6.1	0.0	4.7	2.9	4.0	0.6	4.2	2.7	5.6	0.4	6.7	5.0	2.9	3.9
12/17	5.3	3.8	4.3	4.7	4.1		6.2	5.3	5.9	0.0	4.7	2.9	3.4	1.1	4.1	2.7	5.6	0.6	6.5	4.5	2.8	3.8
12/18	5.1	3.8	4.2	4.8	4.1		6.4	5.2	5.6	0.0	4.6	3.0	2.8	1.6	4.0	2.7	5.5	0.7	6.3	4.0	2.4	3.7
12/19	4.9	3.9	3.9	4.9	4.0		6.5	5.0	5.4	0.0	4.2	3.2	2.3	2.2	3.9	2.8	5.3	0.8	6.0	3.7	1.9	3.6
12/20	4.6	3.8	3.5	4.9	3.9		6.2	4.8	5.2	0.0	3.8	3.4	1.9	2.6	3.6	2.8	4.9	0.9	5.8	3.4	1.5	3.5
12/21	4.5	3.8	2.9	4.9	3.7		5.8	4.6	4.9	0.1	3.3	3.6	1.4	2.9	3.3	2.8	4.6	0.9	5.7	3.2	1.1	3.5
12/22	4.4	3.6	2.2	5.0	3.5		5.4	4.5	4.7	0.5	2.8	3.6	1.1	3.2	3.0	2.8	4.1	0.9	5.8	3.1	0.7	3.6
12/23	4.3	3.4	1.6	4.9	3.5		5.1	4.5	4.5	0.8	2.4	3.5	1.0	3.2	3.0	2.6	3.7	1.1	6.0	3.1	0.3	3.7
12/24	4.3	3.1	1.1	4.7	3.5		4.8	4.4	4.3	1.2	2.2	3.4	1.1	3.1	3.0	2.4	3.3	1.3	6.1	3.2	0.1	4.0
12/25	4.4	2.8	0.7	4.4	3.6		4.6	4.4	4.0	1.5	2.3	3.2	1.2	2.8	3.1	2.3	3.0	1.4	6.0	3.4	0.0	
12/26	4.4	2.6	0.4	4.2	3.7		4.4	4.4	3.7	1.9	2.5	3.0	1.3	2.5	3.2	2.0	2.8	1.5	5.7	3.3	0.0	
12/27	4.5	2.4	0.4	3.9	3.7		4.4	4.4	3.4	2.3	2.8	2.7	1.3	2.2	3.4	2.0	2.7	1.5	5.5	3.0	0.0	
12/28	4.8	2.3	0.8	3.6	3.7		4.5	4.1	3.2	2.5	3.0	2.4	1.4	2.0	3.6	2.0	2.7	1.5	5.1	2.7	0.0	
12/29	5.0	2.4	1.2	3.4	3.6		4.5	3.9	3.2	2.5	3.1	2.3	1.7	1.9	3.9	2.2	2.7	1.3	4.6	2.2	0.0	
12/30	5.2	2.5	1.7	3.1	3.5		4.6	3.7	3.1	2.6	3.0	2.2	2.0	2.0	3.9	2.6	2.6	1.1	4.1	1.8	0.0	
12/31	5.5	2.6	2.2	2.9	3.3		4.5	3.4	3.2	2.8	3.0	2.1	2.2	2.1	3.7	3.1	2.5	1.0	3.6	1.4	0.0	

Table 5
List of alternate Snake River locations referenced by River Mile (RM) used fill in missing data from the temperature dataset measured at HCC inflow location (RM 345.6 MC).

Snake River_345.6_LC
Snake River_345.6_MC
Snake River_345.2_LB
Snake River_345.8_RB
Snake River_354.3_LB
Snake River_354.3_LC
Snake River_354.5_LC
Snake River_354.5_RB

Table 6
Listing of date ranges, alternate Snake River locations used (referenced by River Mile, RM) and number of samples filled in (N, typically samples every hour or half-hour) when filling gaps in the temperature dataset measured at HCC inflow (RM 345.6 MC).

Replaced Data 1996-2016			Replaced Data 2015-2016			Replaced Data 2016-2017			Replaced Data 2017		
Date	Location	N	Date	Location	N	Date	Location	N	Date	Location	N
9/1/1996	Interpolated	0	7/11/2015	Snake River_345.2_LB	48	4/14/2016	Snake River_345.2_LB	48	3/1/2017	Snake River_345.2_LB	48
9/2/1996	Interpolated	0	7/12/2015	Snake River_345.2_LB	48	4/15/2016	Snake River_345.2_LB	48	3/2/2017	Snake River_345.2_LB	48
1/18/1998	Interpolated	0	7/13/2015	Snake River_345.2_LB	48	4/16/2016	Snake River_345.2_LB	48	3/3/2017	Snake River_345.2_LB	48
1/19/1998	Interpolated	0	7/14/2015	Snake River_345.2_LB	48	4/17/2016	Snake River_345.2_LB	48	3/4/2017	Snake River_345.2_LB	48
1/20/1998	Interpolated	0	7/15/2015	Snake River_345.2_LB	48	4/18/2016	Snake River_345.2_LB	48	3/5/2017	Snake River_345.2_LB	48
1/21/1998	Interpolated	0	7/16/2015	Snake River_345.2_LB	48	4/19/2016	Snake River_345.2_LB	48	3/6/2017	Snake River_345.2_LB	48
3/19/1998	Interpolated	0	7/17/2015	Snake River_345.2_LB	48	4/20/2016	Snake River_345.2_LB	48	3/7/2017	Snake River_345.2_LB	48
3/20/1998	Interpolated	0	7/18/2015	Snake River_345.2_LB	48	4/21/2016	Snake River_345.2_LB	48	3/8/2017	Snake River_345.2_LB	48
3/21/1998	Interpolated	0	7/19/2015	Snake River_345.2_LB	48	4/22/2016	Snake River_345.2_LB	48	3/9/2017	Snake River_345.2_LB	48
3/22/1998	Interpolated	0	7/20/2015	Snake River_345.2_LB	48	4/23/2016	Snake River_345.2_LB	48	3/10/2017	Snake River_345.2_LB	48
3/23/1998	Interpolated	0	7/21/2015	Snake River_345.2_LB	48	4/24/2016	Snake River_345.2_LB	48	3/11/2017	Snake River_345.2_LB	48
3/24/1998	Interpolated	0	7/22/2015	Snake River_345.2_LB	48	4/25/2016	Snake River_345.2_LB	48	3/12/2017	Snake River_345.2_LB	48
3/25/1998	Interpolated	0	7/23/2015	Snake River_345.2_LB	48	4/26/2016	Snake River_345.2_LB	48	3/13/2017	Snake River_345.2_LB	48
3/26/1998	Interpolated	0	7/24/2015	Snake River_345.2_LB	48	4/27/2016	Snake River_345.2_LB	48	3/14/2017	Snake River_345.2_LB	48
3/27/1998	Interpolated	0	7/25/2015	Snake River_345.2_LB	48	4/28/2016	Snake River_345.2_LB	48	3/15/2017	Snake River_345.2_LB	48
3/28/1998	Interpolated	0	7/26/2015	Snake River_345.2_LB	48	4/29/2016	Snake River_345.2_LB	48	3/16/2017	Snake River_345.2_LB	48
3/29/1998	Interpolated	0	7/27/2015	Snake River_345.2_LB	48	4/30/2016	Snake River_345.2_LB	48	3/17/2017	Snake River_345.2_LB	48
3/30/1998	Interpolated	0	7/28/2015	Snake River_345.2_LB	48	5/1/2016	Snake River_345.2_LB	48	3/18/2017	Snake River_345.2_LB	48
3/31/1998	Interpolated	0	7/29/2015	Snake River_345.2_LB	48	5/2/2016	Snake River_345.2_LB	48	3/19/2017	Snake River_345.2_LB	48
4/1/1998	Interpolated	0	7/30/2015	Snake River_345.2_LB	48	5/3/2016	Snake River_345.2_LB	48	3/20/2017	Snake River_345.2_LB	48
4/2/1998	Interpolated	0	7/31/2015	Snake River_345.2_LB	48	5/4/2016	Snake River_345.2_LB	48	3/21/2017	Snake River_345.2_LB	48
4/3/1998	Interpolated	0	8/1/2015	Snake River_345.2_LB	48	5/5/2016	Snake River_345.2_LB	48	3/22/2017	Snake River_345.2_LB	48
4/4/1998	Interpolated	0	8/2/2015	Snake River_345.2_LB	48	5/6/2016	Snake River_345.2_LB	48	3/23/2017	Snake River_345.2_LB	48
4/5/1998	Interpolated	0	8/3/2015	Snake River_345.2_LB	48	5/7/2016	Snake River_345.2_LB	48	3/24/2017	Snake River_345.2_LB	48
4/6/1998	Interpolated	0	8/4/2015	Snake River_345.2_LB	48	5/8/2016	Snake River_345.2_LB	48	3/25/2017	Snake River_345.2_LB	48
4/7/1998	Interpolated	0	8/5/2015	Snake River_345.2_LB	48	5/9/2016	Snake River_345.2_LB	48	3/26/2017	Snake River_345.2_LB	48
9/20/1999	Interpolated	0	8/6/2015	Snake River_345.2_LB	48	5/10/2016	Snake River_345.2_LB	48	3/27/2017	Snake River_345.2_LB	48
9/21/1999	Interpolated	0	8/7/2015	Snake River_345.2_LB	48	5/11/2016	Snake River_345.2_LB	48	3/28/2017	Snake River_345.2_LB	48
9/22/1999	Interpolated	0	8/8/2015	Snake River_345.2_LB	48	5/12/2016	Snake River_345.2_LB	48	3/29/2017	Snake River_345.2_LB	48
9/23/1999	Interpolated	0	8/9/2015	Snake River_345.2_LB	48	5/13/2016	Snake River_345.2_LB	48	3/30/2017	Snake River_345.2_LB	48
10/11/2000	Interpolated	0	8/10/2015	Snake River_345.2_LB	48	5/14/2016	Snake River_345.2_LB	48	3/31/2017	Snake River_345.2_LB	48
10/12/2000	Interpolated	0	8/11/2015	Snake River_345.2_LB	48	5/15/2016	Snake River_345.2_LB	48	4/1/2017	Snake River_345.2_LB	48
10/13/2000	Interpolated	0	8/12/2015	Snake River_345.2_LB	48	5/16/2016	Snake River_345.2_LB	48	4/2/2017	Snake River_345.2_LB	48
10/14/2000	Interpolated	0	8/13/2015	Snake River_345.2_LB	48	5/17/2016	Snake River_345.2_LB	48	4/3/2017	Snake River_345.2_LB	48
10/15/2000	Interpolated	0	8/14/2015	Snake River_345.2_LB	48	5/18/2016	Snake River_345.2_LB	48	4/4/2017	Snake River_345.2_LB	48
10/16/2000	Interpolated	0	8/15/2015	Snake River_345.2_LB	48	5/19/2016	Snake River_345.2_LB	48	4/5/2017	Snake River_345.2_LB	48
10/17/2000	Interpolated	0	8/16/2015	Snake River_345.2_LB	48	5/20/2016	Snake River_345.2_LB	48	4/6/2017	Snake River_345.2_LB	48

Replaced Data 1996-2016

Date	Location	N
10/18/2000	Interpolated	0
10/19/2000	Interpolated	0
10/20/2000	Interpolated	0
10/21/2000	Interpolated	0
10/22/2000	Interpolated	0
10/23/2000	Interpolated	0
1/18/2002	Interpolated	0
1/19/2002	Interpolated	0
1/20/2002	Interpolated	0
1/21/2002	Interpolated	0
1/22/2002	Interpolated	0
1/31/2002	Interpolated	0
3/30/2002	Interpolated	0
3/31/2002	Interpolated	0
4/1/2002	Interpolated	0
4/2/2002	Interpolated	0
4/3/2002	Interpolated	0
4/4/2002	Interpolated	0
4/5/2002	Interpolated	0
4/6/2002	Interpolated	0
4/7/2002	Interpolated	0
4/8/2002	Interpolated	0
4/9/2002	Interpolated	0
4/10/2002	Interpolated	0
4/11/2002	Interpolated	0
4/20/2002	Interpolated	0
4/21/2002	Interpolated	0
4/22/2002	Interpolated	0
4/23/2002	Interpolated	0
4/24/2002	Interpolated	0
4/25/2002	Interpolated	0
4/26/2002	Interpolated	0
4/27/2002	Interpolated	0
4/28/2002	Interpolated	0
4/29/2002	Interpolated	0
4/30/2002	Interpolated	0
9/2/2002	Interpolated	0
9/3/2002	Interpolated	0
9/4/2002	Interpolated	0
9/5/2002	Interpolated	0
9/6/2002	Interpolated	0

Replaced Data 2015-2016

Date	Location	N
8/17/2015	Snake River_345.2_LB	48
8/18/2015	Snake River_345.2_LB	48
8/19/2015	Snake River_345.2_LB	48
8/20/2015	Snake River_345.2_LB	48
8/21/2015	Snake River_345.2_LB	48
8/22/2015	Snake River_345.2_LB	48
8/23/2015	Snake River_345.2_LB	48
8/24/2015	Snake River_345.2_LB	48
8/25/2015	Snake River_345.2_LB	48
8/26/2015	Snake River_345.2_LB	48
8/27/2015	Snake River_345.2_LB	48
8/28/2015	Snake River_345.2_LB	48
8/29/2015	Snake River_345.2_LB	48
8/30/2015	Snake River_345.2_LB	48
8/31/2015	Snake River_345.2_LB	48
9/1/2015	Snake River_345.2_LB	48
9/2/2015	Snake River_345.2_LB	48
9/3/2015	Snake River_345.2_LB	48
9/4/2015	Snake River_345.2_LB	48
9/5/2015	Snake River_345.2_LB	48
9/6/2015	Snake River_345.2_LB	48
9/7/2015	Snake River_345.2_LB	48
9/8/2015	Snake River_345.2_LB	48
9/9/2015	Snake River_345.2_LB	48
9/10/2015	Snake River_345.2_LB	48
9/11/2015	Snake River_345.2_LB	48
9/12/2015	Snake River_345.2_LB	48
9/13/2015	Snake River_345.2_LB	48
9/14/2015	Snake River_345.2_LB	48
9/15/2015	Snake River_345.2_LB	48
9/16/2015	Snake River_345.2_LB	48
9/17/2015	Snake River_345.2_LB	48
9/18/2015	Snake River_345.2_LB	48
9/19/2015	Snake River_345.2_LB	48
9/20/2015	Snake River_345.2_LB	48
9/21/2015	Snake River_345.2_LB	48
9/22/2015	Snake River_345.2_LB	48
9/23/2015	Snake River_345.2_LB	48
9/24/2015	Snake River_345.2_LB	48
9/25/2015	Snake River_345.2_LB	48
9/26/2015	Snake River_345.2_LB	48

Replaced Data 2016-2017

Date	Location	N
5/21/2016	Snake River_345.2_LB	48
5/22/2016	Snake River_345.2_LB	48
5/23/2016	Snake River_345.2_LB	48
5/24/2016	Snake River_345.2_LB	48
5/25/2016	Snake River_345.2_LB	48
5/26/2016	Snake River_345.2_LB	48
5/27/2016	Snake River_345.2_LB	48
5/28/2016	Snake River_345.2_LB	48
5/29/2016	Snake River_345.2_LB	48
5/30/2016	Snake River_345.2_LB	48
5/31/2016	Snake River_345.2_LB	48
6/1/2016	Snake River_345.2_LB	48
6/2/2016	Snake River_345.2_LB	48
6/3/2016	Snake River_345.2_LB	48
6/4/2016	Snake River_345.2_LB	48
6/5/2016	Snake River_345.2_LB	48
6/6/2016	Snake River_345.2_LB	48
6/7/2016	Snake River_345.2_LB	48
6/8/2016	Snake River_345.2_LB	48
6/9/2016	Snake River_345.2_LB	48
6/10/2016	Snake River_345.2_LB	48
6/11/2016	Snake River_345.2_LB	48
6/12/2016	Snake River_345.2_LB	48
6/13/2016	Snake River_345.2_LB	48
6/14/2016	Snake River_345.2_LB	48
6/15/2016	Snake River_345.2_LB	48
6/16/2016	Snake River_345.2_LB	48
6/17/2016	Snake River_345.2_LB	48
6/18/2016	Snake River_345.2_LB	48
6/19/2016	Snake River_345.2_LB	48
6/20/2016	Snake River_345.2_LB	48
6/21/2016	Snake River_345.2_LB	48
6/22/2016	Snake River_345.2_LB	48
6/23/2016	Snake River_345.2_LB	48
6/24/2016	Snake River_345.2_LB	48
6/25/2016	Snake River_345.2_LB	48
6/26/2016	Snake River_345.2_LB	48
6/27/2016	Snake River_345.2_LB	48
6/28/2016	Snake River_345.2_LB	48
6/29/2016	Snake River_345.2_LB	48
6/30/2016	Snake River_345.2_LB	48

Replaced Data 2017

Date	Location	N
4/7/2017	Snake River_345.2_LB	48
4/8/2017	Snake River_345.2_LB	48
4/9/2017	Snake River_345.2_LB	48
4/10/2017	Snake River_345.2_LB	48
4/11/2017	Snake River_345.2_LB	48
4/12/2017	Snake River_345.2_LB	48
4/13/2017	Snake River_345.2_LB	48
4/14/2017	Snake River_345.2_LB	48
4/15/2017	Snake River_345.2_LB	48
4/16/2017	Snake River_345.2_LB	48
4/17/2017	Snake River_345.2_LB	48
4/18/2017	Snake River_345.2_LB	48
4/19/2017	Snake River_345.2_LB	48
4/20/2017	Snake River_345.2_LB	48
4/21/2017	Snake River_345.2_LB	48
4/22/2017	Snake River_345.2_LB	48
4/23/2017	Snake River_345.2_LB	48
4/24/2017	Snake River_345.2_LB	48
4/25/2017	Snake River_345.2_LB	48
4/26/2017	Snake River_345.2_LB	48
4/27/2017	Snake River_345.2_LB	48
4/28/2017	Snake River_345.2_LB	48
4/29/2017	Snake River_345.2_LB	48
4/30/2017	Snake River_345.2_LB	48
5/1/2017	Snake River_345.2_LB	48
5/2/2017	Snake River_345.2_LB	48
5/3/2017	Snake River_345.2_LB	48
5/4/2017	Snake River_345.2_LB	48
5/5/2017	Snake River_345.2_LB	48
5/6/2017	Snake River_345.2_LB	48
5/7/2017	Snake River_345.2_LB	48
5/8/2017	Snake River_345.2_LB	48
5/9/2017	Snake River_345.2_LB	48
5/10/2017	Snake River_345.2_LB	48
5/11/2017	Snake River_345.2_LB	48
5/12/2017	Snake River_345.2_LB	48
5/13/2017	Snake River_345.2_LB	48
5/14/2017	Snake River_345.2_LB	48
5/15/2017	Snake River_345.2_LB	48
5/16/2017	Snake River_345.2_LB	48
5/17/2017	Snake River_345.2_LB	48

Replaced Data 1996-2016			Replaced Data 2015-2016			Replaced Data 2016-2017			Replaced Data 2017		
Date	Location	N	Date	Location	N	Date	Location	N	Date	Location	N
9/7/2002	Interpolated	0	9/27/2015	Snake River_345.2_LB	48	7/1/2016	Snake River_345.2_LB	48	5/18/2017	Snake River_345.2_LB	48
9/8/2002	Interpolated	0	9/28/2015	Snake River_345.2_LB	48	7/2/2016	Snake River_345.2_LB	48	5/19/2017	Snake River_345.2_LB	48
10/24/2002	Interpolated	0	9/29/2015	Snake River_345.2_LB	48	7/3/2016	Snake River_345.2_LB	48	5/20/2017	Snake River_345.2_LB	48
4/23/2003	Interpolated	0	9/30/2015	Snake River_345.2_LB	48	7/4/2016	Snake River_345.2_LB	48	5/21/2017	Snake River_345.2_LB	48
9/2/2003	Interpolated	0	10/1/2015	Snake River_345.2_LB	48	7/5/2016	Snake River_345.2_LB	48	5/22/2017	Snake River_345.2_LB	48
1/13/2004	Interpolated	0	10/2/2015	Snake River_345.2_LB	48	7/6/2016	Snake River_345.2_LB	48	5/23/2017	Snake River_345.2_LB	48
1/14/2004	Interpolated	0	10/3/2015	Snake River_345.2_LB	48	7/7/2016	Snake River_345.2_LB	48	5/24/2017	Snake River_345.2_LB	48
1/15/2004	Interpolated	0	10/4/2015	Snake River_345.2_LB	48	7/8/2016	Snake River_345.2_LB	48	5/25/2017	Snake River_345.2_LB	48
4/24/2004	Snake River_345.2_LB	72	10/5/2015	Snake River_345.2_LB	48	7/9/2016	Snake River_345.2_LB	48	5/26/2017	Snake River_345.2_LB	48
4/25/2004	Snake River_345.2_LB	72	10/6/2015	Snake River_345.2_LB	48	7/10/2016	Snake River_345.2_LB	48	5/27/2017	Snake River_345.2_LB	48
4/26/2004	Snake River_345.2_LB	72	10/7/2015	Snake River_345.2_LB	48	7/11/2016	Snake River_345.2_LB	48	5/28/2017	Snake River_345.2_LB	48
4/27/2004	Snake River_345.2_LB	72	10/8/2015	Snake River_345.2_LB	48	7/12/2016	Snake River_345.2_LB	48	5/29/2017	Snake River_345.2_LB	48
4/28/2004	Snake River_345.2_LB	72	10/9/2015	Snake River_345.2_LB	48	7/13/2016	Snake River_345.2_LB	48	5/30/2017	Snake River_345.2_LB	48
4/29/2004	Snake River_345.2_LB	72	10/10/2015	Snake River_345.2_LB	48	7/14/2016	Snake River_345.2_LB	48	5/31/2017	Snake River_345.2_LB	48
4/30/2004	Snake River_345.2_LB	72	10/11/2015	Snake River_345.2_LB	48	7/15/2016	Snake River_345.2_LB	48	6/1/2017	Snake River_345.2_LB	48
5/1/2004	Snake River_345.2_LB	72	10/12/2015	Snake River_345.2_LB	48	7/16/2016	Snake River_345.2_LB	48	6/2/2017	Snake River_345.2_LB	48
5/2/2004	Snake River_345.2_LB	72	10/13/2015	Snake River_345.2_LB	48	7/17/2016	Snake River_345.2_LB	48	6/3/2017	Snake River_345.2_LB	48
5/3/2004	Snake River_345.2_LB	72	10/14/2015	Snake River_345.2_LB	48	7/18/2016	Snake River_345.2_LB	48	6/4/2017	Snake River_345.2_LB	48
5/4/2004	Snake River_345.2_LB	72	10/15/2015	Snake River_345.2_LB	48	7/19/2016	Snake River_345.2_LB	48	6/5/2017	Snake River_345.2_LB	48
6/2/2004	Snake River_345.2_LB	72	10/16/2015	Snake River_345.2_LB	48	7/20/2016	Snake River_345.2_LB	48	6/6/2017	Snake River_345.2_LB	48
6/3/2004	Snake River_345.2_LB	72	10/17/2015	Snake River_345.2_LB	48	7/21/2016	Snake River_345.2_LB	48	6/7/2017	Snake River_345.2_LB	48
7/17/2004	Snake River_345.2_LB	72	10/18/2015	Snake River_345.2_LB	48	7/22/2016	Snake River_345.2_LB	48	6/8/2017	Snake River_345.2_LB	48
7/18/2004	Snake River_345.2_LB	72	10/19/2015	Snake River_345.2_LB	48	7/23/2016	Snake River_345.2_LB	48	6/9/2017	Snake River_345.2_LB	48
7/19/2004	Snake River_345.2_LB	72	10/20/2015	Snake River_345.2_LB	48	7/24/2016	Snake River_345.2_LB	48	6/10/2017	Snake River_345.2_LB	48
7/20/2004	Snake River_345.2_LB	72	10/21/2015	Snake River_345.2_LB	48	7/25/2016	Snake River_345.2_LB	48	6/11/2017	Snake River_345.2_LB	48
7/21/2004	Snake River_345.2_LB	72	10/22/2015	Snake River_345.2_LB	48	7/26/2016	Snake River_345.2_LB	48	6/12/2017	Snake River_345.2_LB	48
7/22/2004	Snake River_345.2_LB	72	10/23/2015	Snake River_345.2_LB	48	7/27/2016	Snake River_345.2_LB	48	6/13/2017	Snake River_345.2_LB	48
8/11/2004	Snake River_345.2_LB	72	10/24/2015	Snake River_345.2_LB	48	7/28/2016	Snake River_345.2_LB	48	6/14/2017	Snake River_345.2_LB	48
8/12/2004	Snake River_345.2_LB	72	10/25/2015	Snake River_345.2_LB	48	7/29/2016	Snake River_345.2_LB	48	6/15/2017	Snake River_345.2_LB	48
8/13/2004	Snake River_345.2_LB	72	10/26/2015	Snake River_345.2_LB	48	7/30/2016	Snake River_345.2_LB	48	6/16/2017	Snake River_345.2_LB	48
8/14/2004	Snake River_345.2_LB	72	10/27/2015	Snake River_345.2_LB	48	7/31/2016	Snake River_345.2_LB	48	6/17/2017	Snake River_345.2_LB	48
8/15/2004	Snake River_345.2_LB	72	10/28/2015	Snake River_345.2_LB	48	8/1/2016	Snake River_345.2_LB	48	6/18/2017	Snake River_345.2_LB	48
8/16/2004	Snake River_345.2_LB	72	10/29/2015	Snake River_345.2_LB	48	8/2/2016	Snake River_345.2_LB	48	6/19/2017	Snake River_345.2_LB	48
8/17/2004	Snake River_345.2_LB	72	10/30/2015	Snake River_345.2_LB	48	8/3/2016	Snake River_345.2_LB	48	6/20/2017	Snake River_345.2_LB	48
8/18/2004	Snake River_345.2_LB	72	10/31/2015	Snake River_345.2_LB	48	8/4/2016	Snake River_345.2_LB	48	6/21/2017	Snake River_345.2_LB	48
9/10/2004	Snake River_345.2_LB	72	11/1/2015	Snake River_345.2_LB	48	8/5/2016	Snake River_345.2_LB	48	6/22/2017	Snake River_345.2_LB	48
9/11/2004	Snake River_345.2_LB	72	11/2/2015	Snake River_345.2_LB	48	8/6/2016	Snake River_345.2_LB	48	6/23/2017	Snake River_345.2_LB	48
9/12/2004	Snake River_345.2_LB	72	11/3/2015	Snake River_345.2_LB	48	8/7/2016	Snake River_345.2_LB	48	6/24/2017	Snake River_345.2_LB	48
9/13/2004	Snake River_345.2_LB	72	11/4/2015	Snake River_345.2_LB	48	8/8/2016	Snake River_345.2_LB	48	6/25/2017	Snake River_345.2_LB	48
9/14/2004	Snake River_345.2_LB	72	11/5/2015	Snake River_345.2_LB	48	8/9/2016	Snake River_345.2_LB	48	6/26/2017	Snake River_345.2_LB	48
9/15/2004	Snake River_345.2_LB	72	11/6/2015	Snake River_345.2_LB	48	8/10/2016	Snake River_345.2_LB	48	6/27/2017	Snake River_345.2_LB	48

Replaced Data 1996-2016			Replaced Data 2015-2016			Replaced Data 2016-2017			Replaced Data 2017		
Date	Location	N	Date	Location	N	Date	Location	N	Date	Location	N
11/1/2004	Snake River_345.2_LB	72	11/7/2015	Snake River_345.2_LB	48	8/11/2016	Snake River_345.2_LB	48	6/28/2017	Snake River_345.2_LB	48
11/2/2004	Snake River_345.2_LB	72	11/8/2015	Snake River_345.2_LB	48	8/12/2016	Snake River_345.2_LB	48	6/29/2017	Snake River_345.2_LB	48
11/3/2004	Snake River_345.2_LB	72	11/9/2015	Snake River_345.2_LB	48	8/13/2016	Snake River_345.2_LB	48	6/30/2017	Snake River_345.2_LB	48
11/4/2004	Snake River_345.2_LB	72	11/10/2015	Snake River_345.2_LB	48	8/14/2016	Snake River_345.2_LB	48	7/1/2017	Snake River_345.2_LB	48
11/5/2004	Snake River_345.2_LB	72	11/11/2015	Snake River_345.2_LB	48	8/15/2016	Snake River_345.2_LB	48	7/2/2017	Snake River_345.2_LB	48
11/6/2004	Snake River_345.2_LB	72	11/12/2015	Snake River_345.2_LB	48	8/16/2016	Snake River_345.2_LB	48	7/3/2017	Snake River_345.2_LB	48
11/7/2004	Snake River_345.2_LB	72	11/13/2015	Snake River_345.2_LB	48	8/17/2016	Snake River_345.2_LB	48	7/4/2017	Snake River_345.2_LB	48
11/8/2004	Snake River_345.2_LB	72	11/14/2015	Snake River_345.2_LB	48	8/18/2016	Snake River_345.2_LB	48	7/5/2017	Snake River_345.2_LB	48
11/9/2004	Snake River_345.2_LB	72	11/15/2015	Snake River_345.2_LB	48	8/19/2016	Snake River_345.2_LB	48	7/6/2017	Snake River_345.2_LB	48
11/10/2004	Snake River_345.2_LB	72	11/16/2015	Snake River_345.2_LB	48	8/20/2016	Snake River_345.2_LB	48	7/7/2017	Snake River_345.2_LB	48
11/11/2004	Snake River_345.2_LB	72	11/17/2015	Snake River_345.2_LB	48	8/21/2016	Snake River_345.2_LB	48	7/8/2017	Snake River_345.2_LB	48
11/12/2004	Snake River_345.2_LB	72	11/18/2015	Snake River_345.2_LB	48	8/22/2016	Snake River_345.2_LB	48	7/9/2017	Snake River_345.2_LB	48
11/13/2004	Snake River_345.2_LB	72	11/19/2015	Snake River_345.2_LB	48	8/23/2016	Snake River_345.2_LB	48	7/10/2017	Snake River_345.2_LB	48
11/14/2004	Snake River_345.2_LB	72	11/20/2015	Snake River_345.2_LB	48	8/24/2016	Snake River_345.2_LB	48	7/11/2017	Snake River_345.2_LB	48
11/15/2004	Snake River_345.2_LB	72	11/21/2015	Snake River_345.2_LB	48	8/25/2016	Snake River_345.2_LB	48	7/12/2017	Snake River_345.2_LB	48
11/16/2004	Snake River_345.2_LB	72	11/22/2015	Snake River_345.2_LB	48	8/26/2016	Snake River_345.2_LB	48	7/13/2017	Snake River_345.2_LB	48
11/17/2004	Snake River_345.2_LB	72	11/23/2015	Snake River_345.2_LB	48	8/27/2016	Snake River_345.2_LB	48	7/14/2017	Snake River_345.2_LB	48
11/18/2004	Snake River_345.2_LB	72	11/24/2015	Snake River_345.2_LB	48	8/28/2016	Snake River_345.2_LB	48	7/15/2017	Snake River_345.2_LB	48
11/19/2004	Snake River_345.2_LB	72	11/25/2015	Snake River_345.2_LB	48	8/29/2016	Snake River_345.2_LB	48	7/16/2017	Snake River_345.2_LB	48
11/20/2004	Snake River_345.2_LB	72	11/26/2015	Snake River_345.2_LB	48	8/30/2016	Snake River_345.2_LB	48	7/17/2017	Snake River_345.2_LB	48
11/21/2004	Snake River_345.2_LB	72	11/27/2015	Snake River_345.2_LB	48	8/31/2016	Snake River_345.2_LB	48	7/18/2017	Snake River_345.2_LB	48
11/22/2004	Snake River_345.2_LB	72	11/28/2015	Snake River_345.2_LB	48	9/1/2016	Snake River_345.2_LB	48	7/19/2017	Snake River_345.2_LB	48
11/23/2004	Snake River_345.2_LB	72	11/29/2015	Snake River_345.2_LB	48	9/2/2016	Snake River_345.2_LB	48	7/20/2017	Snake River_345.2_LB	48
11/24/2004	Snake River_345.2_LB	72	11/30/2015	Snake River_345.2_LB	48	9/3/2016	Snake River_345.2_LB	48	7/21/2017	Snake River_345.2_LB	48
11/25/2004	Snake River_345.2_LB	72	12/1/2015	Snake River_345.2_LB	48	9/4/2016	Snake River_345.2_LB	48	7/22/2017	Snake River_345.2_LB	48
11/26/2004	Snake River_345.2_LB	72	12/2/2015	Snake River_345.2_LB	48	9/5/2016	Snake River_345.2_LB	48	7/23/2017	Snake River_345.2_LB	48
11/27/2004	Snake River_345.2_LB	72	12/3/2015	Snake River_345.2_LB	48	9/6/2016	Snake River_345.2_LB	48	7/24/2017	Snake River_345.2_LB	48
11/28/2004	Snake River_345.2_LB	72	12/4/2015	Snake River_345.2_LB	48	9/7/2016	Snake River_345.2_LB	48	7/25/2017	Snake River_345.2_LB	48
11/29/2004	Snake River_345.2_LB	72	12/5/2015	Snake River_345.2_LB	48	9/8/2016	Snake River_345.2_LB	48	7/26/2017	Snake River_345.2_LB	48
1/22/2005	Snake River_345.2_LB	72	12/6/2015	Snake River_345.2_LB	48	9/9/2016	Snake River_345.2_LB	48	7/27/2017	Snake River_345.2_LB	48
1/23/2005	Snake River_345.2_LB	72	12/7/2015	Snake River_345.2_LB	48	9/10/2016	Snake River_345.2_LB	48	7/28/2017	Snake River_345.2_LB	48
1/24/2005	Snake River_345.2_LB	72	12/8/2015	Snake River_345.2_LB	48	9/11/2016	Snake River_345.2_LB	48	7/29/2017	Snake River_345.2_LB	48
7/30/2005	Interpolated	0	12/9/2015	Snake River_345.2_LB	48	9/12/2016	Snake River_345.2_LB	48	7/30/2017	Snake River_345.2_LB	48
7/31/2005	Interpolated	0	12/10/2015	Snake River_345.2_LB	48	9/13/2016	Snake River_345.2_LB	48	7/31/2017	Snake River_345.2_LB	48
8/1/2005	Interpolated	0	12/11/2015	Snake River_345.2_LB	48	9/14/2016	Snake River_345.2_LB	48	8/1/2017	Snake River_345.2_LB	48
8/2/2005	Interpolated	0	12/12/2015	Snake River_345.2_LB	48	9/15/2016	Snake River_345.2_LB	48	8/2/2017	Snake River_345.2_LB	48
8/3/2005	Interpolated	0	12/13/2015	Snake River_345.2_LB	48	9/16/2016	Snake River_345.2_LB	48	8/3/2017	Snake River_345.2_LB	48
8/4/2005	Interpolated	0	12/14/2015	Snake River_345.2_LB	48	9/17/2016	Snake River_345.2_LB	48	8/4/2017	Snake River_345.2_LB	48
8/5/2005	Interpolated	0	12/15/2015	Snake River_345.2_LB	48	9/18/2016	Snake River_345.2_LB	48	8/5/2017	Snake River_345.2_LB	48
8/6/2005	Interpolated	0	12/16/2015	Snake River_345.2_LB	48	9/19/2016	Snake River_345.2_LB	48	8/6/2017	Snake River_345.2_LB	48
8/7/2005	Interpolated	0	12/17/2015	Snake River_345.2_LB	48	9/20/2016	Snake River_345.2_LB	48	8/7/2017	Snake River_345.2_LB	48

Replaced Data 1996-2016			Replaced Data 2015-2016			Replaced Data 2016-2017			Replaced Data 2017		
Date	Location	N	Date	Location	N	Date	Location	N	Date	Location	N
8/8/2005	Interpolated	0	12/18/2015	Snake River_345.2_LB	48	9/21/2016	Snake River_345.2_LB	48	8/8/2017	Snake River_345.2_LB	48
8/9/2005	Interpolated	0	12/19/2015	Snake River_345.2_LB	48	9/22/2016	Snake River_345.2_LB	48	8/9/2017	Snake River_345.2_LB	48
11/18/2005	Snake River_345.2_LB	48	12/20/2015	Snake River_345.2_LB	48	9/23/2016	Snake River_345.2_LB	48	8/10/2017	Snake River_345.2_LB	48
11/19/2005	Snake River_345.2_LB	48	12/21/2015	Snake River_345.2_LB	48	9/24/2016	Snake River_345.2_LB	48	8/11/2017	Snake River_345.2_LB	47
11/20/2005	Snake River_345.2_LB	48	12/22/2015	Snake River_345.2_LB	48	9/25/2016	Snake River_345.2_LB	48	8/12/2017	Snake River_345.2_LB	48
11/21/2005	Snake River_345.2_LB	48	12/23/2015	Snake River_345.2_LB	48	9/26/2016	Snake River_345.2_LB	48	8/13/2017	Snake River_345.2_LB	48
11/22/2005	Snake River_345.2_LB	48	12/24/2015	Snake River_345.2_LB	48	9/27/2016	Snake River_345.2_LB	48	8/14/2017	Snake River_345.2_LB	48
11/24/2005	Snake River_345.2_LB	48	12/25/2015	Snake River_345.2_LB	48	9/28/2016	Snake River_345.2_LB	48	8/15/2017	Snake River_345.2_LB	48
11/25/2005	Snake River_345.2_LB	48	12/26/2015	Snake River_345.2_LB	48	9/29/2016	Snake River_345.2_LB	48	8/16/2017	Snake River_345.2_LB	48
11/26/2005	Snake River_345.2_LB	48	12/27/2015	Snake River_345.2_LB	48	9/30/2016	Snake River_345.2_LB	48	8/17/2017	Snake River_345.2_LB	48
11/27/2005	Snake River_345.2_LB	48	12/28/2015	Snake River_345.2_LB	48	10/1/2016	Snake River_345.2_LB	48	8/18/2017	Snake River_345.2_LB	48
11/28/2005	Snake River_345.2_LB	48	12/29/2015	Snake River_345.2_LB	48	10/2/2016	Snake River_345.2_LB	48	8/19/2017	Snake River_345.2_LB	48
11/29/2005	Snake River_345.2_LB	48	12/30/2015	Snake River_345.2_LB	48	10/3/2016	Snake River_345.2_LB	48	8/20/2017	Snake River_345.2_LB	48
11/30/2005	Snake River_345.2_LB	48	12/31/2015	Snake River_345.2_LB	48	10/4/2016	Snake River_345.2_LB	48	8/21/2017	Snake River_345.2_LB	48
12/1/2005	Snake River_345.2_LB	48	1/1/2016	Snake River_345.2_LB	48	10/5/2016	Snake River_345.2_LB	48	8/22/2017	Snake River_345.2_LB	48
12/2/2005	Snake River_345.2_LB	48	1/2/2016	Snake River_345.2_LB	48	10/6/2016	Snake River_345.2_LB	48	8/23/2017	Snake River_345.2_LB	48
12/3/2005	Snake River_345.2_LB	48	1/3/2016	Snake River_345.2_LB	48	10/7/2016	Snake River_345.2_LB	48	8/24/2017	Snake River_345.2_LB	48
12/4/2005	Snake River_345.2_LB	48	1/4/2016	Snake River_345.2_LB	48	10/8/2016	Snake River_345.2_LB	48	8/25/2017	Snake River_345.2_LB	48
12/5/2005	Snake River_345.2_LB	48	1/5/2016	Snake River_345.2_LB	48	10/9/2016	Snake River_345.2_LB	48	8/26/2017	Snake River_345.2_LB	48
12/6/2005	Snake River_345.2_LB	48	1/6/2016	Snake River_345.2_LB	48	10/10/2016	Snake River_345.2_LB	48	8/27/2017	Snake River_345.2_LB	48
12/7/2005	Snake River_345.2_LB	48	1/7/2016	Snake River_345.2_LB	48	10/11/2016	Snake River_345.2_LB	48	8/28/2017	Snake River_345.2_LB	48
5/5/2006	Snake River_345.2_LB	48	1/8/2016	Snake River_345.2_LB	48	10/12/2016	Snake River_345.2_LB	48	8/29/2017	Snake River_345.2_LB	48
5/6/2006	Snake River_345.2_LB	48	1/9/2016	Snake River_345.2_LB	48	10/13/2016	Snake River_345.2_LB	48	8/30/2017	Snake River_345.2_LB	48
5/7/2006	Snake River_345.2_LB	48	1/10/2016	Snake River_345.2_LB	48	10/14/2016	Snake River_345.2_LB	48	8/31/2017	Snake River_345.2_LB	48
5/8/2006	Snake River_345.2_LB	48	1/11/2016	Snake River_345.2_LB	48	10/15/2016	Snake River_345.2_LB	48	9/1/2017	Snake River_345.2_LB	48
5/9/2006	Snake River_345.2_LB	48	1/12/2016	Snake River_345.2_LB	48	10/16/2016	Snake River_345.2_LB	48	9/2/2017	Snake River_345.2_LB	48
5/10/2006	Snake River_345.2_LB	48	1/13/2016	Snake River_345.2_LB	48	10/17/2016	Snake River_345.2_LB	48	9/3/2017	Snake River_345.2_LB	48
5/11/2006	Snake River_345.2_LB	48	1/14/2016	Snake River_345.2_LB	48	10/18/2016	Snake River_345.2_LB	48	9/4/2017	Snake River_345.2_LB	48
5/12/2006	Snake River_345.2_LB	48	1/15/2016	Snake River_345.2_LB	48	10/19/2016	Snake River_345.2_LB	48	9/5/2017	Snake River_345.2_LB	48
5/13/2006	Snake River_345.2_LB	48	1/16/2016	Snake River_345.2_LB	48	10/20/2016	Snake River_345.2_LB	48	9/6/2017	Snake River_345.2_LB	48
5/14/2006	Snake River_345.2_LB	48	1/17/2016	Snake River_345.2_LB	48	10/21/2016	Snake River_345.2_LB	48	9/7/2017	Snake River_345.2_LB	48
5/15/2006	Snake River_345.2_LB	48	1/18/2016	Snake River_345.2_LB	48	10/22/2016	Snake River_345.2_LB	48	9/8/2017	Snake River_345.2_LB	48
5/16/2006	Snake River_345.2_LB	48	1/19/2016	Snake River_345.2_LB	48	10/23/2016	Snake River_345.2_LB	48	9/9/2017	Snake River_345.2_LB	48
5/17/2006	Snake River_345.2_LB	48	1/20/2016	Snake River_345.2_LB	48	10/24/2016	Snake River_345.2_LB	48	9/10/2017	Snake River_345.2_LB	48
9/23/2006	Snake River_345.2_LB	48	1/21/2016	Snake River_345.2_LB	48	10/25/2016	Snake River_345.2_LB	48	9/11/2017	Snake River_345.2_LB	48
9/24/2006	Snake River_345.2_LB	48	1/22/2016	Snake River_345.2_LB	48	10/26/2016	Snake River_345.2_LB	48	9/12/2017	Snake River_345.2_LB	48
9/25/2006	Snake River_345.2_LB	48	1/23/2016	Snake River_345.2_LB	48	10/27/2016	Snake River_345.2_LB	48	9/13/2017	Snake River_345.2_LB	48
4/4/2007	Snake River_345.2_LB	48	1/24/2016	Snake River_345.2_LB	48	10/28/2016	Snake River_345.2_LB	48	9/14/2017	Snake River_345.2_LB	48
4/5/2007	Snake River_345.2_LB	48	1/25/2016	Snake River_345.2_LB	48	10/29/2016	Snake River_345.2_LB	48	9/15/2017	Snake River_345.2_LB	48
4/6/2007	Snake River_345.2_LB	48	1/26/2016	Snake River_345.2_LB	48	10/30/2016	Snake River_345.2_LB	48	9/16/2017	Snake River_345.2_LB	48
4/7/2007	Snake River_345.2_LB	48	1/27/2016	Snake River_345.2_LB	48	10/31/2016	Snake River_345.2_LB	48	9/17/2017	Snake River_345.2_LB	48

Replaced Data 1996-2016			Replaced Data 2015-2016			Replaced Data 2016-2017			Replaced Data 2017		
Date	Location	N	Date	Location	N	Date	Location	N	Date	Location	N
4/8/2007	Snake River_345.2_LB	48	1/28/2016	Snake River_345.2_LB	48	11/1/2016	Snake River_345.2_LB	48	9/18/2017	Snake River_345.2_LB	48
4/9/2007	Snake River_345.2_LB	48	1/29/2016	Snake River_345.2_LB	48	11/2/2016	Snake River_345.2_LB	48	9/19/2017	Snake River_345.2_LB	48
4/10/2007	Snake River_345.2_LB	48	1/30/2016	Snake River_345.2_LB	48	11/3/2016	Snake River_345.2_LB	48	9/20/2017	Snake River_345.2_LB	48
4/11/2007	Snake River_345.2_LB	48	1/31/2016	Snake River_345.2_LB	48	11/4/2016	Snake River_345.2_LB	48	9/21/2017	Snake River_345.2_LB	48
4/12/2007	Snake River_345.2_LB	48	2/1/2016	Snake River_345.2_LB	48	11/5/2016	Snake River_345.2_LB	48	9/22/2017	Snake River_345.2_LB	48
4/13/2007	Snake River_345.2_LB	48	2/2/2016	Snake River_345.2_LB	48	11/6/2016	Snake River_345.2_LB	48	9/23/2017	Snake River_345.2_LB	48
4/14/2007	Snake River_345.2_LB	48	2/3/2016	Snake River_345.2_LB	48	11/7/2016	Snake River_345.2_LB	48	9/24/2017	Snake River_345.2_LB	48
4/15/2007	Snake River_345.2_LB	48	2/4/2016	Snake River_345.2_LB	48	11/8/2016	Snake River_345.2_LB	48	9/25/2017	Snake River_345.2_LB	48
4/16/2007	Snake River_345.2_LB	48	2/5/2016	Snake River_345.2_LB	48	11/9/2016	Snake River_345.2_LB	48	9/26/2017	Snake River_345.2_LB	48
8/17/2007	Snake River_345.2_LB	48	2/6/2016	Snake River_345.2_LB	48	11/10/2016	Snake River_345.2_LB	48	9/27/2017	Snake River_345.2_LB	48
8/18/2007	Snake River_345.2_LB	48	2/7/2016	Snake River_345.2_LB	48	11/11/2016	Snake River_345.2_LB	48	9/28/2017	Snake River_345.2_LB	48
8/19/2007	Snake River_345.2_LB	48	2/8/2016	Snake River_345.2_LB	48	11/12/2016	Snake River_345.2_LB	48	9/29/2017	Snake River_345.2_LB	48
8/20/2007	Snake River_345.2_LB	48	2/9/2016	Snake River_345.2_LB	48	11/13/2016	Snake River_345.2_LB	48	9/30/2017	Snake River_345.2_LB	48
8/21/2007	Snake River_345.2_LB	48	2/10/2016	Snake River_345.2_LB	48	11/14/2016	Snake River_345.2_LB	48	10/1/2017	Snake River_345.2_LB	48
8/22/2007	Snake River_345.2_LB	48	2/11/2016	Snake River_345.2_LB	48	11/15/2016	Snake River_345.2_LB	48	10/2/2017	Snake River_345.2_LB	48
8/23/2007	Snake River_345.2_LB	48	2/12/2016	Snake River_345.2_LB	48	11/16/2016	Snake River_345.2_LB	48	10/3/2017	Snake River_345.2_LB	48
8/24/2007	Snake River_345.2_LB	48	2/13/2016	Snake River_345.2_LB	48	11/17/2016	Snake River_345.2_LB	48	10/4/2017	Snake River_345.2_LB	48
8/25/2007	Snake River_345.2_LB	48	2/14/2016	Snake River_345.2_LB	48	11/18/2016	Snake River_345.2_LB	48	10/5/2017	Snake River_345.2_LB	48
8/26/2007	Snake River_345.2_LB	48	2/15/2016	Snake River_345.2_LB	48	11/19/2016	Snake River_345.2_LB	48	10/6/2017	Snake River_345.2_LB	48
8/27/2007	Snake River_345.2_LB	48	2/16/2016	Snake River_345.2_LB	48	11/20/2016	Snake River_345.2_LB	48	10/7/2017	Snake River_345.2_LB	48
6/29/2008	Snake River_345.2_LB	48	2/17/2016	Snake River_345.2_LB	48	11/21/2016	Snake River_345.2_LB	48	10/8/2017	Snake River_345.2_LB	48
6/30/2008	Snake River_345.2_LB	48	2/18/2016	Snake River_345.2_LB	48	11/22/2016	Snake River_345.2_LB	48	10/9/2017	Snake River_345.2_LB	48
7/1/2008	Snake River_345.2_LB	48	2/19/2016	Snake River_345.2_LB	48	11/23/2016	Snake River_345.2_LB	48	10/10/2017	Snake River_345.2_LB	48
7/2/2008	Snake River_345.2_LB	48	2/20/2016	Snake River_345.2_LB	48	11/24/2016	Snake River_345.2_LB	48	10/11/2017	Snake River_345.2_LB	48
1/28/2009	Snake River_345.2_LB	48	2/21/2016	Snake River_345.2_LB	48	11/25/2016	Snake River_345.2_LB	48	10/12/2017	Snake River_345.2_LB	48
1/31/2009	Snake River_345.2_LB	48	2/22/2016	Snake River_345.2_LB	48	11/26/2016	Snake River_345.2_LB	48	10/13/2017	Snake River_345.2_LB	48
2/1/2009	Snake River_345.2_LB	48	2/23/2016	Snake River_345.2_LB	48	11/27/2016	Snake River_345.2_LB	48	10/14/2017	Snake River_345.2_LB	48
2/5/2009	Snake River_345.2_LB	48	2/24/2016	Snake River_345.2_LB	48	11/28/2016	Snake River_345.2_LB	48	10/15/2017	Snake River_345.2_LB	48
9/24/2009	Snake River_345.2_LB	48	2/25/2016	Snake River_345.2_LB	48	11/29/2016	Snake River_345.2_LB	48	10/16/2017	Snake River_345.2_LB	48
9/25/2009	Snake River_345.2_LB	48	2/26/2016	Snake River_345.2_LB	48	11/30/2016	Snake River_345.2_LB	48	10/17/2017	Snake River_345.2_LB	48
9/26/2009	Snake River_345.2_LB	48	2/27/2016	Snake River_345.2_LB	48	12/1/2016	Snake River_345.2_LB	48	10/18/2017	Snake River_345.2_LB	48
9/27/2009	Snake River_345.2_LB	48	2/28/2016	Snake River_345.2_LB	48	12/2/2016	Snake River_345.2_LB	48	10/19/2017	Snake River_345.2_LB	48
9/28/2009	Snake River_345.2_LB	48	2/29/2016	Snake River_345.2_LB	48	12/3/2016	Snake River_345.2_LB	48	10/20/2017	Snake River_345.2_LB	48
9/29/2009	Snake River_345.2_LB	48	3/1/2016	Snake River_345.2_LB	48	12/4/2016	Snake River_345.2_LB	48	10/21/2017	Snake River_345.2_LB	48
9/30/2009	Snake River_345.2_LB	48	3/2/2016	Snake River_345.2_LB	48	12/5/2016	Snake River_345.2_LB	48	10/22/2017	Snake River_345.2_LB	48
10/1/2009	Snake River_345.2_LB	48	3/3/2016	Snake River_345.2_LB	48	12/6/2016	Snake River_345.2_LB	48	10/23/2017	Snake River_345.2_LB	48
10/2/2009	Snake River_345.2_LB	48	3/4/2016	Snake River_345.2_LB	48	12/7/2016	Snake River_345.2_LB	48	10/24/2017	Snake River_345.2_LB	48
10/3/2009	Snake River_345.2_LB	48	3/5/2016	Snake River_345.2_LB	48	12/8/2016	Snake River_345.2_LB	48	10/25/2017	Snake River_345.2_LB	48
10/4/2009	Snake River_345.2_LB	48	3/6/2016	Snake River_345.2_LB	48	12/9/2016	Snake River_345.2_LB	48	10/26/2017	Snake River_345.2_LB	48
10/5/2009	Snake River_345.2_LB	48	3/7/2016	Snake River_345.2_LB	48	12/10/2016	Snake River_345.2_LB	48	10/27/2017	Snake River_345.2_LB	48
10/6/2009	Snake River_345.2_LB	48	3/8/2016	Snake River_345.2_LB	48	12/11/2016	Snake River_345.2_LB	48	10/28/2017	Snake River_345.2_LB	48

Replaced Data 1996-2016			Replaced Data 2015-2016			Replaced Data 2016-2017			Replaced Data 2017		
Date	Location	N	Date	Location	N	Date	Location	N	Date	Location	N
10/7/2009	Snake River_345.2_LB	48	3/9/2016	Snake River_345.2_LB	48	12/12/2016	Snake River_345.2_LB	48	10/29/2017	Snake River_345.2_LB	48
10/8/2009	Snake River_345.2_LB	48	3/10/2016	Snake River_345.2_LB	48	12/13/2016	Snake River_345.2_LB	48	10/30/2017	Snake River_345.2_LB	48
10/9/2009	Snake River_345.2_LB	48	3/11/2016	Snake River_345.2_LB	48	12/14/2016	Snake River_345.2_LB	48	10/31/2017	Snake River_345.2_LB	48
10/10/2009	Snake River_345.2_LB	48	3/12/2016	Snake River_345.2_LB	48	12/15/2016	Snake River_345.2_LB	48	11/1/2017	Snake River_345.2_LB	48
10/11/2009	Snake River_345.2_LB	48	3/13/2016	Snake River_345.2_LB	48	12/16/2016	Snake River_345.2_LB	48	11/2/2017	Snake River_345.2_LB	48
10/12/2009	Snake River_345.2_LB	48	3/14/2016	Snake River_345.2_LB	48	12/17/2016	Snake River_345.2_LB	48	11/3/2017	Snake River_345.2_LB	48
10/13/2009	Snake River_345.2_LB	48	3/15/2016	Snake River_345.2_LB	48	12/18/2016	Snake River_345.2_LB	48	11/4/2017	Snake River_345.2_LB	48
10/14/2009	Snake River_345.2_LB	48	3/16/2016	Snake River_345.2_LB	48	12/19/2016	Snake River_345.2_LB	48	11/5/2017	Snake River_345.2_LB	48
11/30/2009	Snake River_345.2_LB	48	3/17/2016	Snake River_345.2_LB	48	12/20/2016	Snake River_345.2_LB	48	11/6/2017	Snake River_345.2_LB	48
12/1/2009	Snake River_345.2_LB	48	3/18/2016	Snake River_345.2_LB	48	12/21/2016	Snake River_345.2_LB	48	11/7/2017	Snake River_345.2_LB	48
2/19/2010	Snake River_345.2_LB	48	3/19/2016	Snake River_345.2_LB	48	12/22/2016	Snake River_345.2_LB	48	11/8/2017	Snake River_345.2_LB	48
2/20/2010	Snake River_345.2_LB	48	3/20/2016	Snake River_345.2_LB	48	12/23/2016	Snake River_345.2_LB	48	11/9/2017	Snake River_345.2_LB	48
2/21/2010	Snake River_345.2_LB	48	3/21/2016	Snake River_345.2_LB	48	12/24/2016	Snake River_345.2_LB	48	11/10/2017	Snake River_345.2_LB	48
2/22/2010	Snake River_345.2_LB	48	3/22/2016	Snake River_345.2_LB	48	12/25/2016	Snake River_345.2_LB	48	11/11/2017	Snake River_345.2_LB	48
2/23/2010	Snake River_345.2_LB	48	3/23/2016	Snake River_345.2_LB	48	12/26/2016	Snake River_345.2_LB	48	11/12/2017	Snake River_345.2_LB	48
2/24/2010	Snake River_345.2_LB	48	3/24/2016	Snake River_345.2_LB	48	12/27/2016	Snake River_345.2_LB	48	11/13/2017	Snake River_345.2_LB	48
2/25/2010	Snake River_345.2_LB	48	3/25/2016	Snake River_345.2_LB	48	12/28/2016	Snake River_345.2_LB	48	11/14/2017	Snake River_345.2_LB	48
2/26/2010	Snake River_345.2_LB	48	3/26/2016	Snake River_345.2_LB	48	12/29/2016	Snake River_345.2_LB	48	11/15/2017	Snake River_345.2_LB	48
2/27/2010	Snake River_345.2_LB	48	3/27/2016	Snake River_345.2_LB	48	12/30/2016	Snake River_345.2_LB	48	11/16/2017	Snake River_345.2_LB	48
2/28/2010	Snake River_345.2_LB	48	3/28/2016	Snake River_345.2_LB	48	12/31/2016	Snake River_345.2_LB	48	11/17/2017	Snake River_345.2_LB	48
3/1/2010	Snake River_345.2_LB	48	3/29/2016	Snake River_345.2_LB	48	1/1/2017	Snake River_345.2_LB	48	11/18/2017	Snake River_345.2_LB	48
3/2/2010	Snake River_345.2_LB	48	3/30/2016	Snake River_345.2_LB	48	1/2/2017	Snake River_345.2_LB	48	11/19/2017	Snake River_345.2_LB	48
8/19/2010	Snake River_345.2_LB	48	3/31/2016	Snake River_345.2_LB	48	1/3/2017	Snake River_345.2_LB	48	11/20/2017	Snake River_345.2_LB	48
8/20/2010	Snake River_345.2_LB	48	4/1/2016	Snake River_345.2_LB	48	1/4/2017	Snake River_345.2_LB	48	11/21/2017	Snake River_345.2_LB	48
8/21/2010	Snake River_345.2_LB	48	4/2/2016	Snake River_345.2_LB	48	1/5/2017	Snake River_345.2_LB	48	11/22/2017	Snake River_345.2_LB	48
8/22/2010	Snake River_345.2_LB	48	4/3/2016	Snake River_345.2_LB	48	1/6/2017	Snake River_345.2_LB	48	11/23/2017	Snake River_345.2_LB	48
8/23/2010	Snake River_345.2_LB	48	4/4/2016	Snake River_345.2_LB	48	1/7/2017	Snake River_345.2_LB	48	11/24/2017	Snake River_345.2_LB	48
8/24/2010	Snake River_345.2_LB	48	4/5/2016	Snake River_345.2_LB	48	1/8/2017	Snake River_345.2_LB	48	11/25/2017	Snake River_345.2_LB	48
8/25/2010	Snake River_345.2_LB	48	4/6/2016	Snake River_345.2_LB	48	1/9/2017	Snake River_345.2_LB	48	11/26/2017	Snake River_345.2_LB	48
8/26/2010	Snake River_345.2_LB	48	4/7/2016	Snake River_345.2_LB	48	1/10/2017	Snake River_345.2_LB	48	11/27/2017	Snake River_345.2_LB	48
8/27/2010	Snake River_345.2_LB	48	4/8/2016	Snake River_345.2_LB	48	1/11/2017	Snake River_345.2_LB	48	11/28/2017	Snake River_345.2_LB	48
8/28/2010	Snake River_345.2_LB	48	4/9/2016	Snake River_345.2_LB	48	1/12/2017	Snake River_345.2_LB	48	11/29/2017	Snake River_345.2_LB	48
8/29/2010	Snake River_345.2_LB	48	4/10/2016	Snake River_345.2_LB	48	1/13/2017	Snake River_345.2_LB	48	11/30/2017	Snake River_345.2_LB	48
8/30/2010	Snake River_345.2_LB	48	4/11/2016	Snake River_345.2_LB	48	1/14/2017	Snake River_345.2_LB	48	12/1/2017	Snake River_345.2_LB	48
8/31/2010	Snake River_345.2_LB	48	4/12/2016	Snake River_345.2_LB	48	1/15/2017	Snake River_345.2_LB	48	12/2/2017	Snake River_345.2_LB	48
9/1/2010	Snake River_345.2_LB	48	4/13/2016	Snake River_345.2_LB	48	1/16/2017	Snake River_345.2_LB	48	12/3/2017	Snake River_345.2_LB	48
10/2/2010	Snake River_345.2_LB	48				1/17/2017	Snake River_345.2_LB	48	12/4/2017	Snake River_345.2_LB	48
10/3/2010	Snake River_345.2_LB	48				1/18/2017	Snake River_345.2_LB	48	12/5/2017	Snake River_345.2_LB	48
10/4/2010	Snake River_345.2_LB	48				1/19/2017	Snake River_345.2_LB	48	12/6/2017	Snake River_345.2_LB	48
10/5/2010	Snake River_345.2_LB	48				1/20/2017	Snake River_345.2_LB	48	12/7/2017	Snake River_345.2_LB	48
10/6/2010	Snake River_345.2_LB	48				1/21/2017	Snake River_345.2_LB	48	12/8/2017	Snake River_345.2_LB	48

Replaced Data 1996-2016

Date	Location	N
10/7/2010	Snake River_345.2_LB	48
10/8/2010	Snake River_345.2_LB	48
10/9/2010	Snake River_345.2_LB	48
10/10/2010	Snake River_345.2_LB	48
10/11/2010	Snake River_345.2_LB	48
10/12/2010	Snake River_345.2_LB	48
10/13/2010	Snake River_345.2_LB	48
10/14/2010	Snake River_345.2_LB	48
10/15/2010	Snake River_345.2_LB	48
10/16/2010	Snake River_345.2_LB	48
10/17/2010	Snake River_345.2_LB	48
11/22/2010	Snake River_345.2_LB	48
11/23/2010	Snake River_345.2_LB	48
11/24/2010	Snake River_345.2_LB	48
11/25/2010	Snake River_345.2_LB	48
11/26/2010	Snake River_345.2_LB	48
11/27/2010	Snake River_345.2_LB	48
11/28/2010	Snake River_345.2_LB	48
11/29/2010	Snake River_345.2_LB	48
11/30/2010	Snake River_345.2_LB	48
9/12/2014	Snake River_345.2_LB	48
9/13/2014	Snake River_345.2_LB	48
9/14/2014	Snake River_345.2_LB	48
9/15/2014	Snake River_345.2_LB	48
9/16/2014	Snake River_345.2_LB	48
9/17/2014	Snake River_345.2_LB	48
9/18/2014	Snake River_345.2_LB	48
9/19/2014	Snake River_345.2_LB	48
9/20/2014	Snake River_345.2_LB	48
9/21/2014	Snake River_345.2_LB	48
9/22/2014	Snake River_345.2_LB	48
9/23/2014	Snake River_345.2_LB	48
12/16/2014	Snake River_345.2_LB	48
12/17/2014	Snake River_345.2_LB	48
12/18/2014	Snake River_345.2_LB	48
12/19/2014	Snake River_345.2_LB	48
12/20/2014	Snake River_345.2_LB	48
12/21/2014	Snake River_345.2_LB	48

Replaced Data 2015-2016

Date	Location	N

Replaced Data 2016-2017

Date	Location	N
1/22/2017	Snake River_345.2_LB	48
1/23/2017	Snake River_345.2_LB	48
1/24/2017	Snake River_345.2_LB	48
1/25/2017	Snake River_345.2_LB	48
1/26/2017	Snake River_345.2_LB	48
1/27/2017	Snake River_345.2_LB	48
1/28/2017	Snake River_345.2_LB	48
1/29/2017	Snake River_345.2_LB	48
1/30/2017	Snake River_345.2_LB	48
1/31/2017	Snake River_345.2_LB	48
2/1/2017	Snake River_345.2_LB	48
2/2/2017	Snake River_345.2_LB	48
2/3/2017	Snake River_345.2_LB	48
2/4/2017	Snake River_345.2_LB	48
2/5/2017	Snake River_345.2_LB	48
2/6/2017	Snake River_345.2_LB	48
2/7/2017	Snake River_345.2_LB	48
2/8/2017	Snake River_345.2_LB	48
2/9/2017	Snake River_345.2_LB	48
2/10/2017	Snake River_345.2_LB	48
2/11/2017	Snake River_345.2_LB	48
2/12/2017	Snake River_345.2_LB	48
2/13/2017	Snake River_345.2_LB	48
2/14/2017	Snake River_345.2_LB	48
2/15/2017	Snake River_345.2_LB	48
2/16/2017	Snake River_345.2_LB	48
2/17/2017	Snake River_345.2_LB	48
2/18/2017	Snake River_345.2_LB	48
2/19/2017	Snake River_345.2_LB	48
2/20/2017	Snake River_345.2_LB	48
2/21/2017	Snake River_345.2_LB	48
2/22/2017	Snake River_345.2_LB	48
2/23/2017	Snake River_345.2_LB	48
2/24/2017	Snake River_345.2_LB	48
2/25/2017	Snake River_345.2_LB	48
2/26/2017	Snake River_345.2_LB	48
2/27/2017	Snake River_345.2_LB	48
2/28/2017	Snake River_345.2_LB	48

Replaced Data 2017

Date	Location	N
12/9/2017	Snake River_345.2_LB	48
12/10/2017	Snake River_345.2_LB	48
12/11/2017	Snake River_345.2_LB	48
12/12/2017	Snake River_345.2_LB	48
12/13/2017	Snake River_345.2_LB	48
12/14/2017	Snake River_345.2_LB	48
12/15/2017	Snake River_345.2_LB	48
12/16/2017	Snake River_345.2_LB	48
12/17/2017	Snake River_345.2_LB	48
12/18/2017	Snake River_345.2_LB	28

Exhibit 6.1-3

HCC outflow temperature exceedence, daily average flow rate and calculated daily thermal load

Exhibit 6.1-3
HCC outflow temperature exceedence, daily average flow rate and calculated daily thermal load exceedance during the 1991-2017 period.

This exhibit presents daily temperature exceedences (Table 1) and daily average flow rate (Table 2) for each day of the 1991-2017 period when HCC outflow temperature was above the salmonid spawning criterion. The measured data in Tables 1 and 2 was incorporated into the formula outlined in Section 6.1.2.3.2.1 of the 401 application and used to calculate daily thermal load exceedances for each year (Table 3). Values are left blank in the tables when there was no exceedance of the salmonid spawning criterion. The daily thermal load exceedences were then summed to calculate the cumulative thermal load exceedence for each year during the 1991 through 2017 period.

Table 1
HCC outflow daily temperature exceedences (°C) of the 13.3°C 7-Day Average Maximum (7DAM) salmonid spawning criterion.

Date	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
10/29	3.1	2.5	2.4	2.2	1.3	1.5		0.7	1.2	1.7	2.5	2.0	3.5	3.0	2.4	2.0	1.2	1.6	1.3	3.5	2.1	2.5	2.0	3.9	4.6	2.7	1.1
10/30	2.8	2.4	2.3	2.1	1.1	1.2		0.6	1.1	1.5	2.3	1.8	3.4	2.8	2.3	1.7	1.1	1.4	1.1	3.3	1.9	2.2	1.8	3.7	4.5	2.6	1.0
10/31	2.6	2.4	2.2	2.0	0.9	1.1		0.5	1.0	1.2	2.1	1.6	3.2	2.6	2.2	1.5	0.9	1.2	0.9	3.1	1.8	2.0	1.7	3.6	4.3	2.5	0.8
11/1	2.3	2.3	2.1	1.8	0.7	0.9		0.4	0.8	1.0	1.9	1.4	3.0	2.4	2.1	1.2	0.7	0.9	0.6	2.9	1.6	1.8	1.5	3.5	4.2	2.4	0.7
11/2	2.1	2.2	1.8	1.7	0.5	0.7		0.2	0.7	0.8	1.8	1.1	2.7	2.2	1.9	1.0	0.6	0.8	0.4	2.7	1.4	1.6	1.4	3.3	4.0	2.3	0.6
11/3	1.8	2.1	1.6	1.5	0.3	0.6		0.1	0.5	0.7	1.6	0.8	2.4	2.0	1.8	0.7	0.4	0.6	0.1	2.5	1.1	1.4	1.2	3.1	3.9	2.2	0.4
11/4	1.5	2.0	1.3	1.3	0.1	0.4			0.3	0.5	1.5	0.5	2.1	1.8	1.6	0.5	0.3	0.5		2.3	0.9	1.3	1.0	3.0	3.7	2.1	0.3
11/5	1.2	1.8	1.0	1.0		0.1			0.1	0.4	1.4	0.2	1.8	1.6	1.4	0.2	0.2	0.4		2.1	0.7	1.2	0.8	2.8	3.5	1.9	0.1
11/6	0.9	1.6	0.7	0.8						0.2	1.2		1.5	1.4	1.2		0.1	0.3		2.0	0.5	1.1	0.6	2.6	3.3	1.8	
11/7	0.6	1.4	0.4	0.6							1.0		1.1	1.2	1.1			0.2		1.9	0.3	1.0	0.4	2.5	3.1	1.7	
11/8	0.3	1.2		0.4							0.8		0.8	0.9	0.9					1.8	0.1	0.9	0.2	2.3	2.9	1.5	
11/9	0.1	0.9		0.2							0.6		0.5	0.7	0.7					1.7		0.8		2.1	2.7	1.4	
11/10		0.7									0.4		0.3	0.5	0.5					1.6		0.6		2.0	2.4	1.2	
11/11		0.5									0.2			0.2	0.3					1.5		0.5		1.9	2.2	1.0	
11/12		0.3												0.1	0.2					1.3		0.3		1.7	1.9	0.9	
11/13		0.1																		1.1		0.1		1.5	1.7	0.8	
11/14																				0.9				1.3	1.5	0.7	
11/15																				0.6				1.1	1.3	0.6	
11/16																				0.4				0.8	1.0	0.5	
11/17																				0.1				0.5	0.8	0.5	
11/18																								0.2	0.7	0.4	
11/19																									0.4	0.3	
11/20																									0.2	0.3	
11/21																										0.2	
11/22																										0.1	

Table 2

Daily average HCC outflow in cubic feet per second (cfs) during the period of HCC outflow temperature exceedences.

Date	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
10/29	9590	9300	9530	9250	9560	9550		9580	13100	9840	8820	9160	8520	8750	8750	8590	8600	8990	8830	8890	14100	9370	9100	8900	8740	8610	8440
10/30	9590	9290	9490	9240	9540	9480		9600	13000	9770	8920	9160	8500	8780	8750	8470	8600	9030	8860	8900	14100	9430	9110	8890	8730	8640	8450
10/31	9560	9250	9480	9230	9580	9400		9590	13000	9850	8960	9120	8510	8750	8780	8500	8650	9110	8860	8880	14100	9340	9010	8890	8730	8600	8560
11/1	9530	9240	9450	9250	9630	9380		9610	13000	9810	8980	9130	8490	8700	8880	8630	8670	9110	8870	8880	14200	9340	8940	8910	8720	8620	8840
11/2	9560	9190	9450	9310	9630	9370		9620	13000	9900	8980	9140	8480	8700	9050	8680	8690	9160	8800	8870	14200	9330	8910	8850	8730	8650	8920
11/3	9530	9190	9450	9250	9580	9350		9560	12900	9940	8960	9140	8510	8700	8990	8690	8670	9050	8810	8890	14100	9260	8930	8930	8790	8620	8920
11/4	9530	9240	9470	9230	9560	9410			12900	9950	9010	9150	8490	8700	9010	8700	8650	9030		8900	14100	9260	8960	8930	8660	8630	8940
11/5	9720	9190	9510	9240		9430			13000	9970	9000	9120	8520	8880	9000	8700	8710	9010		8890	14000	9240	8940	8940	8680	8590	8920
11/6	9800	9190	9460	9200						9820	8940		8600	8800	9030		8680	9020		8870	13900	9240	8940	8920	8740	8550	
11/7	9810	9200	9450	9210							8900		8540	8760	9230			9020		8890	13900	9360	8930	9100	8720	8570	
11/8	9840	9200		9230							8890		8510	8640	9590					8880	14100	9190	8990	9170	8710	8600	
11/9	9860	9230		9250							8910		8470	8700	10100					8860		8920		9200	8740	8620	
11/10		9170									8980		8480	8650	10200					8850		8910		9240	8740	8610	
11/11		9170									9030			8670	10100					8800		8960		9170	8750	8590	
11/12		9220												8670	10100					8780		8930		9180	8760	8600	
11/13		9200																		8790		8920		9120	8750	8570	
11/14																				8800				9160	8730	8540	
11/15																				8900				9190	8760	8620	
11/16																				9040				9160	8710	8670	
11/17																				8940				9360	8620	8610	
11/18																								9490	8890	8520	
11/19																									8910	8520	
11/20																									8790	8540	
11/21																										8570	
11/22																										8490	

Table 3
HCC outflow daily thermal load exceedences of the salmonid spawning criterion in billion kilocalories (bkcal) calculated from the daily temperature exceedences (Table 1) and daily average flow rate (Table 2). Also shown is the total, cumulative thermal load exceedance (CTLE) for each year.

Date	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
10/29	72.8	56.9	56.0	49.8	30.4	35.1		16.4	38.5	40.9	54.0	44.8	73.0	64.2	51.4	42.0	25.3	35.2	28.1	76.1	72.5	57.3	44.5	84.9	98.4	56.9	22.7
10/30	65.7	54.6	53.4	47.5	25.7	27.8		14.1	35.0	35.9	50.2	40.3	70.7	60.2	49.2	35.2	23.2	30.9	23.9	71.9	65.6	50.8	40.1	80.5	96.1	55.0	20.7
10/31	60.8	54.3	51.0	45.2	21.1	25.3		11.7	31.8	28.9	46.0	35.7	66.6	55.7	47.3	31.2	19.1	26.8	19.5	67.4	62.1	45.7	37.5	78.3	91.9	52.6	16.8
11/1	53.6	52.0	48.6	40.7	16.5	20.7		9.4	25.5	24.0	41.8	31.3	62.3	51.1	45.6	25.3	14.9	20.1	13.0	63.0	55.6	41.1	32.8	76.3	89.6	50.6	15.1
11/2	49.1	49.5	41.6	38.7	11.8	16.1		4.7	22.3	19.4	39.6	24.6	56.0	46.8	42.1	21.2	12.8	17.9	8.6	58.6	48.7	36.5	30.5	71.5	85.5	48.7	13.1
11/3	42.0	47.2	37.0	34.0	7.0	13.7		2.3	15.8	17.0	35.1	17.9	50.0	42.6	39.6	14.9	8.5	13.3	2.2	54.4	38.0	31.7	26.2	67.7	83.9	46.4	8.7
11/4	35.0	45.2	30.1	29.4	2.3	9.2			9.5	12.2	33.1	11.2	43.6	38.3	35.3	10.6	6.4	11.0		50.1	31.1	29.5	21.9	65.6	78.4	44.4	6.6
11/5	28.5	40.5	23.3	22.6		2.3			3.2	9.8	30.8	4.5	37.5	34.8	30.8	4.3	4.3	8.8		45.7	24.0	27.1	17.5	61.3	74.3	39.9	2.2
11/6	21.6	36.0	16.2	18.0						4.8	26.3		31.6	30.1	26.5		2.1	6.6		43.4	17.0	24.9	13.1	56.8	70.6	37.7	
11/7	14.4	31.5	9.3	13.5							21.8		23.0	25.7	24.8			4.4		41.3	10.2	22.9	8.7	55.7	66.2	35.7	
11/8	7.2	27.0		9.0							17.4		16.7	19.0	21.1					39.1	3.5	20.2	4.4	51.6	61.8	31.6	
11/9	2.4	20.3		4.5							13.1		10.4	14.9	17.3					36.9		17.5		47.3	57.7	29.5	
11/10		15.7									8.8		6.2	10.6	12.5					34.7		13.1		45.2	51.3	25.3	
11/11		11.2									4.4			4.2	7.4					32.3		11.0		42.6	47.1	21.0	
11/12		6.8												2.1	4.9					27.9		6.6		38.2	40.7	18.9	
11/13		2.3																		23.7		2.2		33.5	36.4	16.8	
11/14																				19.4				29.1	32.0	14.6	
11/15																				13.1				24.7	27.9	12.7	
11/16																				8.8				17.9	21.3	10.6	
11/17																				2.2				11.5	16.9	10.5	
11/18																								4.6	15.2	8.3	
11/19																									8.7	6.3	
11/20																									4.3	6.3	
11/21																										4.2	
11/22																										2.1	
Total	**453.2**	**551.0**	**366.5**	**353.0**	**114.8**	**150.2**	**0.0**	**58.7**	**181.4**	**192.9**	**422.2**	**210.3**	**547.7**	**500.4**	**456.0**	**184.9**	**116.3**	**175.1**	**95.2**	**809.9**	**428.0**	**438.1**	**277.4**	**1044.9**	**1256.4**	**686.5**	**105.9**

Exhibit 6.3-1

December 2006 Hells Canyon Complex (HCC) gas bubble trauma monitoring study, final report

HCC Gas Bubble Trauma Monitoring Study

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Final Report

Hells Canyon Complex
FERC No. 1971

December 2006

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ABSTRACT

In 2006, Idaho Power Company monitored salmonid and nonsalmonid species for symptoms of Gas Bubble Trauma (GBT) caused by periods of spill discharge within the Hells Canyon Complex. Total Dissolved Gas (TDG) levels associated with spill discharge ranged from 90% to 143% of saturation. No GBT symptoms were observed at TDG levels below 120%. However, severe GBT symptoms were present in fish exposed to TDG levels above 125% within the 12 hours prior to sampling. The significance of severe GBT symptoms is unknown, as are the long-term effects and odds of recovery from prolonged exposure. Future monitoring may involve individually tagging fish to monitor the effects of severe GBT symptoms and the progression of health affects.

1. INTRODUCTION

Water is released over project spillways when inflows exceed the discharge capacity of a hydroelectric facility's turbine units. Depending on the configuration of the spillway, such as the level or elevation of the spill gates, spill water typically entrains air and becomes supersaturated with dissolved gases relative to atmospheric pressures. Gas supersaturation can cause bubbles, referred to as gas bubble trauma (GBT), to form in fish and invertebrates (Ebel et al. 1975; Weitkamp and Katz 1980). GBT can directly or indirectly increase mortality rates. Oregon and Idaho have adopted a gas saturation criterion for total dissolved gas (TDG). To protect fish and invertebrate species, TDG must not exceed 110% saturation. In Oregon, this criterion does not apply to flows above the seven-day, ten-year frequency flow (7Q10) flood flow. Nor does it apply in Idaho at excess streamflows, as determined by the Director of the Idaho Department of Environmental Equality. GBT has been described for a variety of fish species and invertebrates. Factors that can affect tolerance or the severity of trauma from supersaturation include life stage, size, species, and depth distribution of the organism.

The Hells Canyon Complex (HCC) is comprised of three high-head dams. Brownlee Dam (395 feet) is the uppermost dam, followed by Oxbow Dam (209 feet) and Hells Canyon Dam (330 feet). Brownlee and Hells Canyon dams have upper level crest gates and lower level outlet gates. Oxbow Dam is equipped only with radial crest gates that discharge near the surface into a concrete spillway. Spillway configurations at all three dams are such that spill plunges to a depth where hydrostatic pressure forces gas into solution at high levels, resulting in elevated TDG.

The purpose of this study was to determine a relationship between GBT and levels of TDG within the HCC. The study focused on sampling fish upstream of Brownlee Dam (to compare GBT symptoms with levels of TDG prior to spill), the Brownlee Dam tailrace, the Oxbow Reservoir, the Oxbow Bypass, and the upper section of Hells Canyon Reservoir (immediately downstream of the Oxbow Powerhouse discharge). The incidence and severity of GBT in nonmigratory, resident fish species in Brownlee and Oxbow tailraces are reported in this study.

2. STUDY AREA

Brownlee Reservoir—Brownlee Reservoir, constructed in 1958, is the uppermost in a series of three reservoirs on the Snake River known as the HCC. Brownlee Reservoir is a large storage reservoir with approximately 1,000,000 acre-feet of active storage. At full pool (2,077 feet mean sea level), Brownlee Reservoir has a surface area of 6,100 hectares and is 92 kilometers (km) long (Ebel and Koski 1968). Average depth is 32 meters (m) with a maximum depth of 92 m near the dam. The Brownlee Project has a hydraulic capacity of about 35,000 cubic feet per second (cfs), and the 7Q10 average flood statistic is about 67,900 cfs. The U.S. Army Corps of Engineers mandates flood control requirements at the Brownlee Project. Water-level fluctuations during spring and summer months are common but considerably less in magnitude, ranging from 1 to 10 m. Shoreline areas are typically steep and consist of bedrock or mixtures of boulders, sand, and gravel substrate.

Oxbow Reservoir—Oxbow Reservoir, constructed in 1961, is a small run-of-the-river reservoir that is approximately 19 km long. The Snake River, from the tailrace of Brownlee Dam to the mouth of Wildhorse Creek (1.6 km), is a high-velocity, narrow channel. The rest of Oxbow Reservoir is relatively narrow and shallow, with maximum depths approaching 24 to 30 m. Frequent daily fluctuations upwards of 1.2 m are common. Shorelines are primarily basalt outcrops and talus, except for areas of alluvial input from small tributaries. Oxbow Dam has a hydraulic capacity of about 28,000 cfs, and the 7Q10 average flood statistic is about 69,000 cfs.

Oxbow Bypass—The unique design of the Oxbow Powerhouse and Dam renders a 3-km stretch of the original river channel from Oxbow Dam to the outflow of the powerhouse with a minimum flow of 100 cfs. It is to this bypassed reach that spill occurs. The wetted area of the Oxbow Bypass is primarily influenced by Hells Canyon Reservoir surface elevations. At high elevations, water backs up into the bypass channel over much of the area. As such, the Oxbow Bypass is a relatively shallow backwater type habitat with overall low water velocities, except during spill periods when velocity increases. Indian Creek enters the Snake River in this reach.

Hells Canyon Reservoir—Hells Canyon Reservoir, constructed in 1967, is 35 km long and approaches a maximum depth of 60 m. Shorelines in the reservoir are generally very steep with substrates primarily composed of basalt outcrops and talus slopes. Hells Canyon Dam has a hydraulic capacity of about 30,000 cfs, and the 7Q10 average flood statistic is about 71,500 cfs.

3. METHODS

3.1. Total Dissolved Gas Monitoring

Five sampling locations were chosen for continuous TDG monitoring: both ends of the bridge within the Brownlee tailwater area, the Oxbow Dam forebay/pool area, the Oxbow Bypass, and the Hells Canyon Reservoir (Figure 1 and Figure 2).

Hydrolab® multi-parameter probes were used to continuously monitor TDG. Measurements were taken every ten minutes. Daily average, minimums, and maximums or hourly data are reported. Hydrolab® probes were placed on the bridge below Brownlee Dam in both the left and right channel positions (Figure 1), above and below the spill gates at Oxbow Dam, below the gravel bar in the Oxbow Bypass, and at the hatchery pump intake on Hells Canyon Reservoir (Figure 2). Hydrolab® probes were downloaded and either recalibrated or replaced with a freshly calibrated probe approximately weekly. Hydrolab® probes at continuous locations were deployed to a depth of greater than 3 m where possible. At most locations, a depth of greater than 3 m was maintained during spill. During periods at the Oxbow forebay site, the depth of the Hydrolab® probe was less than 3 m.

Whenever technicians visited a sampling location, they took an instantaneous TDG measurement using a freshly calibrated Hydrolab® probe. In addition, technicians took instantaneous TDG measurements at the beginning and end of each electrofished transect. For instantaneous measurements, probes were deployed to a depth greater of than 3 m, if possible, and allowed to equilibrate for 15 minutes.

3.2. Gas Bubble Trauma Monitoring

Five sampling locations were chosen for weekly fish monitoring; the area immediately above Brownlee Dam; the Brownlee tailwater area (from Brownlee Dam to Wildhorse River) (Figure 1); the Oxbow Dam forebay/pool area; the Oxbow Bypass; and the Hells Canyon Reservoir (from the Oxbow Powerhouse discharge to the boat ramp below Copperfield Park) (Figure 2).

Weekly fish monitoring was completed using a jet boat-based electrofishing unit. All stunned fish were collected and held in a live well until sampling at the site was completed (not longer than 10 minutes). A specially designed tray, which allowed the fish to be continually anesthetized during the GBT examination, was used to hold the fish. All fish were examined for symptoms of GBT according to established protocols used by the Columbia River Fish Passage Center (USGS 1997; FPC 2006; DeHart 2006). A TDG measurement was taken at the beginning and end of each electrofished transect. The goal was to collect at least 30 fish.

Fish were examined using a variable magnification (6X–40X) dissecting scope. A minimum magnification of 10X was used for the examinations. The technician examined the unpaired fins (on the left side) first and then he or she examined the eyes. The area covered with bubbles was estimated using the examiners best judgment. A visual technique for estimating the area of the fin covered by bubbles is illustrated in Figure 3 and Figure 4.

A rank was assigned based on the percent area of the fin or eye covered with bubbles. A rank 0 was assigned if no bubbles were observed, a rank 1 was assigned if 1% to 5% of the fin or eye was covered with bubbles, a rank 2 was assigned if 6% to 25% of the fin or eye was covered with bubbles, a rank 3 was assigned if 26% to 50% of the fin or eye was covered with bubbles, and a rank 4 was assigned if more than 50% of the fin or eye was covered with bubbles. When the area covered was within the boundary of two ranks then the higher rank was assigned. For example, if 25% to 26% of a fin or eye was covered with bubbles, a rank of 3 was assigned. A summary of ranks is listed in Table 1. References to "GBT" throughout this study denote external symptoms of GBT regardless of severity, whereas "severe GBT" denotes external symptoms that cover more than 25% of a fin or eye.

Other information collected and recorded included: species; time of examination; total length in millimeters (mm); origin (hatchery, wild, or unknown), and comments regarding tags and fish condition as deemed relevant by the examiner.

4. RESULTS

4.1. Total Dissolved Gases Monitoring

During the sampling period, the maximum daily flow through the study area ranged from approximately 10,000 to 89,000 cfs (Figure 5 and Figure 6). Water temperatures ranged from 2 °C to 19 °C. TDG saturation at the beginning and end of each electrofished transect ranged from 90% to 140%. Continuous TDG levels measured by the probes placed in both the Brownlee and Oxbow tailraces were similar, ranging from 90% to 143%. Similar TDG levels confirm that the fish sampling was conducted across the range of TDG levels that occurred during spill.

The highest TDG levels observed were in the Brownlee tailrace. The configuration of the Brownlee Powerhouse and spillway separates spill and turbine flows (Figure 1). The permanent monitoring locations at the bridge below Brownlee Dam took TDG measurements from both the left (spillway side) and the right channel (turbine discharge side). Comparing these measurements showed that spill flow and some portion of turbine flow were not mixed until spill flow reached approximately 40,000 to 50,000 cfs (Figure 7). TDG measured in the right channel remained below 110% until spill flow reached approximately 35,000 cfs. When spill flow was greater than 50,000 cfs, TDG in the right channel reached 143%. At these very high spills, turbine flows and spill flows were mixed quickly and there was little dissipation downstream through the Oxbow Reservoir. On May 3, 2006, instantaneous TDG measurements were taken downstream through the Oxbow Reservoir. At this time, spill was between 35,000 and 42,000 cfs. Measurements at Brownlee Dam showed unmixed conditions at the bridge (113%–138%), mixed conditions about four miles downstream of the dam (135%) (river mile 280.4), and a dissipation of 5% throughout the Oxbow Reservoir with levels of 130% measured near Oxbow Dam (Table 2). TDG measured across the channel at 5,000 to 7,500 cfs showed that spill flow was mixed quickly with turbine flow and TDG levels across the entire channel were below 110% of saturation within 0.7 miles.

4.2. Gas Bubble Trauma Monitoring

Preliminary sampling began January 3, 2006, during a brief spill event of approximately 30,000 cfs at Oxbow Dam. During this event, the Oxbow forebay/pool area TDG saturation was below 100%, while TDG levels were above 120% in the Oxbow Bypass. Three of the 47 fish examined during this sampling effort had severe GBT. The TDG level below the Oxbow Powerhouse discharge was 120% of saturation. Only 2 of the 31 fish examined showed any signs of GBT. All received a ranking of 1.

Regular weekly sampling began March 14, 2006, and ended June 22, 2006. The Brownlee Pool was sampled as a control to compare the prevalence of GBT symptoms under nonspill conditions. As expected, no signs of GBT were observed in the 307 fish sampled from the Brownlee Pool. The total number of fish collected during the monitoring period was 3,012, excluding those collected in the Brownlee Pool. The total number of fish with GBT was 316 (Table 4). Twenty different species were collected during the sampling period. Of the 20 species, fall chinook (*Oncorhynchus tschawytscha*), kokanee (*O. nerka*), mottled sculpin (*Cottus bairdi*), pumpkinseed (*Lepomis gibbosus*) and steelhead (*O. mykis*) did not shown any GBT symptoms but were collected in extremely low numbers (Table 5). White crappie (*Pomoxis annularis*), smallmouth bass (*Micropterus dolomieui*), and rainbow trout (*O. mykiss*) had the highest percentage of GBT with the exception of the one brown bullhead (*Ictalurus nebulosus*) and the one largemouth bass (*M. salmoides*) collected with GBT. The remaining ten species collected had varying levels of GBT and included black crappie (*P. nigromaculatus*), bluegil (*L. macrochirus*), channel catfish (*I. punctatus*), chiselmouth (*Acrocheilus alutaceus*), common carp (*Cyprinus carpio*), northern pikeminnow (*Ptychocheilus oregonensis*), bridgelip sucker (*Castostomus columbianus*), largescale sucker (*C. macrocheilus*), mountain whitefish (*Prosopium williamsoni*), and yellow perch (*Perca flavescens*).(Table 5).

The Brownlee tailwater area had the highest percentage of fish with GBT (17.5%) while the area with the lowest percentage (5.5%), excluding the Brownlee Pool, was the Oxbow Bypass. On May 4, 2006, after 30 consecutive days of TDG levels greater than 120% (Table 6), 63.1% of all fish collected downstream of Brownlee Dam showed some level of GBT (Table 7). This was the highest rate observed during the study period.

GBT was only observed in fish when TDG levels within 12 hours of sampling were greater than 120% (Figure 8, Figure 9, Figure 10, and Figure 11). However, severe GBT was consistently observed in most fish collected in the Brownlee tailwater when TDG exceeded 125% (daily maximums between 130% and 140%) (Figure 12). Generally, severe GBT was not observed at TDG levels less than 125%. The only exception to this was on May 9, 2006 in the Oxbow forebay/pool site (Figure 13). While the measured TDG at the time of collection was 114%, the TDG measured at the continuous monitoring site less than 12 hours prior to sampling had a daily maximum reading of 125%. During this time, Brownlee Dam spill resulted in levels of TDG exceeding 130%. It is likely that fish retrieved from the Oxbow forebay/pool area with severe GBT had originated in the Brownlee tailwater where they had been exposed to TDG levels greater than 125%. These fish were then transported downstream because of the very high flows.

Fish sampled in the Oxbow Powerhouse discharge had a higher occurrence of GBT than fish sampled in the Oxbow Bypass (Figure 14), which is counter to our expectations since this area does not receive direct spill. Although we have incomplete TDG data for the Oxbow Bypass section (Figure 15), readings taken above the spill gates at the continuous monitoring station indicate that TDG levels greater than 125% entering the Oxbow Bypass may be reduced as water flows over the spillway. Reduction of TDG may be dependent on the volume of spill and the level of TDG. However, any reduction supports the idea that the Oxbow spillway may improve conditions (i.e. lower TDG) for resident fish in the Oxbow Bypass when TDG below Brownlee Dam exceeds 125%.

5. DISCUSSION

Extensive research during the 1960s and 1970s determined that a substantial difference occurs in the prevalence of GBT for juvenile salmonids, both in terms of the number of deaths that occur and the time to death as TDG levels approach 120% to 125% for fish residing in water less than one meter in depth (Antcliffe et al. 2002). Much of this past research has focused on migratory juvenile salmonids. More recent studies have documented the affects of TDG on nonmigratory resident fish. Ryan et al. (2000), attempting to model the effects of supersaturation on resident fish, reported that GBT in nonsalmonid fish was rare when TDG saturation was less than 120%. Weitkamp et al. (2003a) observed that few resident fish showed signs of GBT in the lower Clark Fork River when TDG was in the range of 125% to 130% of saturation. They attributed this observation to the generally deep depth distribution of these fish (Weitkamp et al. 2003b). Other recent literature supports the findings that effects to fish (migratory or not) and invertebrates from TDG levels less than 120% of saturation are minimal (Toner and Dawley 1995; Toner et al. 1995; Ryan and Dawley 1998; NMFS 1999; NOAA 2000; Ryan et al. 2000; Backman and Evans 2002; Backman et al. 2002; Weitkamp et al. 2003a; Schrank et al. 1997). Other research indicates that invertebrates and other food organisms are also sensitive to GBT (White et al. 1991).

Our findings in this study were similar to those reported above. We did not find GBT signs present in fish sampled from TDG levels less than 120% of saturation. However, when TDG levels were greater than 125% within 12 hours prior to sampling, fish were more likely to show signs of severe GBT. Extended exposure to TDG levels greater than 125% could alter fish community composition and dynamics if substantial mortality occurred or could substantially affect growth and fitness of individuals or populations. Quantitative affects are unknown because fish differ in vulnerability and sensitivity to GBT.

Effects of multiple exposures of GBT incidence and varying severities of GBT are poorly understood. In general, the behavior of fish with GBT appears to follow what is expected from fish suffering from severe physical stress (Dawley and Ebel 1975; Meekin and Turner 1974). Thus, it follows that fish exposed multiple times to TDG levels greater than 120% may suffer latent mortality from stresses or vulnerabilities associated with a weakening condition. Our future monitoring of fish during periods of elevated TDG may include tagging (e.g. PIT tags or individually number Floy tags) to enable us to identify individuals and compare body condition and severity of GBT symptoms to previous time periods.

6. SUMMARY

From these surveys, several conclusions can be made regarding the relationship between TDG levels and the presence of GBT:

- Fish sampled when TDG levels were less than 120% did not show GBT.
- Fish sampled when TDG levels were greater than 125% did show severe GBT.

Continuous measurements of TDG indicated that the highest levels of TDG were observed in the Brownlee tailwater when spill exceeded 50,000 cfs.

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Table 1. Rank scores assigned based on percent area of fins or eyes covered with bubbles.

Rank	**Percent area covered with bubbles**
0	0
1	1 to 5
2	6 to 25
3	26 to 50
4	Greater than 50

Table 2. TDG data collected by river mile (RM) throughout the Oxbow Reservoir when the Brownlee Reservoir was spilling 35,000 to 42,000 cfs (A) and 5000 to 7500 cfs (B). Channel position is designated from the perspective of looking downstream as left bank (LB), left channel (LC), mid-channel (MC), right channel (RC) and right bank (RB).

RM	**Location**	**Channel Position and TDG Saturation (%)**				
		LB	**LC**	**MC**	**RC**	**RB**
(A)						
272.8	Oxbow Dam					
273.4				130		
274.4				131		
275.4				131		
276.4				132		
277.4				133		
279.4				135		
280.4			135	135	135	
282.0			133	132	131	
283.1	Below Wildhorse River		134	129	130	
283.9	Bridge in Brownlee tailwater		135	138	125	113
(B)						
283.1	Below Wildhorse Reservoir	99	97	97	97	97
283.5		103	99	97	96	96
283.8	Just downstream of bridge	111	107	101	96	95
284.2	Directly below spillway	114	107	103	96	95

Table 3. The total length range in millimeters (mm) and the number of fish collected during the 2006 sampling (January–June).

Species	Total Length Range (mm)	Sites					Total
		Brownlee Pool	Brownlee Tailwater	Oxbow Forebay/ Pool	Oxbow Bypass	Hells Canyon Reservoir (Oxbow Powerhouse Discharge)	
Black Crappie	154–310	5	5	3	3	0	16
Bluegil	32–230	5	14	58	16	9	102
Brown Bullhead	185	0	0	1	0	0	1
Channel Catfish	233–813	1	48	1	11	27	88
Chiselmouth	81–368	0	19	0	10	18	47
Common Carp	308–940	3	32	7	68	36	146
Fall Chinook	132	0	0	0	1	0	1
Kokanee	120–213	0	1	0	0	1	2
Largemouth Bass	177–298	2	0	1	0	0	3
Mottled Sculpin	76–80	8	0	1	0	1	10
Pumpkinseed	104–157	0	0	3	0	0	3
Rainbow Trout	97–545	0	119	1	173	85	378
Northern Pikeminnow	40–658	1	73	2	65	155	296
Bridgelip Sucker	265–732	0	63	0	43	92	198
Largescale Sucker	287–645	3	95	3	120	159	380
Steelhead	590–770	0	0	0	12	1	13
Smallmouth Bass	30–500	259	267	274	253	228	1281
White Crappie	63–343	15	36	45	10	0	106
Mountain Whitefish	139–434	3	37	1	28	43	112
Yellow Perch	25–322	2	36	10	76	12	136
Total		307	845	411	889	867	3,319

Table 4. The total length range in millimeters (mm) and number of fish collected during the 2006 sampling (January–June) with any sign of GBT regardless of the rank. See Table 1 for rank definitions.

Species	Total Length Range (mm)	Number of Fish with GBT by Site					
		Brownlee Pool	Brownlee Tailwater	Oxbow Forebay/ Pool	Oxbow Bypass	Hells Canyon Reservoir (Oxbow Powerhouse Discharge)	Total
Black Crappie	264	0	0	1	0	0	1
Bluegil	97–190	0	0	4	2	2	8
Brown Bullhead	185	0	0	1	0	0	1
Channel Catfish	450–570	0	4	0	0	0	4
Chiselmouth	221–341	0	2	0	1	2	5
Common Carp	579–773	0	11	0	1	0	12
Fall Chinook		0	0	0	0	0	0
Kokanee		0	0	0	0	0	0
Largemouth Bass	177	0	0	1	0	0	1
Mottled Sculpin		0	0	0	0	0	0
Pumpkinseed		0	0	0	0	0	0
Rainbow Trout	250–506	0	25	0	35	3	63
Northern Pikeminnow	161–515	0	14	0	1	3	18
Bridgelip Sucker	387–430	0	2	0	0	3	5
Largescale Sucker	381–572	0	4	0	1	7	12
Steelhead		0	0	0	0	0	0
Smallmouth Bass	128–480	0	76	36	3	31	146
White Crappie	250–343	0	2	16	2	0	20
Mountain Whitefish	241–434	0	2	0	3	4	9
Yellow Perch	152–273	0	6	3	0	2	11
Total		0	148	32	49	57	316

Table 5. The percentage of each species collected during the 2006 sampling season (January–June) by the rank of GBT. See Table 1 for rank definitions.

	Percentage by Rank					**Total**
Species	**0**	**1**	**2**	**3**	**4**	**Number Collected**
Black Crappie	90.9	9.1	0	0	0	11
Bluegil	91.8	5.2	1	0	2	97
Brown Bullhead	0	100	0	0	0	1
Channel Catfish	95.4	1.2	0	1.2	2.3	87
Chiselmouth	89.4	4.3	0	6.4	0	47
Common Carp	91.6	3.5	2.1	2.1	0.7	143
Fall Chinook	100	0	0	0	0	1
Kokanee	100	0	0	0	0	2
Largemouth Bass	0	0	0	100	0	1
Mottled Sculpin	100	0	0	0	0	2
Pumpkinseed	100	0	0	0	0	3
Rainbow Trout	83.3	4.5	3.4	3.7	5.0	378
Northern Pikeminnow	93.9	2.7	2.7	0.7	0	295
Bridgelip Sucker	97.5	1	1	0.5	0	198
Largescale Sucker	96.8	2.1	0	0.5	0.5	377
Steelhead	100	0	0	0	0	13
Smallmouth Bass	85.7	6.4	3.2	2	2.7	1022
White Crappie	78	5.5	7.7	4.4	4.4	91
Mountain Whitefish	91.7	0.9	1.8	0.8	4.6	109
Yellow Perch	91.8	5.2	0.8	0.8	1.5	134
Total Percentage for each Rank	89.5	4.3	2.3	1.8	2.2	3,012

Table 6. The number of consecutive days and date ranges when daily mean total dissolved gases (TDG) concentration was greater than 120%.

Location	Consecutive Days > 120%	Date Ranges
Brownlee Right Channel		
	8	April 13 to April 20
	6	April 23 to April 28
	2	April 30 to May 1
Brownlee Left Channel		
	30	April 5 to May 4
	5[1]	May 5 to May 9
	6	May 10 to May 15
	5	May 23 to May 27
Oxbow Forebay		
	32	April 6 to May 10
Oxbow Bypass		
	3	January 1to January 3
	33[1]	April 5 to May 9

[1] No data is available for these periods; however, based on spill vs. TDG relationships, it can be assumed TDG was near or greater than 120% saturation.

Table 7. The number of fish collected and percent occurrence of fish with any sign of GBT, regardless of the rank during each sampling survey.

Date	Percentage by Rank					Total Number Collected
	0	1	2	3	4	
January 3	92.3	2.5			5.1	78
January 4	100					44
March 14	100					156
March 15	100					45
March 21	100					90
March 22	100					36
March 28	100					146
March 29	100					59
April 4	100					162
April 5	100					77
April 11	91.3	6.5	1.1		1.1	92
April 12	70.9	8.1	6.5	4.8	9.7	62
April 26	73.8	8.7	6.9	4.1	6.4	172
April 27	52.8	11.5	11.5	13.8	10.3	87
May 3	67.9	13.6	7.7	5.3	5.3	206
May 4	36.9	21.9	12.3	9.6	19.2	73
May 9	79.8	10.6	5.3	3.2	1.1	188
May 10	49.4	24.7	8.6	8.6	8.6	81
May 17	97.5	2.0	0.5			197
May 18	97.0	2.9				67
May 31	100					212
June 1	100					68
June 7	100					200
June 8	100					52
June 14	100					157
June 15	100					61
June 21	100					107
June 22	100					37
Total	89.5	4.35	2.3	1.8	2.2	3,012

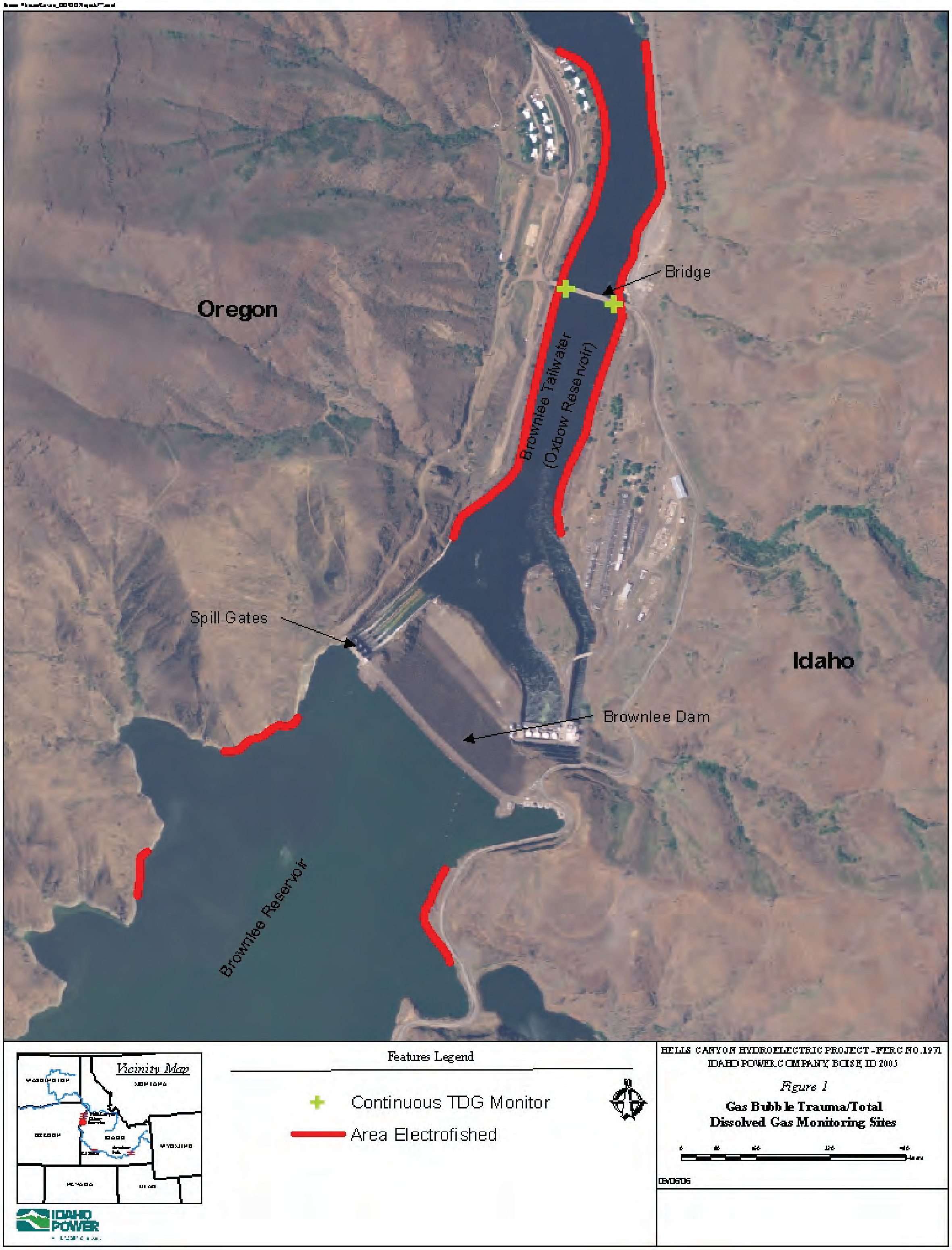

Figure 1. Brownlee Dam study area showing reservoir and tailwater sites electrofished for GBT monitoring and continuously monitored for TDG.

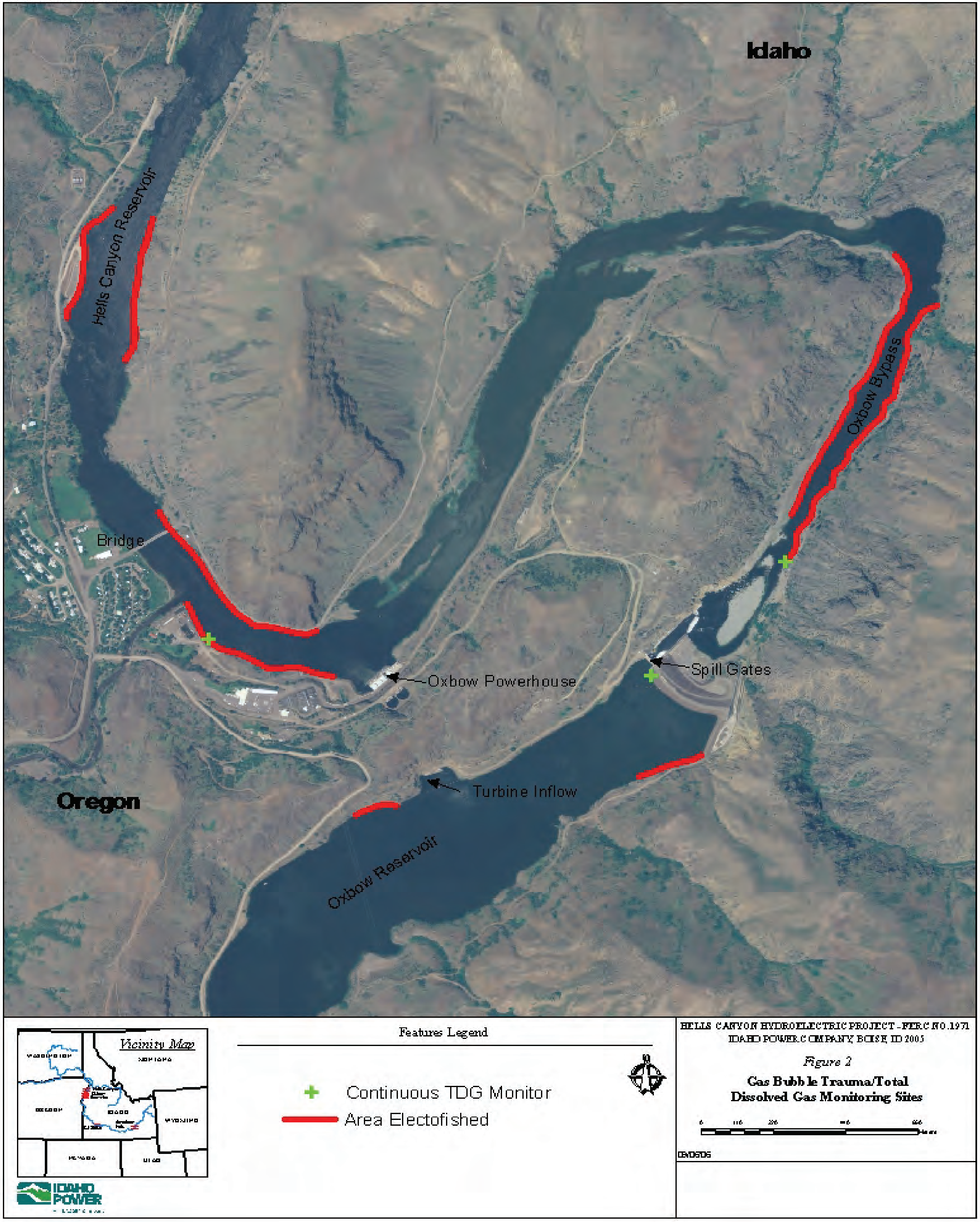

Figure 2. Oxbow Dam study area showing forebay/pool, bypass, and reservoir areas electrofished for GBT monitoring and continuously monitored TDG

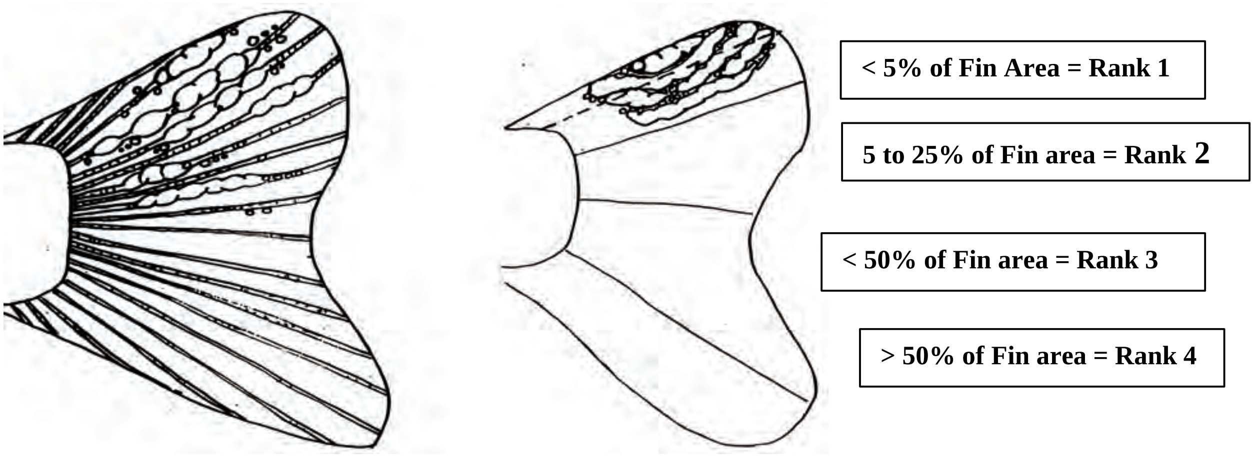

Figure 3. Conceptual drawing depicting the estimation of area of a fin occluded. The fin on the left is what might actually be viewed on a fish, and the fin on the right shows the fin are divided in areas approximating 25% of fin area and occlusion grouped to estimate actual percent area covered.

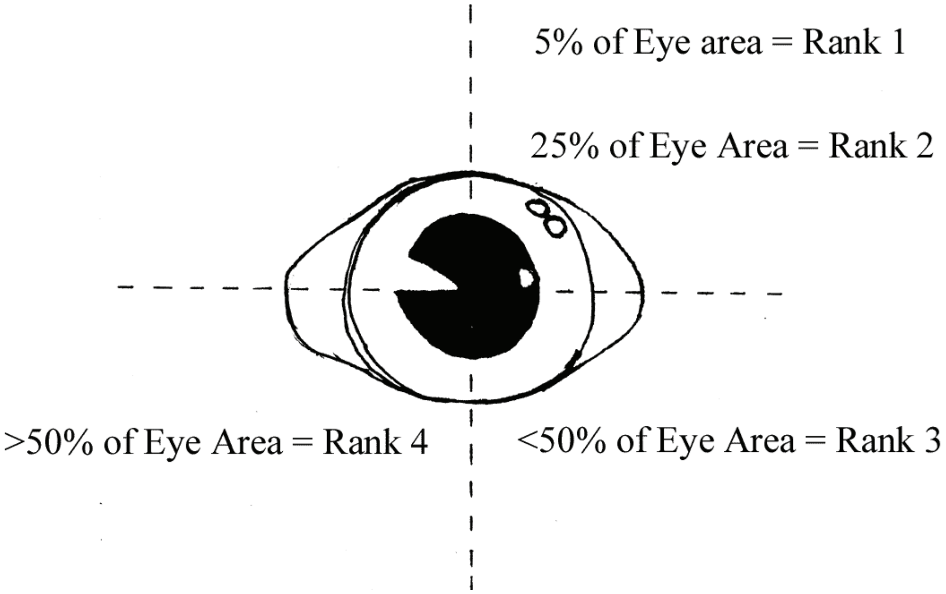

Figure 4. Conceptual drawing depicting the estimation of area of an eye occluded.

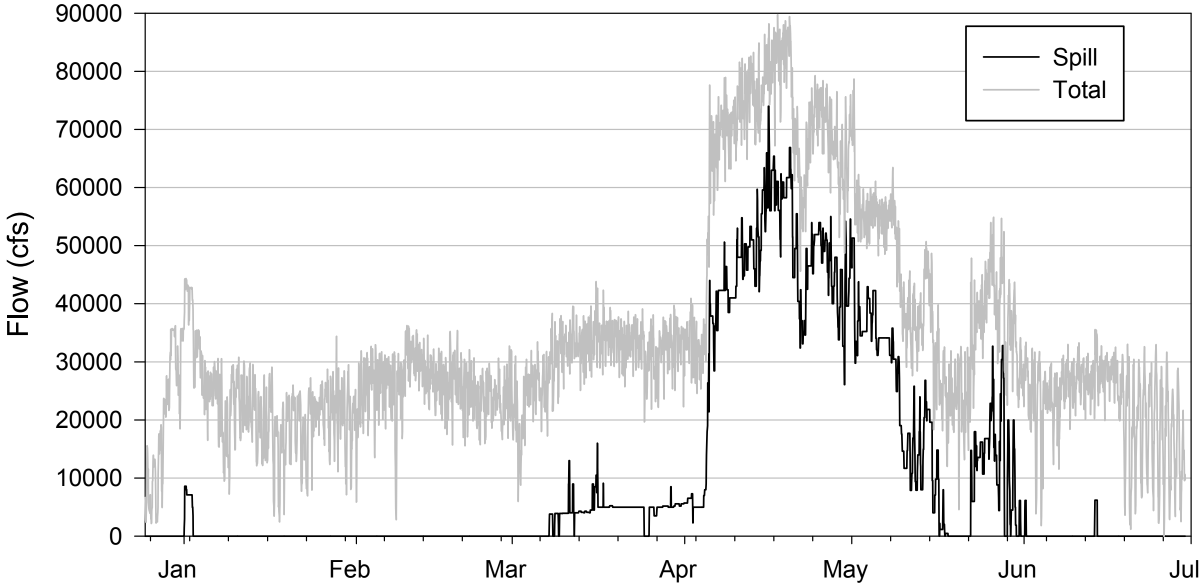

Figure 5. Daily spill and total flow past the Brownlee Project during the study period. Hydraulic capacity at the Brownlee Project is about 35,000 cfs.

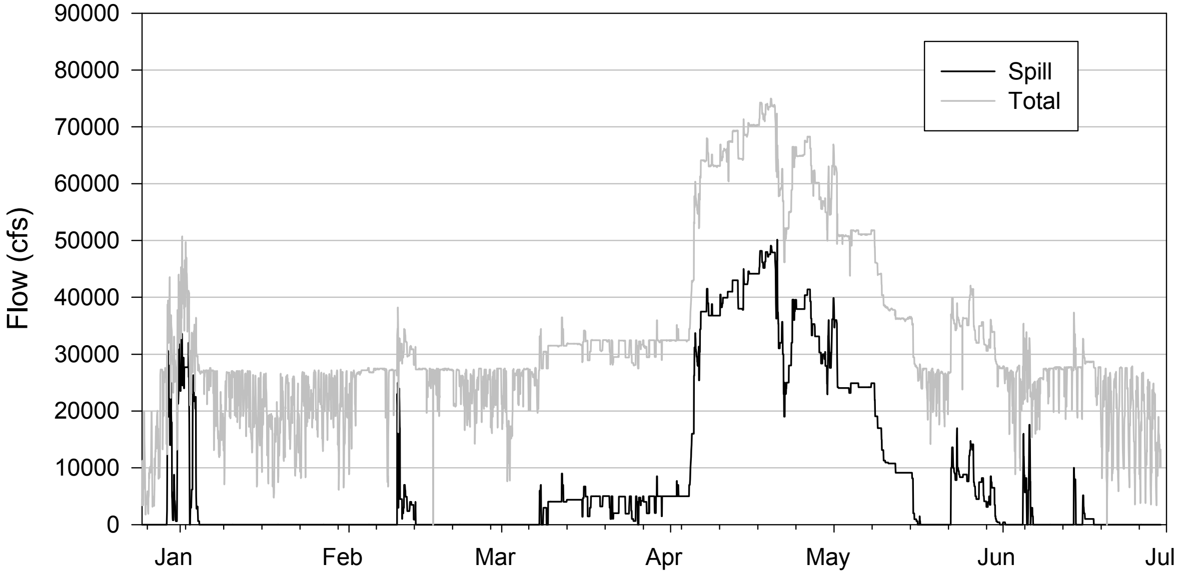

Figure 6. Daily spill and total flow past the Oxbow Project during the study period. Hydraulic capacity at the Oxbow Project is about 28,000 cfs.

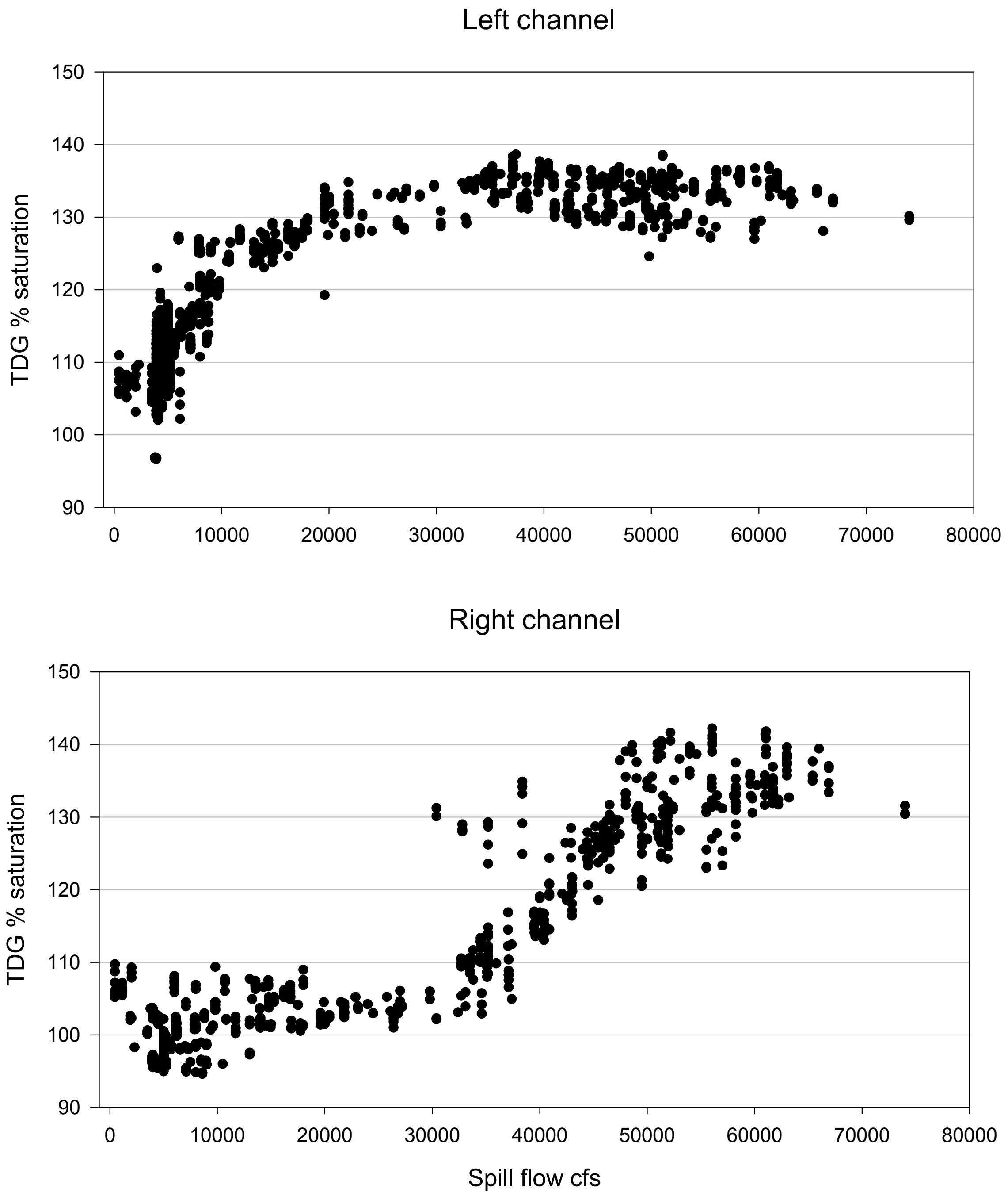

Figure 7. Spill versus TDG for the left and right channel (looking downstream) locations on the bridge below Brownlee Dam.

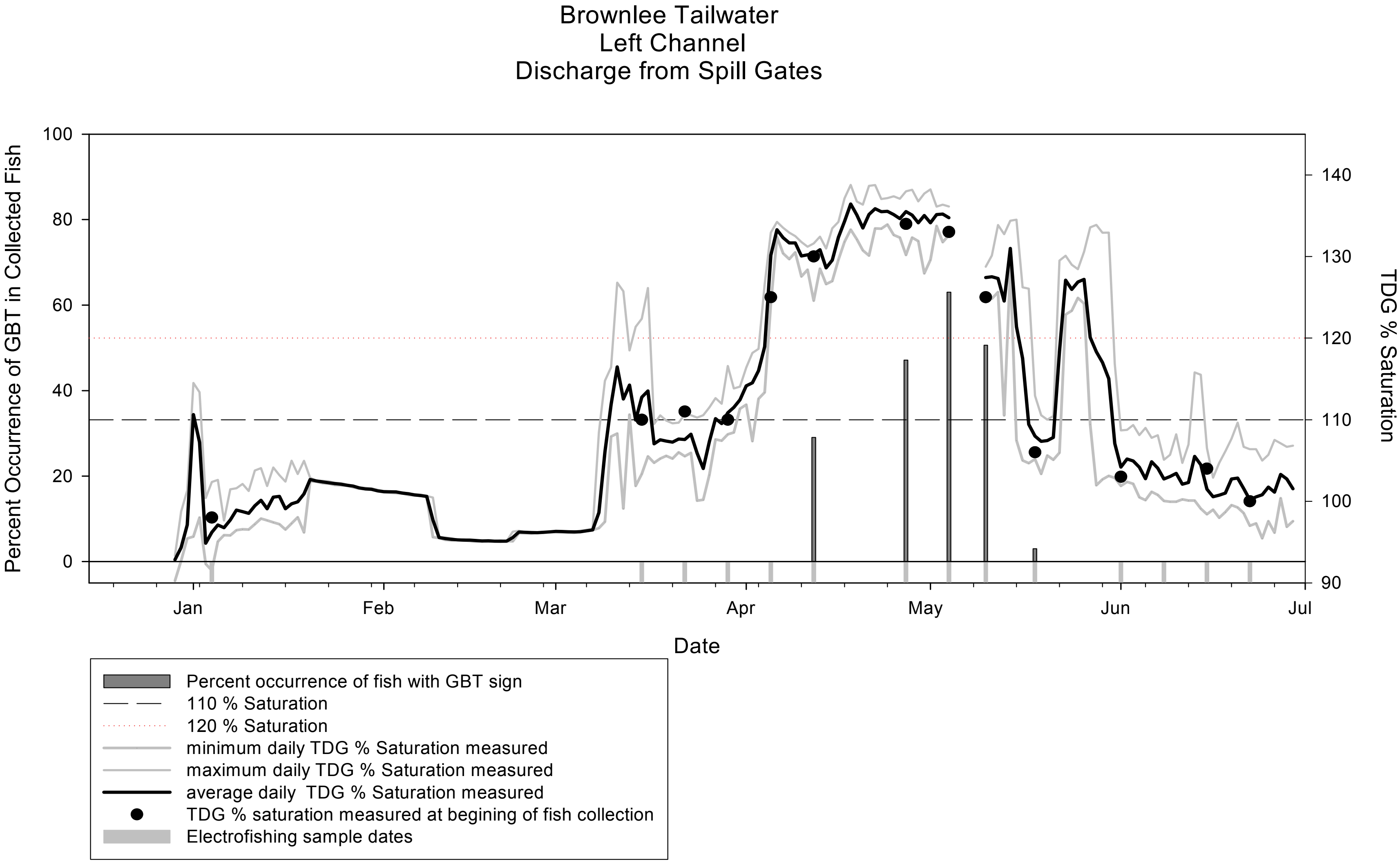

Figure 8. Percent occurrence of fish with any GBT and percent saturation of TDG taken during weekly sampling in Brownlee tailwater in the spring of 2006.

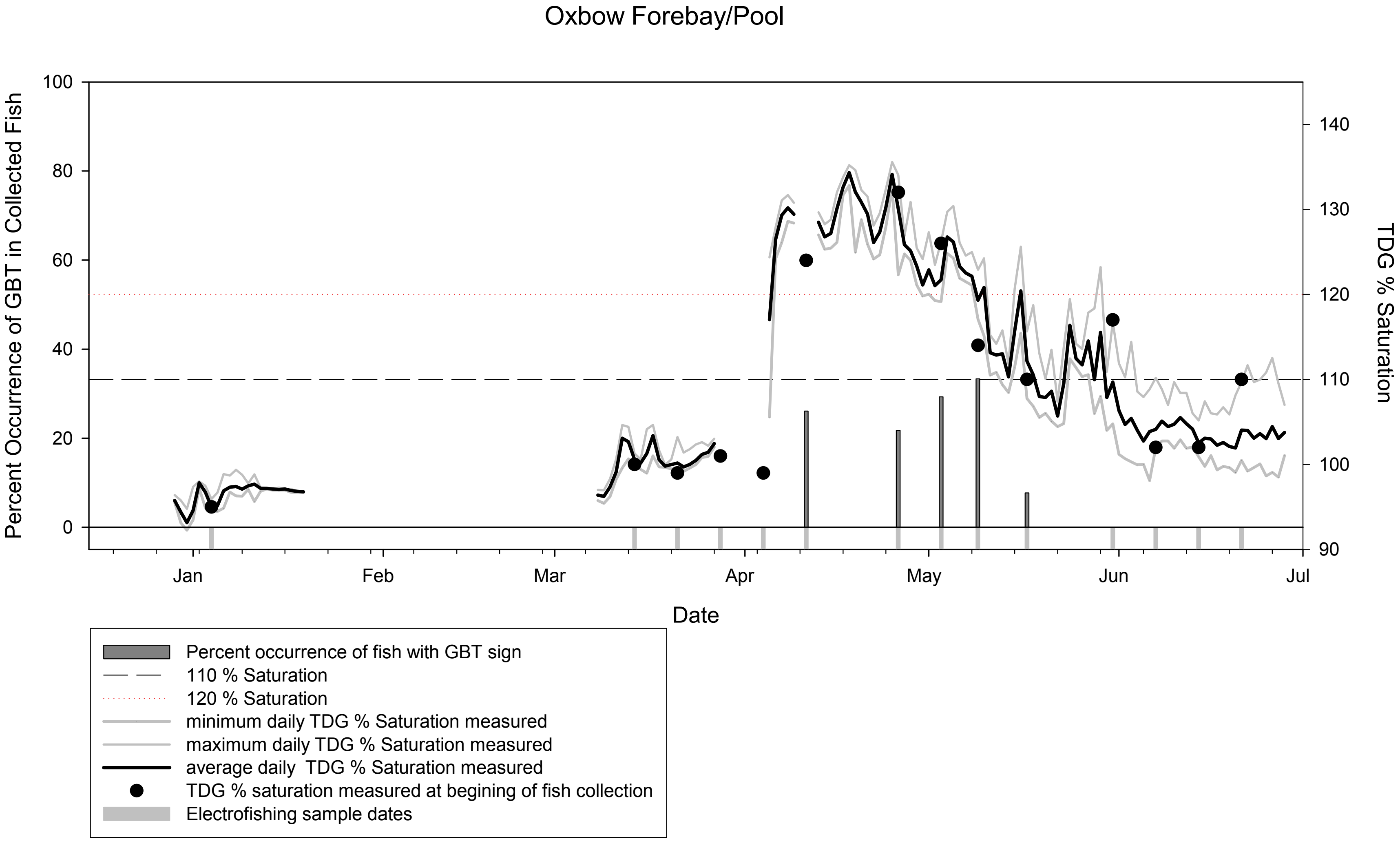

Figure 9. Percent occurrence of fish with any GBT and percent saturation of TDG taken during weekly sampling in the Oxbow forebay/pool area in the spring of 2006.

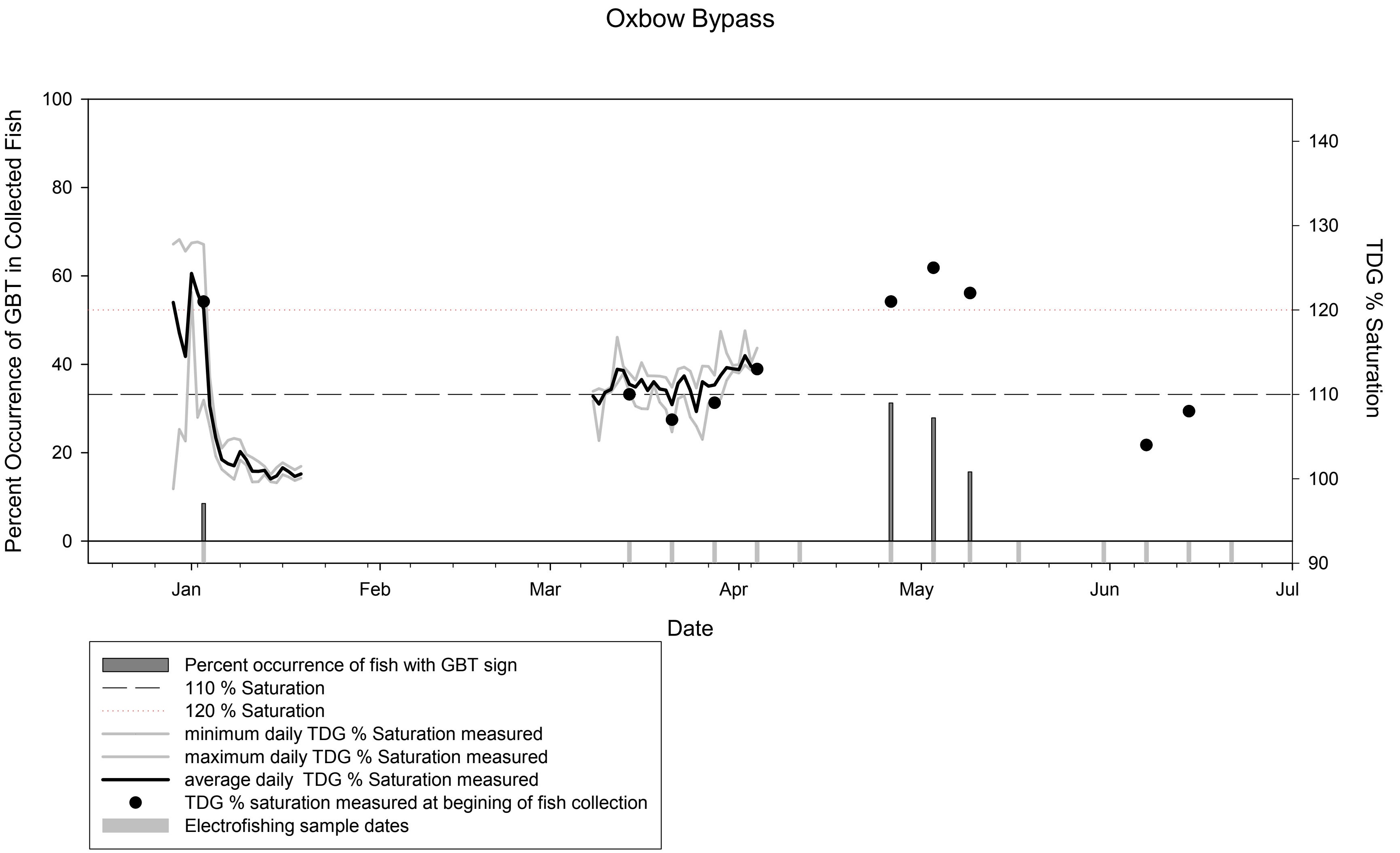

Figure 10. Percent occurrence of fish with any GBT and percent saturation of TDG taken during weekly sampling in the Oxbow Bypass in the spring of 2006.

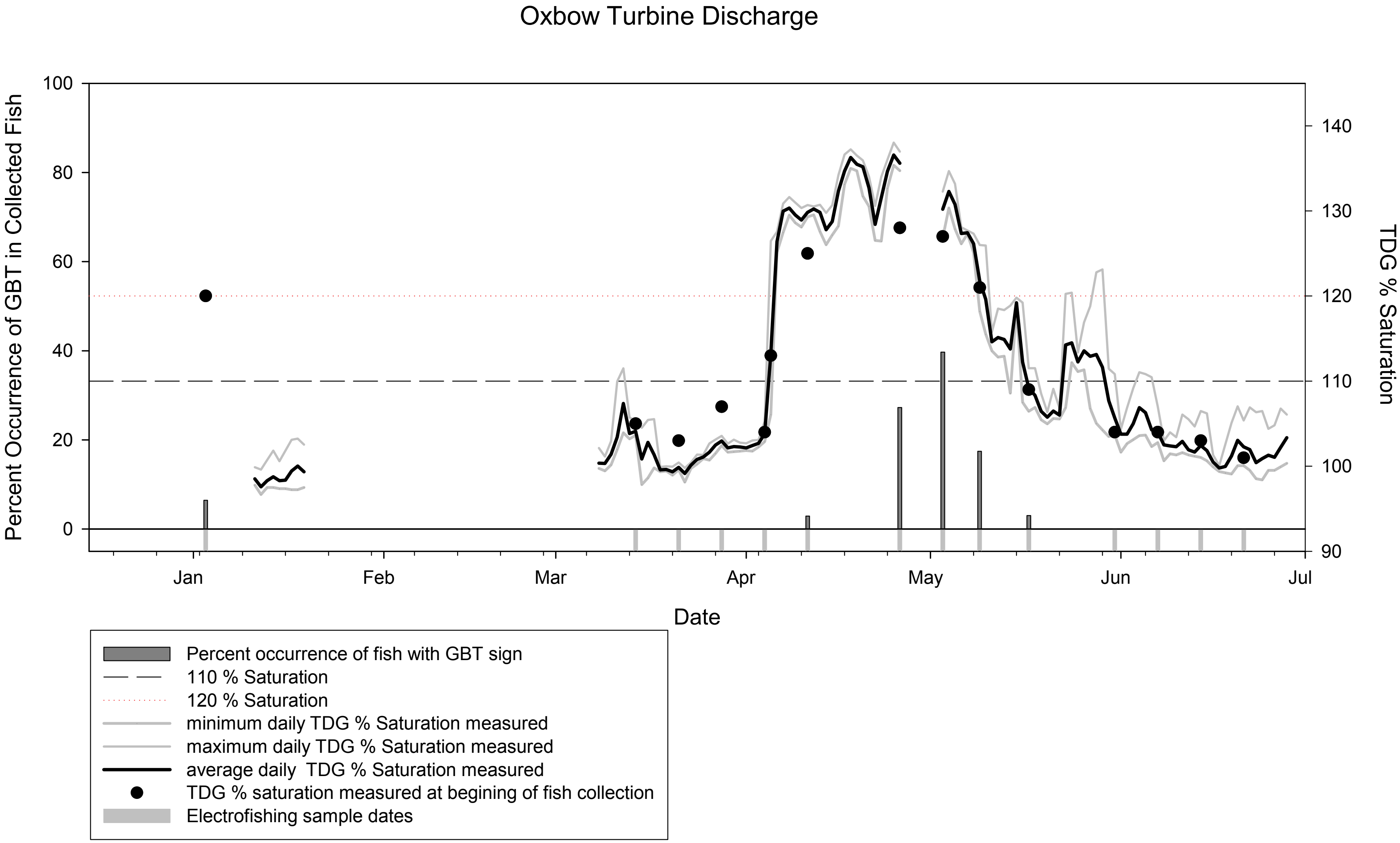

Figure 11. Percent occurrence of fish with any GBT and percent saturation of TDG taken during weekly sampling in Hells Canyon Reservoir (Oxbow Powerhouse discharge) in the spring of 2006.

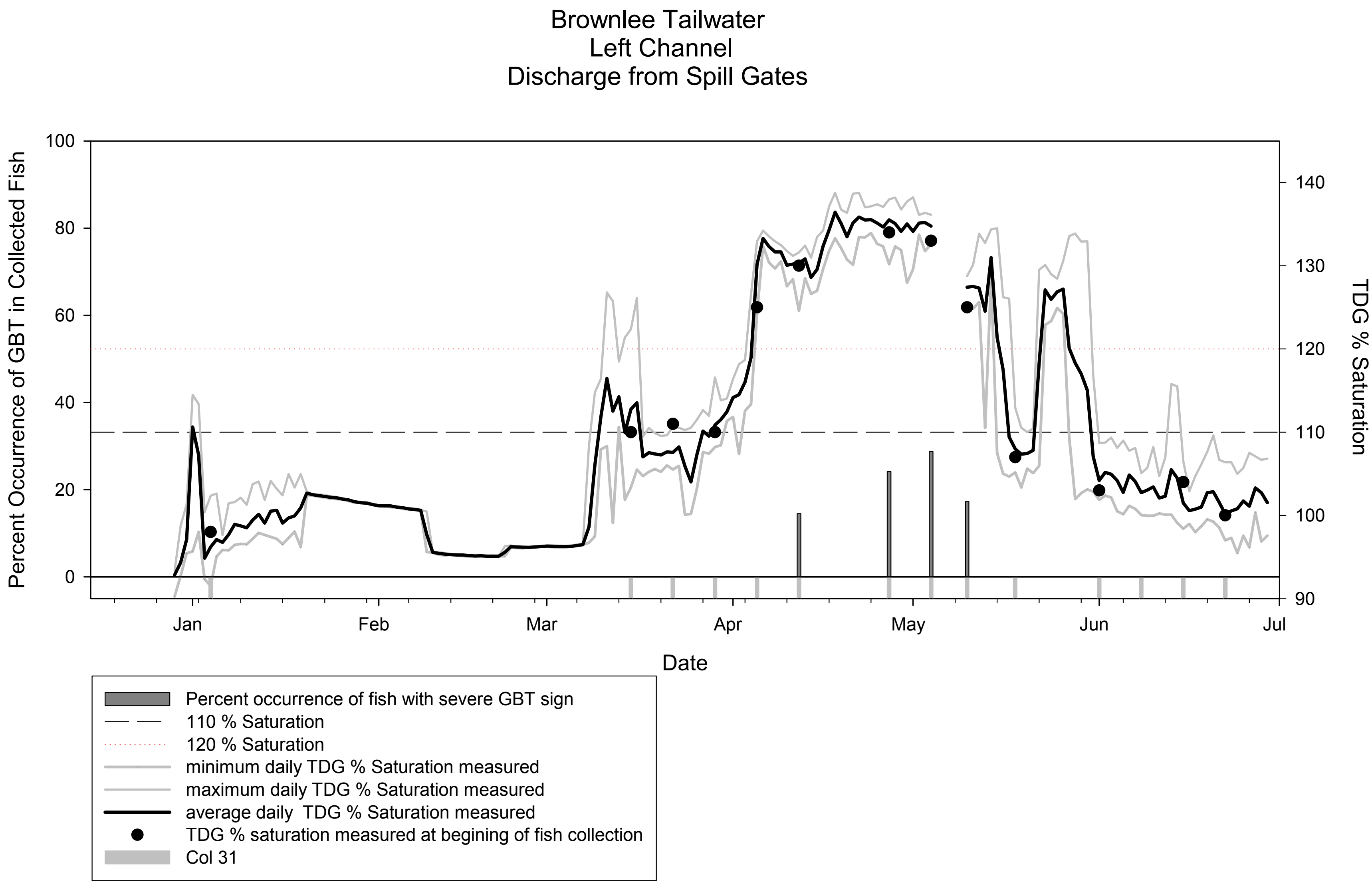

Figure 12. Percent occurrence of fish with severe GBT and percent saturation of TDG taken during weekly sampling in the Brownlee tailwater in the spring of 2006.

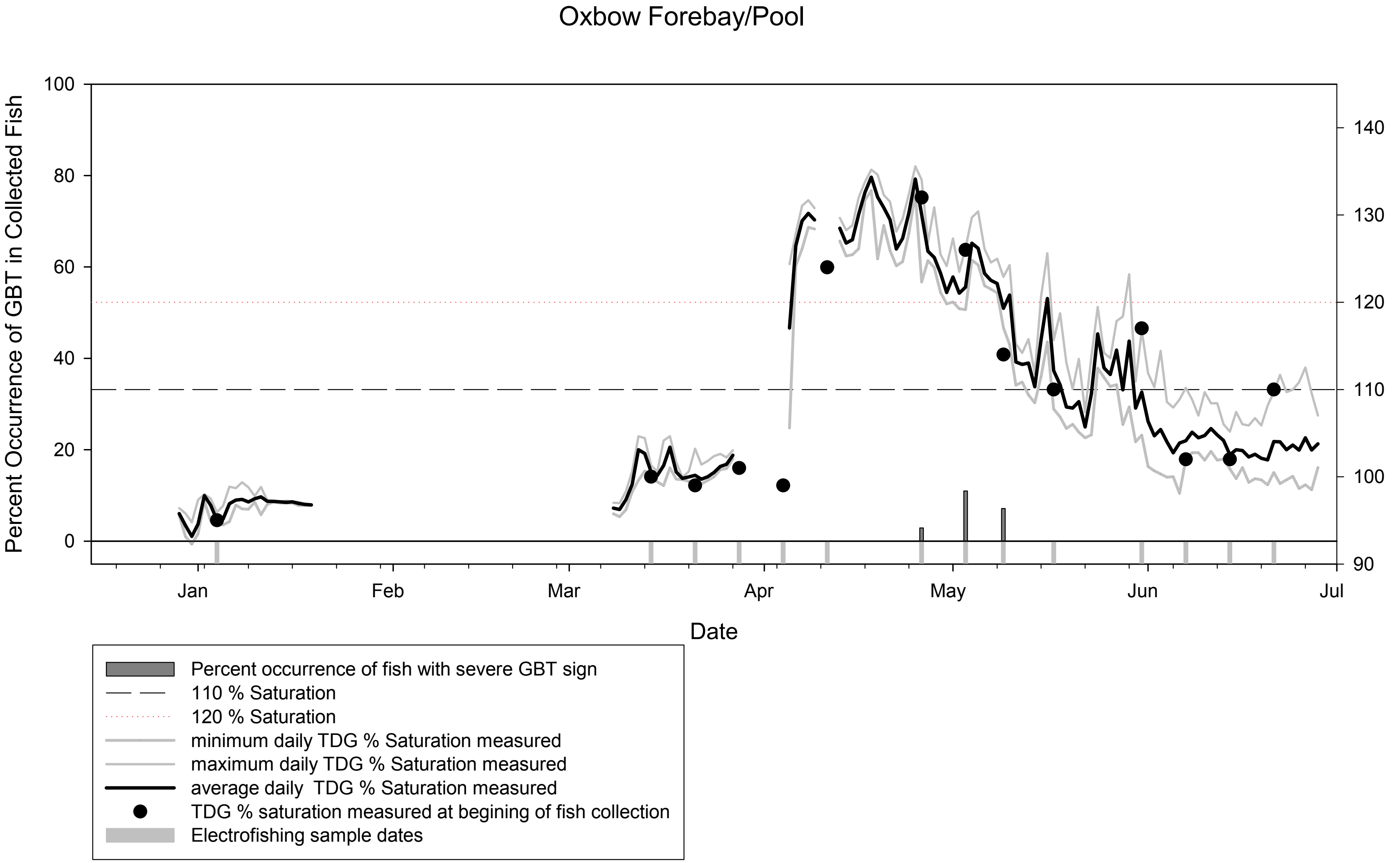

Figure 13. Percent occurrence of fish with severe GBT and percent saturation of TDG taken during weekly sampling in the Oxbow forebay/pool area in the spring of 2006.

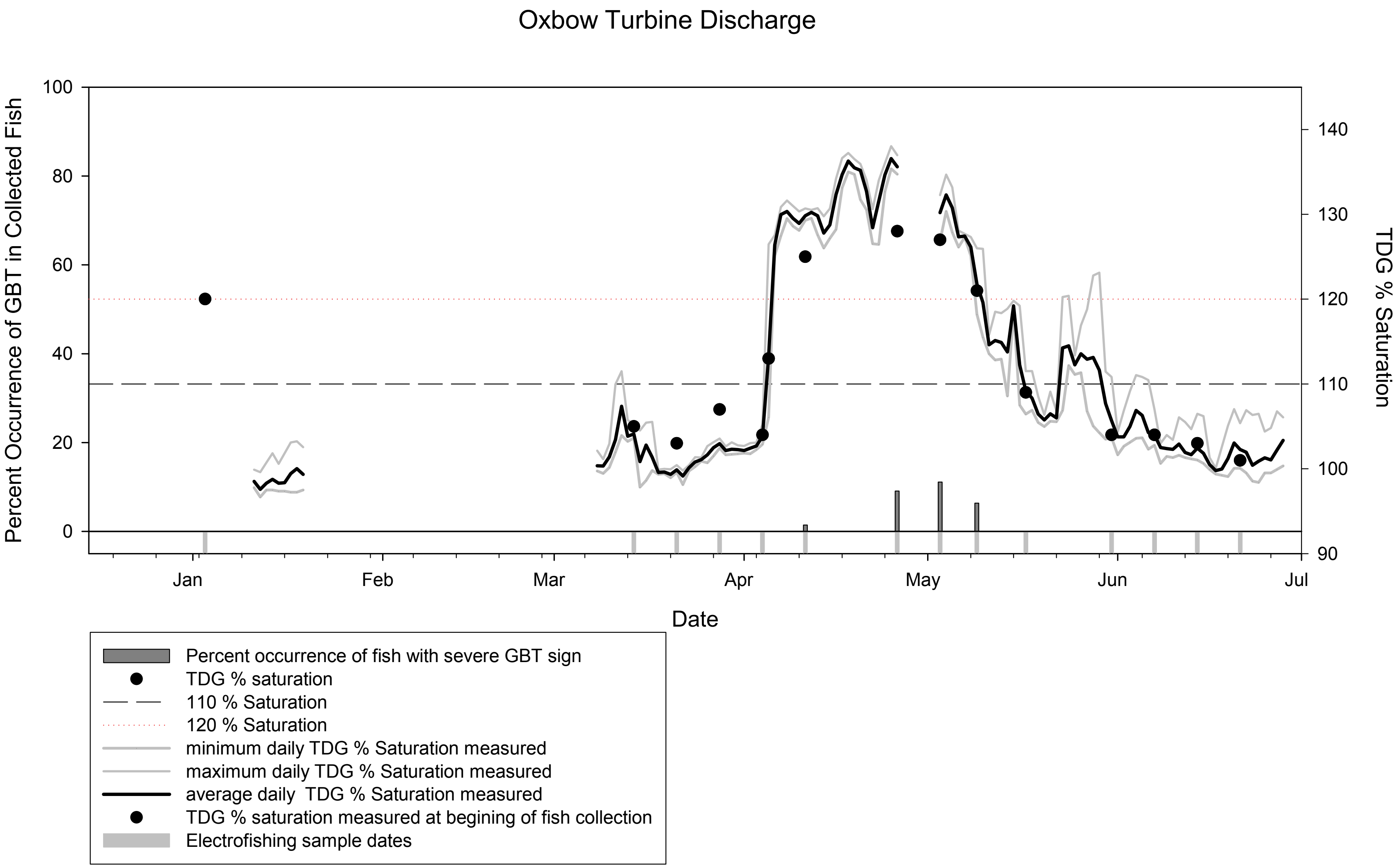

Figure 14. Percent occurrence of fish with severe GBT and percent saturation of TDG taken during weekly sampling in Hells Canyon Reservoir (Oxbow Powerhouse discharge) in the spring of 2006.

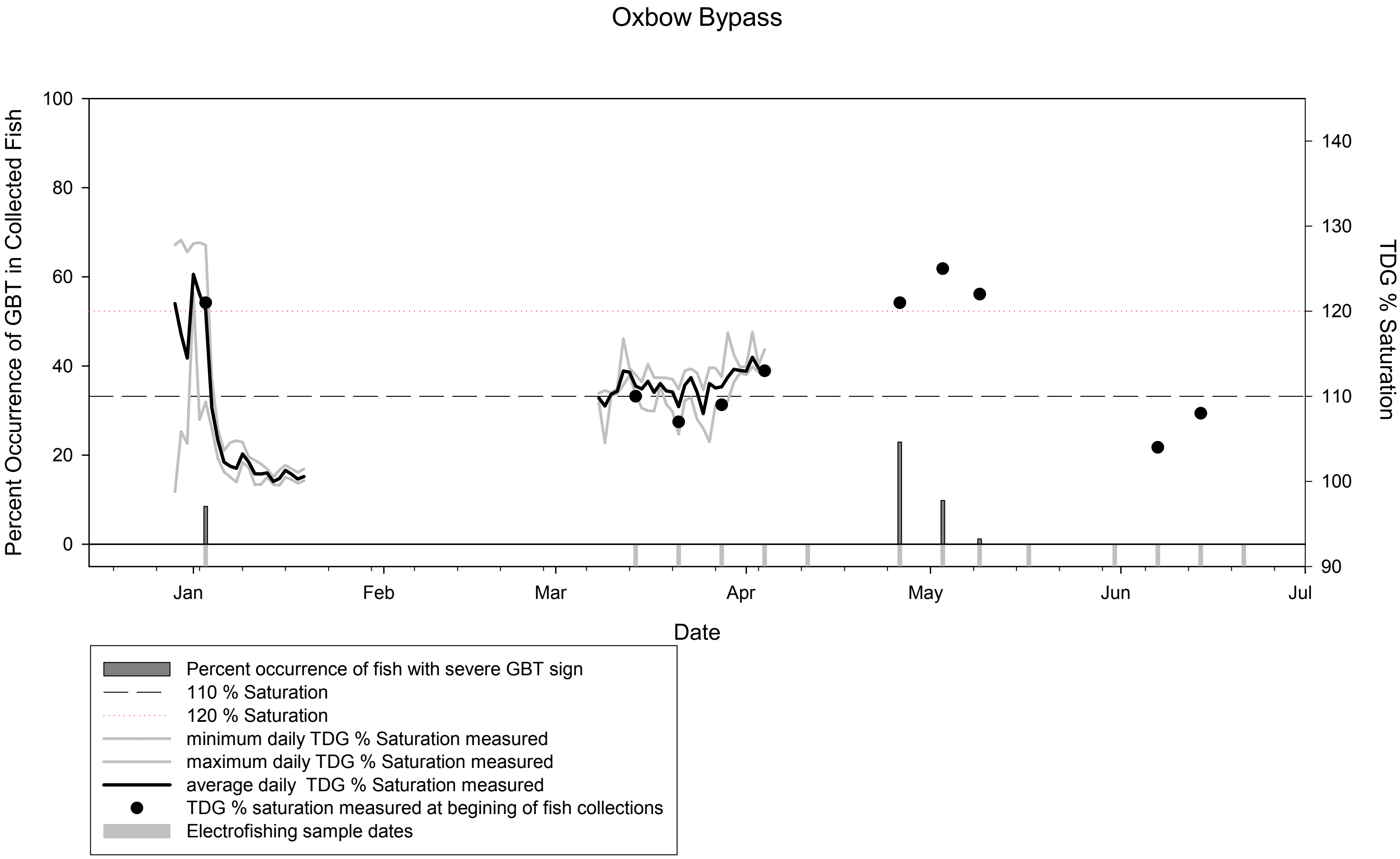

Figure 15. Percent occurrence of fish with severe GBT and percent saturation of TDG taken during weekly sampling in the Oxbow Bypass in the spring of 2006.

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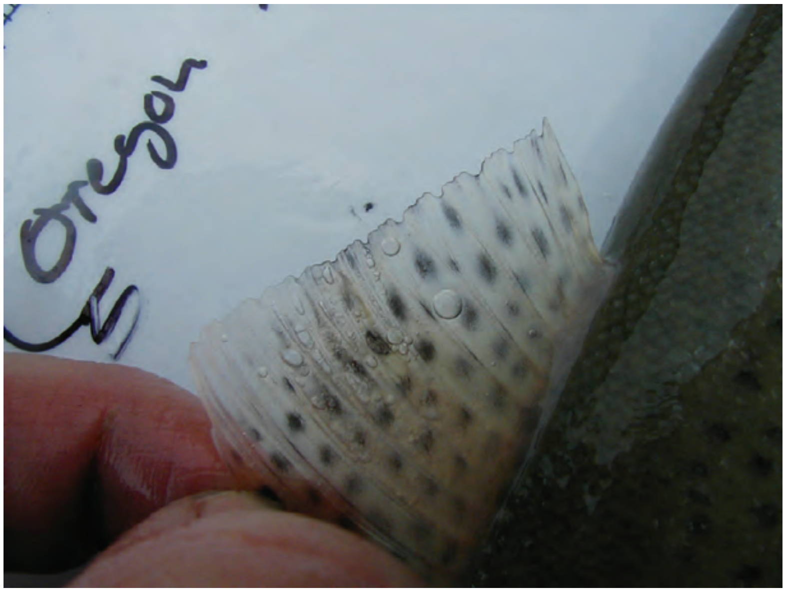
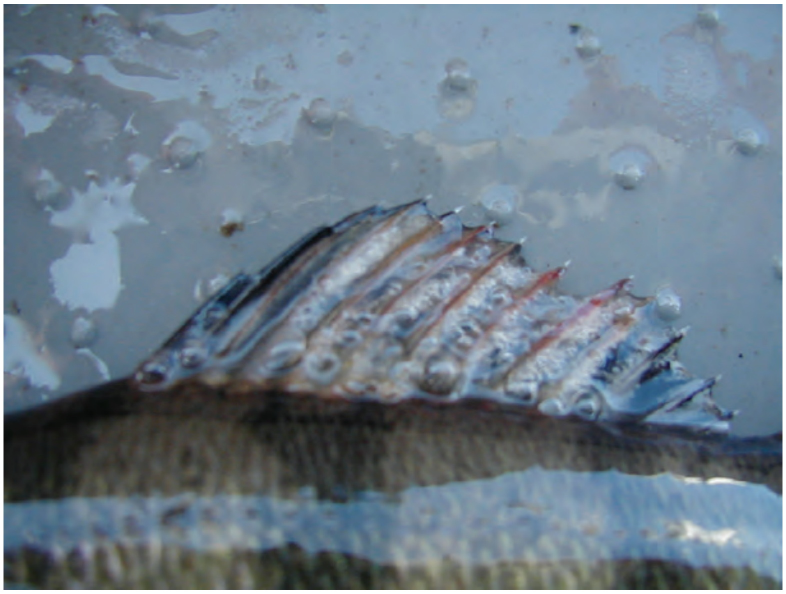
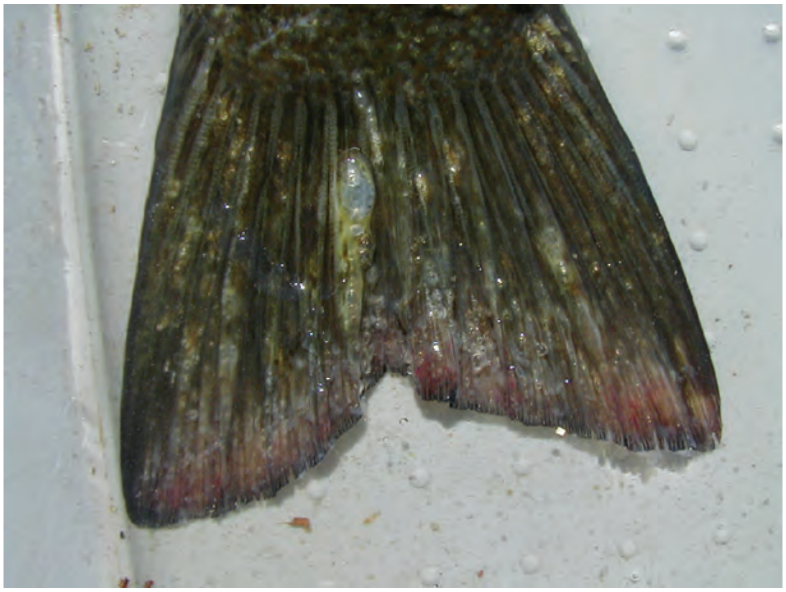
Appendix 1. Wild rainbow trout (total length = 332 mm) collected in the Oxbow Powerhouse discharge section on April 12, 2006, with GBT present in dorsal fin. The dorsal fin was given a rank of 2 (5%–25%). TDG was 132% of saturation.



Appendix 2. Yellow perch (total length = 184 mm) collected in the Oxbow forebay/pool area on May 3, 2006, with GBT present in the dorsal fin. The dorsal fin was given a rank of 4 (50%–100%). TDG was 126% of saturation.



Appendix 3. Smallmouth bass (total length = 335 mm) collected in the Oxbow forebay/pool area on May 3, 2006, with GBT present in the caudal fin. The caudal fin was given a rank of 4 (50%–100%). TDG was 126% of saturation.



Appendix 4. Mountain whitefish (total length = 241 mm) collected in the Oxbow Powerhouse discharge below the bridge on April 11, 2006, with GBT present in the dorsal fin. The dorsal fin was given a rank of 4 (50%–100%). TDG was 124% of saturation.

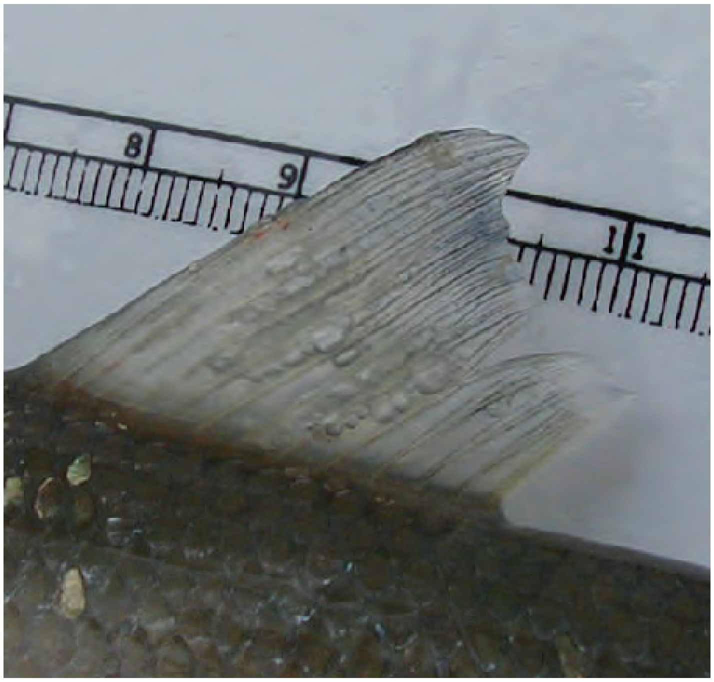


Exhibit 6.6-1

August 2012 Brownlee Reservoir hypolimnion and discharge water column toxics report, with attachments to the Brownlee Reservoir hypolimnion and discharge water column toxics report

HyQual
Hydraulics
Hydrology
Water Quality

Brownlee Reservoir Hypolimnion and Discharge Water-Column Toxics Report

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August 2012

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Final

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1. INTRODUCTION

Idaho Power Company (IPC) is assessing the effects of using cold water from the hypolimnion of Brownlee Reservoir to cool discharge waters. Cold water in the hypolimnion could be mixed with water from the upper layers of the reservoir, passed through the turbines, and discharged downstream. Water-quality samples were collected in Brownlee Reservoir and its discharge to assess water-quality "parameters of concern," generally referred to in this report as organic and inorganic toxics. Additional sampling has been conducted this spring to assess toxics levels in reservoir sediments that could also affect downstream water quality if sediments were entrained while accessing cooler hypolimnetic waters.

This report presents Brownlee Reservoir hypolimnion and discharge organic and inorganic toxics concentrations, along with the field and laboratory methods used, laboratory reporting levels (RL) (i.e., limits of quantification [LOQ]), the quality assurance and quality control (QA/QC) procedures, and a discussion of results. In addition to comparing organic and inorganic toxics concentrations with criteria, concentrations of the hypolimnetic waters within Brownlee Reservoir are compared with the concentrations of water discharging from the reservoir to assess potential changes in toxic concentrations that could occur if hypolimnetic waters are accessed.

The reservoir is the uppermost reservoir of the Hells Canyon Complex (HCC), located along the boundary of Idaho and Oregon (Figure 1).The Snake River upstream of Brownlee Reservoir drains a basin of approximately 72,590 square miles. This land is located primarily in southern Idaho but also includes land in Oregon, Nevada, and Wyoming. Most of Idaho's population (over 1.5 million people) live in southern Idaho, and many cities discharge (directly or indirectly) wastewater and stormwater to the Snake River or its tributaries, impacting downstream water quality. Agriculture, a significant land use in the basin, is also identified as a major nonpoint source of sediment, nutrients, and pesticides in many water-quality plans, referred to as total maximum daily loads (TMDLs) (e.g., IDEQ and ODEQ 2004). Additionally, IDEQ and ODEQ (2004) identified legacy mining and natural loading, both associated with geological deposits within the Owyhee and Weiser river watersheds, as primary sources of mercury in the southwestern Snake River basin.

The water samples were collected in Brownlee Reservoir and the discharge below Brownlee Dam in late October 2010 (Harrison and Hinson 2011) and 2011. 2011 was an unusually high-flow year, while 2010 was a low-flow year (USGS 2011). Because of flood-control operations in 2011, a shallower and slightly warmer hypolimnion developed as compared to low-flow years. Due to this and other operations, the flows and quality of the discharge water may vary significantly relative to more average conditions. The effect of flow year on discharge water quality will be discussed later.

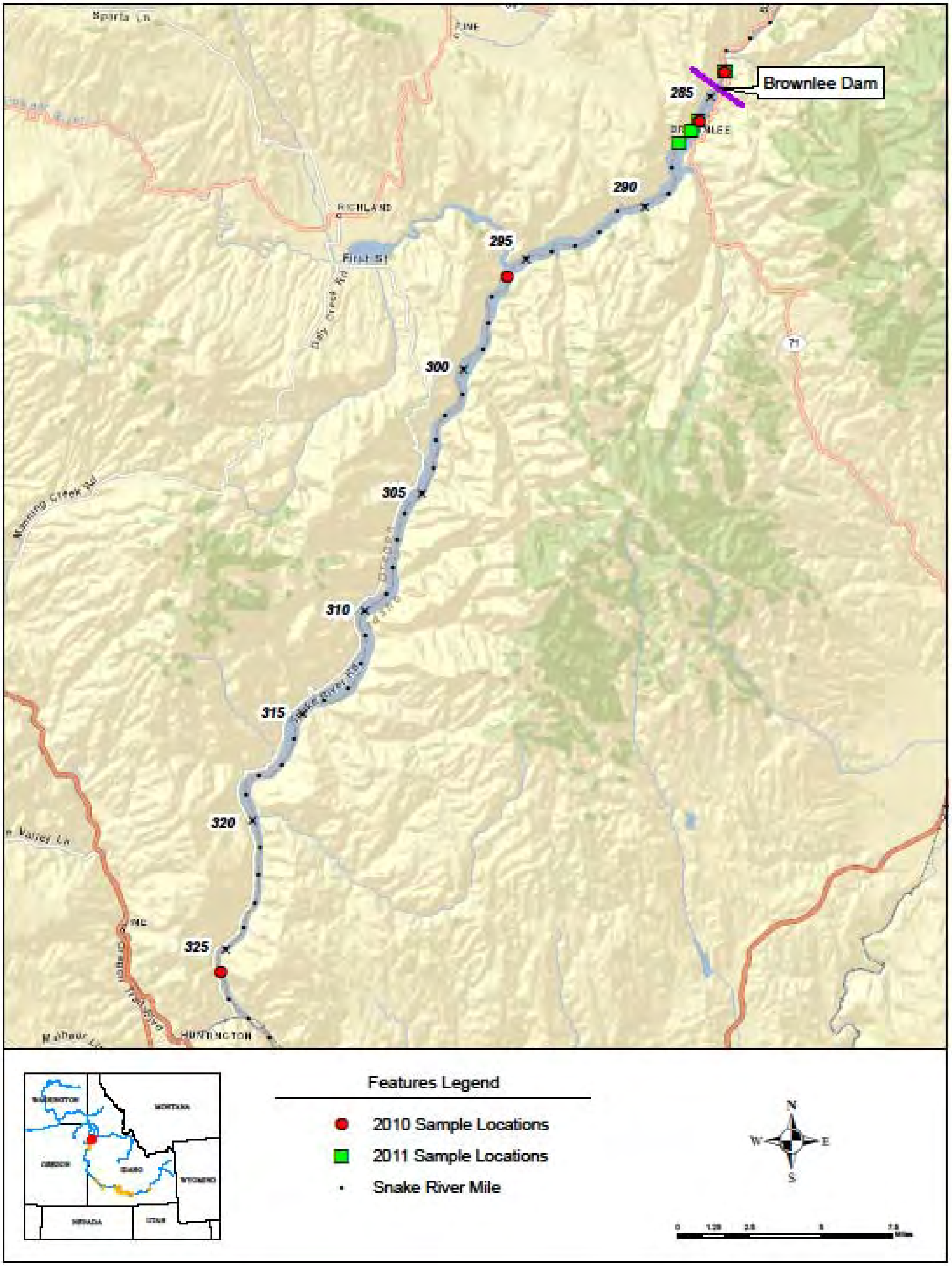

Figure 1
2010 and 2011 Brownlee Reservoir water-column toxics sampling locations

1.1. TMDLs

A water-quality improvement plan for the subbasin inclusive of the HCC, referred to as the Snake River–Hells Canyon Total Daily Maximum Load (SR–HC TMDL), was developed in the early 2000s (IDEQ and ODEQ 2004). The SR–HC TMDL established water-quality targets and load and wasteload allocations to address nutrient eutrophication concerns and related low dissolved oxygen (DO), total dissolved gases (TDG), a few legacy pesticides, and temperature. A TMDL for mercury was deferred due to a lack of data.

As part of the SR–HC TMDL, pesticides were identified as "…a water quality concern as these substances can be composed of organic chemicals or inorganic elements that are toxic to aquatic life at relatively low concentrations" (IDEQ and ODEQ 2004). The pesticides addressed in the SR–HC TMDL were 1,1,1-trichloro-2,2-bis (p-chlorophenyl)-ethane (total-DDT), referred to as DDT (dichlorodiphenyltrichloroethane), and dieldrin. Both DDT and dieldrin have been banned (in 1973 and 1987, respectively) in part due to their persistence in the environment. Each also has breakdown products that can persist. For example, breakdown products of DDT include dichlorophenyldichloroethylene (DDE) and dichlorophenyldichloroethane (DDD).

The Snake River, Brownlee, and Oxbow reservoir load allocations (IDEQ and ODEQ 2004) were developed to address concerns related to elevated levels of organics in fish tissue. Because no water-column data were available, targets and load allocations were set using Oregon's water-column criteria (then current) established for the protection of human health for the ingestion of fish and water consumption (i.e., 0.024 nanograms per liter [ng/L] and 0.071 ng/L for DDT and dieldrin, respectively). The SR–HC TMDL was developed in the early 2000s, and since that time water-quality criteria for these and many other organics have become more stringent. The more current criteria associated with the toxics found at or near reportable levels are presented in the results section of this report.

The SR–HC TMDL also established requirements to lower water temperature in the discharge from the HCC during the late fall. The cold water that accumulates in the hypolimnion of Brownlee Reservoir, the upstream-most reservoir of the HCC, could be mixed with water from the upper strata of the reservoir, passed through the turbines, and discharged downstream. The purpose of sampling water-column parameters of concern is to measure organic and inorganic toxics concentrations that could be discharged from the reservoir when accessing the cooler hypolimnetic waters and assess the potential effects on water quality in and downstream of Brownlee Reservoir. The period of focus is the last week in October when the HCC discharge temperature is typically greater than the 13° Celsius (C) criteria for salmonid spawning.

1.2. Historical Data

1.2.1. Inorganic Parameters

In general, data for most inorganic toxics (e.g., arsenic, cadmium, copper, lead, and selenium) for Brownlee Reservoir is limited. However, some fish-tissue data have been collected and provide an indication of levels affecting aquatic life. The U.S. Geological Survey (USGS) reports that fish-tissue concentrations of the inorganics listed above were generally lower in the lower Snake River Basin (e.g., in southwestern Idaho) than in the upper Snake River Basin

(Clark and Maret 1998). In contrast, mercury concentrations in fish tissues were higher in Brownlee Reservoir and have been reported in excess of Oregon’s level of concern (i.e., 0.35 milligrams [mg]/kilogram [kg]) in over 80 percent of the 1990s data for fish collected in or near Brownlee Reservoir (IDEQ and ODEQ 2004). While fish tissue consumption advisories were and are still in place for Brownlee Reservoir (IDHW 2011; ODHS 2011), a TMDL was not prepared at the time due to a lack of water-column data.

More recently, the Idaho Department of Environmental Quality (IDEQ) sampled mercury in Brownlee Reservoir on a monthly basis from May through November 2007 to prepare for a TMDL in the lower Snake River (Stone 2008). The samples were collected in multiple locations and composited for sample analyses; thus, results represent an average for the reservoir. Mercury levels in Brownlee Reservoir water samples averaged 4.8 ng/L, with the highest levels in September and lowest levels in June (i.e., 9.0 and 2.7 ng/L, respectively). In 2008, water samples analyzed for mercury were collected in the Snake River upstream of Brownlee Reservoir (Essig 2010). Reported total mercury levels of 1.71 ng/L were well below the current chronic aquatic-life criteria (12 ng/L) for the State of Oregon.

1.2.2. Organic Parameters

Water-column data to assess organic toxics (e.g., pesticides, semi-volatile organic compounds, dioxin, and phthalates) within Brownlee Reservoir are even more limited. However, recent studies upstream in the Boise River and downstream in the Columbia River provide some context. The Idaho State Department of Agriculture (ISDA) has reported on organic toxics levels in the lower Boise River, which discharges into the Snake River approximately 25 miles upstream of Brownlee Reservoir (Campbell 2010). At the Boise River sampling location (LBR-1) southwest of the city of Parma, Idaho, 13 different pesticides (10 herbicides and 3 insecticides) were detected. Of the detected pesticides, only Malathion exceeded the Environmental Protection Agency’s (EPA) chronic benchmark for invertebrates (Campbell 2010).

The EPA (2009) conducted an extensive review of organic toxics data available for the Columbia River. The subsequent report, entitled *The State of the River Report for Toxics*, focused on 4 widespread contaminants in the Columbia River Basin: mercury, DDT and its breakdown products, polychlorinated biphenyls (PCBs), and polybrominated diphenyl ether (PBDE) flame retardants. The EPA also acknowledged that toxics, including additional metals, dioxins, radionuclides, and pesticides, as well as pharmaceuticals and personal-care products, are also potential contaminants of concern. Regarding concentrations of DDT compounds in the Columbia River and its wildlife, the EPA concluded that concentrations have decreased over the last 20 years but that DDT is still regularly detected in the fish, plants, and sediments of the river and many of its tributaries.

2. METHODS

2.1. Parameter Selection

Sampling was conducted in late October 2010 and 2011. In 2010, a small set of inorganic parameters (17) were the focus, while in 2011, a much larger set of organic parameters (almost 500) along with total and methyl mercury (MHg) were analyzed.

The inorganic toxics selected for the 2010 laboratory analysis were parameters with aquatic-life freshwater acute and chronic criteria as established in water-quality standards for Idaho and Oregon (*Idaho Administrative Procedures Act* [IDAPA] and Oregon Administrative Rules [OAR]). The laboratory analysis and methods are provided in Table 1. Trivalent chromium is calculated as the difference between total chromium and hexavalent chromium. The LOQ (i.e., practical qualification limits [PQL]) for these parameters are provided in Attachment A.

Table 1
Summary of analyses included in the 2010 inorganic toxic analytes

Parameter	Method
Arsenic	EPA 200.8
Cadmium	EPA 200.8
Calcium	EPA 200.8
Chromium	EPA 200.8
Copper	EPA 200.8
Iron	EPA 200.8
Lead	EPA 200.8
Magnesium	EPA 200.8
Nickel	EPA 200.8
Selenium	EPA 200.8
Silver	EPA 200.8
Total Hardness by 2340B	EPA 200.8
Zinc	EPA 200.8
Nitrogen, Ammonia	EPA 350.1
Chromium, Hexavalent	SM 3500-Cr B (Online)
Cyanide	SM 4500-CN-E
Chromium, Trivalent	Trivalent Chromium Calculation

The large set of organic parameters selected for analysis in 2011 included current-use and banned pesticides (i.e., insecticides, fungicides, and herbicides) and other parameters of concern, such as semi-volatile anthropogenic organic compounds, dioxin, and inorganic mercury. These parameters are either considered ubiquitous in the environment or related to agricultural land use. The list of parameters was selected by the Oregon Department of Environmental Quality (ODEQ), IDEQ, U.S. Fish and Wildlife Service (FWS), and IPC during a series of meetings conducted in summer 2011. Parameters were excluded if there was limited potential for concern (e.g., volatile organic compounds [VOCs]) or there were other available data considered sufficient for assessment. Water samples collected in 2011 were shipped or delivered to 4 analytical laboratories, each selected according to targeted analytes and/or detection limit requirements. The proposed list of analytes summarized in Table 2 was captured through a series of screens where 1 laboratory procedure returned results for a number of similar compounds (Attachment A) or through targeted individual analyses when necessary.

Table 2
Summary of 2011 toxic analytes (or screens) and EPA methods

List/Screen	EPA Methods
Idaho Pesticides	
Carbamates Pesticides	632
Chlorinated Acid Herbicides	515.2
Gas Chromatography–Mass Spectrometry (GCMS) Extras	507/508
Organochlorine Pesticides	508
Organophosphate Organonitogen Pesticides	507
Urea Pesticides	632
Oregon Organics	
Oregon Department of Agriculture (ODA) Pesticides	8141, 8081, 8770, 8321
Pollutant of Interest (POI) list organics	8141, 8081, 8770, 8321
Oregon Table 20	
Semi-Volatile Organic Compounds	8270
Polynuclear Aromatic Hydrocarbons (PAHs)	8270 (SIM)
PCBs	8082
Pesticides	8081, 8150, 8270
Dioxin	8290
DDTs	8081
Phthalates	8270
Inorganic	
Mercury (Total)	1631E
Methyl Mercury	1630

2.2. Sampling Locations

In 2010, a total of 6 water samples were collected at 4 river mile (RM) locations (Figure 1 and Table 3). In Brownlee Reservoir near the dam at RM 286, 2 replicate samples were collected to sample the eplimnion (approximately 30 feet) and 1 sample was collected from the hypolimnion (approximately 175 feet). A second hypolimnion sample was collected upstream at RM 296. Samples were also collected at the upper end the reservoir (RM 326) and from the discharge (RM 283.9).

Table 3
2010 sample location and information

Sample ID	Description	Depth (ft)	Elevation (ft)	RM (mile)
RM 283.9	Discharge below Brownlee Dam	3.3	1,802	RM 283.9
RM 286 EPI1	Epilimnion upstream dam	29.5	2,020	RM 286.0
RM 286 EPI2	Epilimnion upstream dam	29.5	2,020	RM 286.0
RM 286 HYPO1	Hypolimnion upstream dam	175.0	1,875	RM 286.0
RM296MC 50 meters (m)	Upstream end of hypolimnion	164.0	1,886	RM 296.0
RM326MC 5 feet (ft)	Inflow	5.6	2,044	RM 326.0

In 2011, 3 discrete water samples were collected from the hypolimnion of Brownlee Reservoir (RM 286, 286.5, and 287) at a depth of over 200 feet (Table 4). Additionally, 3 discrete water samples were collected downstream of Brownlee Dam (RM 283.8) from the left, middle, and right channel (LC, MC and RC, respectively) of the reservoir discharge.

Table 4
2011 sample location and information

Sample ID	Description	Depth (ft)	Elevation (ft)	RM (mile)
IPC-1	Hypolimnion—286	213	1,822	286.0
IPC-2	Hypolimnion—286.5	212	1,823	286.5
IPC-3	Hypolimnion—287	212	1,823	287.0
IPC-4	Brownlee Discharge—RC	~5	1,803	283.8
IPC-5	Brownlee Discharge—MC	~5	1,803	283.8
IPC-6	Brownlee Discharge—LC	~5	1,803	283.8

2.3. Sampling Methods

The following discussion provides information on water-column sampling methods, QA, and laboratory RLs for the 2010 and 2011 sampling events. Many of the procedures and protocol used were based on established guidance for sampling low levels of metals (e.g., EPA 1996). Additional information on procedures, as well as sections of a *Quality Assurance Sampling Plan* prepared for the 2011 event (not included below), are provided in attachments B and C.

The reservoir water samples were collected from near each specified RM (tables 3 and 4). Reservoir discharge samples were collected approximately ¼-mile downstream of Brownlee Dam. All water samples, including discharge samples for field measurements, were collected with a peristaltic pump and pre-cleaned tubing cut to lengths specific to each sample depth. The pre-cleaning and sampling methods conformed to ultra-clean sampling techniques (EPA 1996; Florida 2008).

A detailed description of the sampling protocols used for the 2011 sampling of organic toxics and mercury are presented as follows. For the most part, similar procedures were used for the 2010 sampling of inorganic toxics. Differences in sample collection methodology in 2010 included the selection of tubing appropriate for inorganic sampling. Also, some of the ultra-clean techniques recommended for low-level mercury sampling were not used in 2010, such as discharging samples into a “glove box” to limit airborne exposure and wearing Tyvek suits to lower concern with contamination from clothing.

Key equipment used for the field sampling effort included the following:

1. Pump and pump apparatus: Pegasus Alexis variable-speed peristaltic pump with internal battery.

2. Flexible peristaltic pumphead tubing: SEBS “C-FLEX” tubing was used for mercury (EPA 1996), and TYGON “Ultra Chemical Resistant” tubing was used for organics.

3. Tubing extending from pumphead tubing to depth—TEFLON fluorinated ethylene propylene (FEP).

Tubing was pre-cleaned and packaged to minimize field preparations. The procedures for cleaning sample tubing (EPA 1996; Florida 2008) were completed in a laboratory prior to sampling and included the following:

1. Rinse tubing with a 10-percent (by volume) hydrochloric acid bath and rinse with deionized water.

2. Immerse tubing in a 10-percent (by volume) hydrochloric acid bath for a minimum of 8 hours.

3. Dry tubing by purging with mercury-free air or nitrogen at the clean bench.

4. Double bag the tubing in a new plastic, self-sealing bag.

All water samples were collected using a peristaltic pump and sterilized tubing that was lowered to the appropriate depth for sampling. All sample containers used were prepared and provided by the laboratories responsible for sample analysis. The boat-end of the tubing was plugged prior to the descent of the sampling-end of the tubing to prevent inflow of water from non-sampling depths as the tubing was lowered through the water column. A weight was attached to the sampling-end of the tubing that allowed the vertical descent of the tubing and allowed the tubing to hang perpendicular to the surface of the water. When the tubing reached the appropriate sampling depth, the tubing “plug” was removed and the peristaltic pump started. Water was allowed to purge over the side of the boat or into a bucket until approximately 5 gallons of water were pumped through the tubing system prior to sample collection. During sample collection, sample containers were filled without pre-rinse directly from the pump head tubing discharging inside a plexiglas “glove box” to limit contact with airborne particles. Following sample collection, sample container caps were rinsed with sample water 3 times prior to replacement on each sample container inside a plexiglas “glove box” (the latter was used in 2011 sampling only).

All water samples were collected using the “clean hands” sampling methodology developed by the EPA (1996) for sampling ambient waters for trace metals. The collection of water samples was carried out by one individual designated as “clean hands,” one designated as “dirty hands,” and a third responsible for boat operation and other “non-clean” tasks. All operations involving contact with the sample bottle and with the transfer of the sample from the sample collection device to the sample bottle were handled by the individual designated as “clean hands.” “Dirty hands” was responsible for all activities not involving direct contact with the sample. All hands on deck wore sterile nitrile gloves and Tyvek suits to prevent contamination from skin and clothing (Tyvek used in 2011 sampling only). All hands changed gloves between samples; “clean hands” changed gloves and Tyvek suits between samples.

The following protocols describe the collection of each water sample:

1. After the sampling equipment was in place, “clean hands” put on a new set of sterile gloves.

2. “Dirty hands” opened the cooler containing the sample bottles and unzipped the outer bag; “clean hands” reached into the outer bag, opened the inner bag, and removed the bottle.

3. “Dirty hands” removed the zip tie from the end of the silicon tubing that was inserted into the pump and turned on the pump. When water began flowing from the end of the tubing in the pump, the tubing was purged until approximately 5 gallons of water were pumped through the tubing system.

4. Inside the glove box (in 2011 only), “clean hands” removed the cap to the sample container and immediately began filling the container. After filling, the sample container cap was rinsed with sampling water three times before replacement. Sample containers were not pre-rinsed. After the container was filled near the top, “clean hands” replaced the cap. Outside the glove box, “clean hands” put the bottle back into the inner bag, then zipped the inner bag. “Dirty hands” closed the outer bag and placed it in a cooler.

5. Number 4 was repeated until all sample containers (5 containers per sampling location) were filled with the sample water.

The third team member was responsible for completing the necessary sample documentation (e.g., to document the sampling location, time, sample number, etc).

2.3.1. QA and QC

In 2010 and 2011, additional samples were collected to assess data quality. These samples included replicate samples, equipment blanks, and field blanks for mercury. QC samples were generally collected following the procedures discussed previously. The results of QC sampling are presented in Attachment C.

Laboratory QA/QC was also included in this study as part of standard laboratory procedures. This included method blanks, laboratory control spikes, sample duplicates, and matrix spikes/matrix spike duplicates (MS/MSD), along with the accuracy and precision data.

Standard laboratory reporting included copies of the Chain of Custody, a Sample Condition Upon Receipt report, and a batch QC cross-reference table. The results of the laboratory QC procedures were provided with the raw laboratory results available on request to IPC.

2.3.2. LOQ and Method Detection Levels

The following laboratory results are either above or near the LOQ or the lower method detection level (MDL) when provided by the laboratory. The LOQ, which may be listed by the various labs as RLs, PQLs, etc. in the laboratory reports, are established by each laboratory based on sample characteristics, equipment, procedures, and laboratory QA/QC results. The LOQ are given in the tables for the summarized parameters and in Attachment A for all parameters. The raw data in the laboratory reports are available on request.

As stated previously, some tables provide results at or below the MDL, which are lower than LOQ and therefore less reliable in terms of quantification. This project requires analytical data based on various criteria and benchmarks that can be below the LOQ (e.g., Table 20 in OAR 340-041 n.d.), and therefore MDLs were requested. When provided by the laboratory, these results are summarized in the following tables. However, a value less than the laboratory's LOQ is considered an estimate and is only useful for qualitative purposes, such as presence or absence.

Additionally, some of the data-quality indicators did not meet the project's specifications. These results are provided in Attachment C and appropriately flagged if provided in the report. To the extent possible, the apparent causes of the problems were identified and limitations on data explained.

3. RESULTS

The results from 2010 inorganic and 2011 organic and mercury sampling events are summarized in tables 5–7. Results are compared with criteria and benchmarks established by the EPA, Oregon, and Idaho. However, the primary focus was on assessing the toxics in the cooler hypolimnion waters near the dam of Brownlee Reservoir and comparing them with the warmer discharge waters. To accomplish this objective, results for samples collected near the dam (RM 286) in the hypolimnion are compared with samples collected in the reservoir discharge (RM 283). For some parameters, the maximum concentrations are presented, as these provide worst-case comparisons.

Results for many of the parameters analyzed were below the laboratory RLs. Generally, only concentrations above or near the LOQ are provided. However, some organic concentrations near or below the lower MDL are provided. Results below the LOQ are considered estimated values and used only to indicate the presence of the analyte.

Prior to the collection of water samples, water-column temperature and DO were measured using a Sea-Bird electronics profiling instrument to help establish the depth of the hypolimnion. These were used to generate isopleths showing reservoir conditions during sampling events (figures 2 and 3). Additional field data measured at sampling locations are provided in

Attachment D. These include the temperature and DO of the discharge water downstream of Brownlee Dam measured with a HYDROLAB.

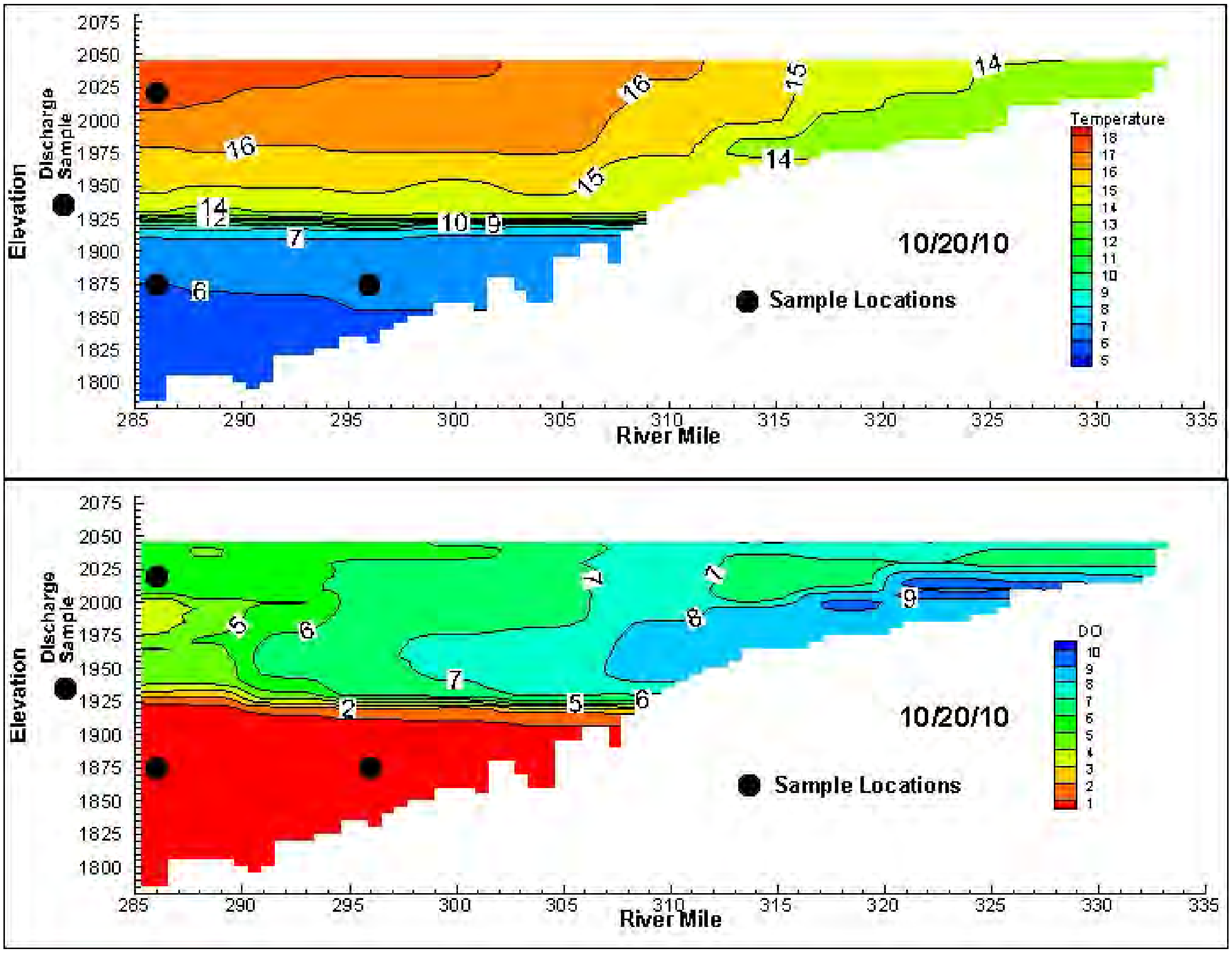

Figure 2
Brownlee Reservoir temperature and DO contour plots measured on October 25, 2010, prior to reservoir sampling

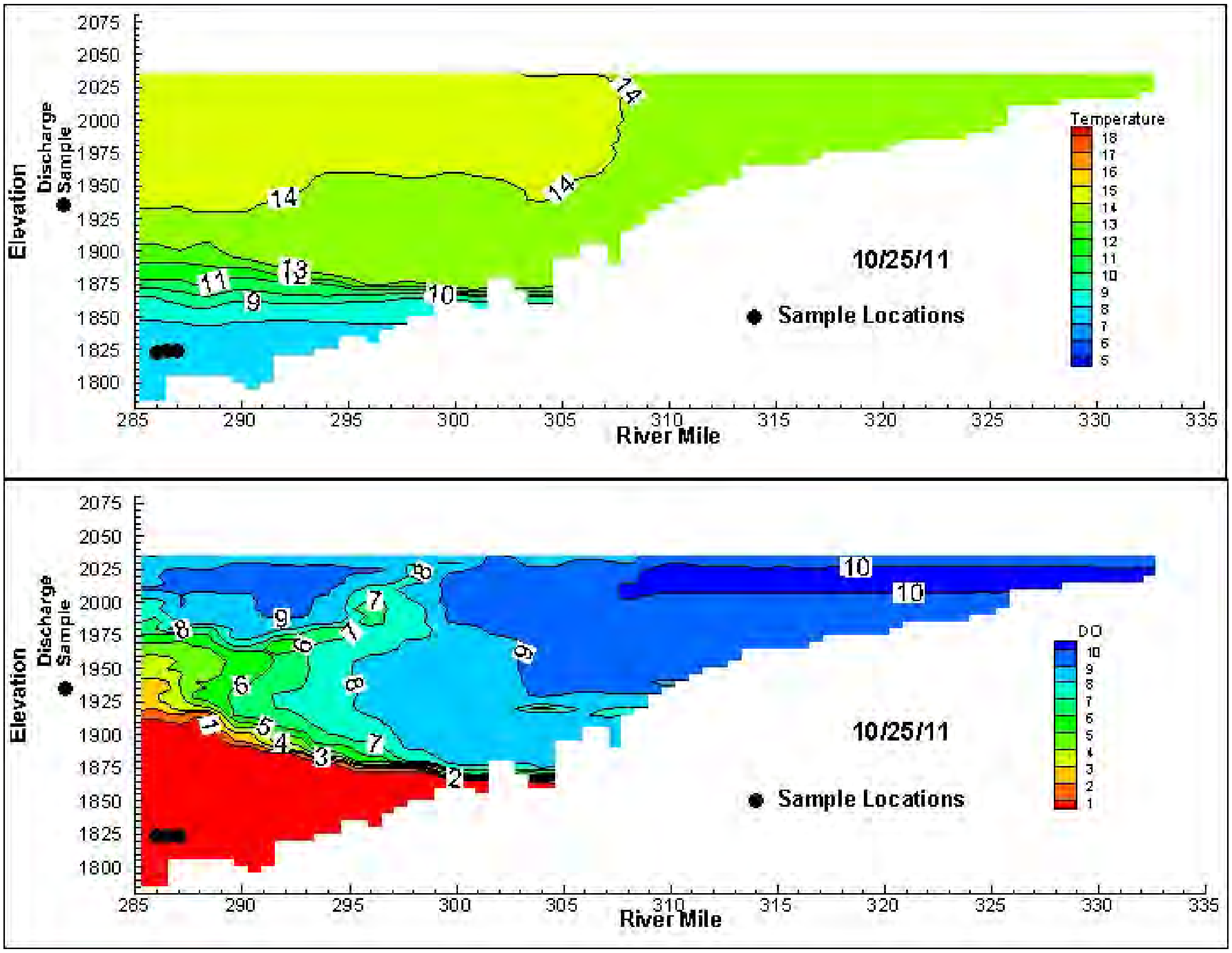

Figure 3
Brownlee Reservoir temperature and DO contour plots measured on October 25, 2011, prior to reservoir sampling

As noted earlier, 2011 was an unusually high-flow year, while 2010 was a low-flow year (USGS 2011). Because of the anticipated high spring runoff in 2011, Brownlee Reservoir water levels were lowered to allow capacity for flood control. This resulted in a shallower and slightly warmer hypolimnion compared to average flow years, as evident when comparing figures 2 and 3. Additionally, in fall 2011 the reservoir water-surface elevation was lowered to provide some storage capacity for higher-than-normal fall inflows occurring during the sampling period. While these changes may have affected the overall volume of the hypolimnion, substantial changes to water-quality characteristics in the hypolimnion were not anticipated because of the limited mixing during the summer and early fall. However, because of the high fall flow releases from upstream reservoirs and sizable fall drawdown in Brownlee Reservoir, the flows and quality of the discharge water, which are more responsive to inflow conditions, may vary significantly relative to average conditions.

A primary focus of the sampling was on assessing inorganic toxics in the hypolimnetic waters near the dam that could be withdrawn to cool discharge waters. For the hypolimnion, samples in 2010 were collected at 2 locations, 1 near the dam (RM 286) and the other 10 miles upstream

(RM 296). In 2011, samples were collected at 3 locations along the dam (RM 286, RM 286.5, and RM 287). All hypolimnion samples, which are in the cooler and lower DO reservoir strata as shown in figures 2 and 3, were collected below the reservoir outlet elevation (1,930 feet).

While collecting samples from the hypolimnion in 2011, samplers noticed a relatively strong rotten-egg odor, indicating the presence of hydrogen sulfide. Hydrogen sulfide was not included in the list of analytes but is known to occur in organic-rich, low-DO waters (Maier et al. 2000). The unique odor of hydrogen sulfide is a qualitative indicator of its presence, suggesting the potential for increased levels of hydrogen sulfide in the reservoir discharge if hypolimnetic waters were used for cooling the discharge waters. However, in more oxic conditions, the levels of hydrogen sulfide would likely decrease rapidly, as this reduced substance would tend oxidize rapidly (Wetzel 2001).

3.1. Inorganic Parameters

Maximum inorganic results (excluding ammonia and mercury) are summarized in Table 5 for all locations sampled and provide an indication of the environmentally conservative, worse-case levels observed in the reservoir and discharge. A comparison of these results with aquatic-life criteria show all the results are below the criteria. Note that the LOQ for these parameters were low enough to detect levels that would provide a meaningful comparison with the state criteria. Reported values for cyanide and nickel, which were flagged because data-quality indicators did not meet the project's specifications and therefore not included Table 5, are discussed below and provided in Attachment C. The reported concentrations for these inorganic analytes at each location are given in Attachment E.

Cadmium, chromium III, chromium VI, silver, and zinc were reported as below the LOQ at all locations. Reportable concentrations of arsenic, total chromium, copper, iron, lead, and selenium were above the LOQ but below applicable aquatic-life criteria at all locations.

For samples collected in the Brownlee Reservoir hypolimnion and discharge (the primary areas of focus), there were 4 parameters with results above the LOQ. Of these, arsenic, copper, and selenium concentrations were higher in the discharge compared to the hypolimnion (Table 6). The laboratory reported chromium III and VI as below the LOQ of 10 and 1 micrograms per liter (µg/L), respectively. The highest levels of total chromium observed were in the hypolimnion but were well below aquatic-life criteria for chromium III and VI (Table 6).

The inorganic results are for total metal concentrations, while many of the aquatic-life criteria are for dissolved forms. For the 2010 screen-level study (Harrison and Hinson 2011), total metal results provide more information on the overall levels of the trace metals found in the reservoir (and downstream) and are therefore more conservative. The dissolved metal levels could be estimated using the conversion factor for the criteria. Also, many of the criteria are hardness based. The hardness observed in the reservoir [180 mg per liter (mg/L) average] compared to that used for the criteria (100 mg/L) is higher and would produce higher criteria if recalculated.

Table 5
Summary of 2010 Brownlee Reservoir reported inorganic toxics results with Idaho and Oregon aquatic-life criteria (IDAPA n.d. and OAR n.d., respectively) and laboratory LOQ (all units are µg/L)

	Idaho		Oregon			All Locations		
	Acute	Chronic	Acute	Chronic	Note	Maximum	Count	LOQ
Arsenic	340.0	150.0	360.0	190.00	–	6.40	6	0.500
Cadmium	1.3	0.6	3.9	1.10	(+)	ND	0	0.080
Chromium III	570.0	74.0	1,700.0	210.00	(+)	ND	0	1.000
Chromium VI	160.0	11.0	16.0	11.00	(+)	ND	0	10.000
Chromium	–	–	–	–	–	2.10	6	0.500
Copper	17.0	11.0	18.0	12.00	(+)	1.10	4	0.500
Iron	–	–	–	1,000.00	–	221.00	1	50.000
Lead	65.0	2.5	82.0	3.20	(+)	0.14	1	0.100
Selenium	20.0	5.0	260.0	35.00	T	0.70	4	0.500
Silver	3.4	–	4.1	0.12	(+)	ND	0	0.500
Zinc	120.0	120.0	120.0	110.00	(+)	ND	0	5.000

Notes:
Most criteria for Idaho and Oregon are “dissolved” levels; selenium is “total” (T).
Results are shown as reported “total” levels (i.e., more conservative).
(+) = Hardness-dependent criteria (100 mg/L used); with higher hardness, criteria would be higher.

Table 6
2010 Brownlee Reservoir hypolimnion and discharge inorganic toxics sampling results, with Idaho and Oregon aquatic-life criteria (IDAPA and OAR, respectively) and laboratory LOQ (all units are µg/L)

	Idaho		Oregon			Hypolimnion		Discharge	
	Acute	Chronic	Acute	Chronic	Note	RM 296	RM 286	RM 283.9	LOQ
Arsenic	340	150	360	190	–	5.10	4.80	6.10	0.50
Chromium III	570	74	1,700	210	(+)	ND	ND	ND	1.00
Chromium VI	160	11	16	11	(+)	ND	ND	ND	10.00
Chromium	–	–	–	–	–	0.86	2.10	0.63	0.50
Copper	17	11	18	12	(+)	ND	ND	0.77	0.50
Selenium	20	5	260	35	T	ND	ND	0.55	0.50

Notes:
Most criteria for Idaho and Oregon are “dissolved” levels; selenium is “total” (T).
Results are shown as reported “total” levels (i.e., more conservative).
(+) = Hardness-dependent criteria (100 mg/L used); with higher hardness, criteria would be higher.

Ammonia criteria were calculated based on the pH and temperature at each site (Table 7). Total ammonia results (as nitrogen) were also shown to be below criteria after comparison with the calculated criteria. The raw laboratory results are presented in Attachment E.

Table 7
Results of total ammonia as nitrogen in mg/L and calculated acute (CMC) and chronic (CCC) ammonia criteria and screening level; criteria are calculated for Oregon's and Idaho's cold water aquatic life when early life stages are present (based on EPA 1999) (LOQ were 0.020 mg/L)

	Hypolimnion		Discharge
	RM 296	**RM 286**	**RM 283.9**
pH	8.00	7.90	7.71
Temperature	6.10	5.90	16.40
CMC	5.62	6.77	9.48
CCC	2.43	2.80	3.13
Total ammonia as nitrogen	**0.43**	**0.11**	**0.03**

Laboratory results reported for nickel and cyanide, which were flagged because data-quality indicators did not meet the project's specifications, are provided in Attachment C. The nickel results were flagged as estimated because the field blank concentration was just above the LOQ (0.68 and 0.5 µg/L, respectively). This could have been caused by field contamination or the pre-cleaning of equipment (suggesting a problem with procedures), or possibly it was a false positive. All samples had reported levels near the LOQ (maximum estimated concentration was 1.2 µg/L). However, because all reported concentrations are within 10 times the blank concentration (6.8 µg/L), results are considered estimates (Attachment C). Still, with a maximum estimated concentration of 1.2 µg/L, the nickel levels appear to be of limited concern because all reported levels are almost 1 order of magnitude below the lowest aquatic criteria (Idaho's chronic criteria of 52 µg/L).

An estimated cyanide concentration of 10.6 µg/L (flagged), which was near the LOQ of 10 µg/L, was reported in 1 of the 2 replicates of the epilimnion samples collected near the dam. This cyanide result was flagged because the reported level for the other replicate was below detection and the QC control limit could not be calculated. While the epilimnion conditions are not the focus of this report, it should be noted that this was the only location and sample with a reported inorganic toxic concentration that exceeded the water-quality criterion (i.e., the chronic criterion of 5.2 µg/L), and the LOQ for this parameter was also above the criterion.

3.2. Mercury

In fall 2011, hypolimnion samples were collected at a depth of over 200 feet from 3 locations along the thalweg of the reservoir upstream of Brownlee Dam and analyzed for total and MHg (Table 8). Samples were also collected from the discharge below Brownlee Dam at 3 locations across the channel. All samples were collected and analyzed using ultra-clean procedures as previously discussed. QC information is also provided in Attachment B.

Table 8
Laboratory results (in ng/L) for mercury along with the methyl to total ratios

	Hypolimnion			Discharge			
Site ID	**IPC-1**	**IPC-2**	**IPC-3**	**IPC-4**	**IPC-5**	**IPC-6**	**RL**
RM	**286**	**286.5**	**287**	**283.8**	**283.8**	**283.8**	**–**
Total Mercury (ng/L)	4.20	3.90	4.80	0.60	0.6	0.70	0.5
Methyl Mercury (ng/L)	2.70	2.50	2.90	0.10	<0.1	0.10	0.1
Methyl/Total Ratio	0.64	0.64	0.60	0.17	–	0.14	–

The highest concentration of mercury reported was 4.8 ng/L, which is below established aquatic-life criteria. The ratio of methyl to total mercury is considerably higher in the hypolimnion, showing a higher proportion of the more toxic MHg in these hypolimnion samples. Oregon has established acute and chronic mercury criteria for the protection of freshwater aquatic life at 2,400 and 12 ng/L, respectively (OAR, Table 33A). The EPA has also recommended acute and chronic mercury criteria for the protection of freshwater aquatic life at 1,400 and 770 ng/L, respectively (EPA 2011b). The State of Idaho has not established aquatic-life criterion for inorganic mercury.

3.3. Organic Parameters

In general, the organic results from water-column samples collected in 2011 from the hypolimnion of Brownlee Reservoir and the discharge downstream of Brownlee Dam indicate relatively low levels of toxic organic compounds (tables 9 and 10). The vast majority of over 470 organics analyzed (Attachment A) were reported as not detected (ND) at the LOQ. The only 2 anthropogenic organic compounds with levels above the LOQ were atrazine (a widely used herbicide) and desethyl atrazine (a chlorinated degradate of atrazine), which were reported in the discharge (Table 9). Similar to the inorganic results, the maximum concentrations of the results are presented and indicate worst-case conditions. Results for 5 other organic toxics were provided that were below the LOQ but detected above or near the lower MDL (Table 10). A value less than the laboratory's LOQ is considered an estimate and will only be used for qualitative purposes, such as presence or absence.

All other analytes were below the LOQ or the MDL, when provided, with the exception of 2 organic toxics, hexachlorobenzene (a fungicide not in current use) and pentachloroanisole (a degrade of pentachlorophenol). However, these results have been flagged because laboratory blank results indicate laboratory interference (Attachment C).

3.3.1. Toxic Organics at or Near the LOQ

The 2 toxic organic compounds identified above or at the LOQ were atrazine and desethyl atrazine (Table 9). The latter was reported in 2 of the 3 discharge samples (IPC-5 and IPC-6) at 0.03 µg/L, which was just above the reporting limit of 0.025 µg/L. Atrazine was also reported in these same 2 samples at less than the reporting limit of 0.025 µg/L. As shown in Table 9, these levels are well below the EPA benchmark.

Table 9
Maximum levels of pesticides detected near or above the LOQ and the associated EPA benchmarks

	EPA Benchmarks (µg/L)						Maximum Concentration(µg/L)		
	Acute Fish	Chronic Fish	Acute Invert.	Chronic Invert.	Non-Vascular Plants Acute	Vascular Plants Chronic	Hypolimnion	Discharge	LOQ (µg/L)
Atrazine	2,650	65	360	60	1	37	ND	<0.025	0.025
Desethyl Atrazine	–	–	–	–	–	–	ND	0.030	0.025

Notes:
EPA (2011a) Office of Pesticide Management benchmarks from: http://www.epa.gov/oppefed1/ecorisk_ders/aquatic_life_benchmark.htm (8/3/11)
ND indicates not detected at or above the LOQ

Table 10
Maximum estimated concentrations of pesticide, which were below the LOQ and associated Oregon (OR) water-quality criteria

	OR Aquatic-Life Criteria (µg/L)		OR Human-Health Criteria (µg/L)		Maximum Concentration and MDLs (µg/L)				
	Fresh Acute	Fresh Chronic	Water and Organism	Organism Only	Hypolimnion	Flag	Discharge	Flag	Actual MDL
Chlordane	2.400	–	0.0000810	0.0000810	–		–		–
Alpha-Chlordane	–	–	–	–	ND		0.000820	Q	0.00070
Chlorpyrifos	0.083	0.0410	–	–	0.000940	Q	0.000670	J	0.00086
Dieldrin	2.500	0.0019	0.0000053	0.0000054	ND		0.000160	J	0.00077
DDT	1.100	0.0010	–	–	–		–		–
4,4'-DDE	–	–	0.0000220	0.0000220	0.000107	J	0.000150	J	0.00074
Endosulfan	0.220	0.0560	–	–	–		–		–
Endosulfan Sulfate	–	–	8.5000000	8.9000000	ND		0.000100	J	0.00078

Notes:
Units in µg/L; quantification limits are 0.005 µg/L for all analytes
ND indicates not detected near or above the actual MDL
Q = Analyte detected above the MDL and below the LOQ (5 ng/L)
J = Analyte detected below the MDL

3.3.2. Toxic Organics Detected Below the LOQ

Five toxic organics were detected near the MDLs but below the LOQ (Table 10). Therefore, these results should be considered estimated values and only used for qualitative purposes, such as presence or absence. Of these pesticides (or isomers or breakdown products), only chlorpyifos, an organophosphate insecticide, has widespread use. Endosulfan sulfate is a breakdown product of the insecticide and acaricide endosulfan, which may soon be banned in the U.S. (EPA 2002). The other organics detected have been banned for reasons discussed below. Most of these pesticides' maximum estimated concentrations exceed the human health criteria but are well below aquatic-life criteria (Table 10).

4. DISCUSSION

Oregon standards define toxics as the following:

> Those pollutants or combinations of pollutants, including disease-causing agents, that after introduction to waters of the state and upon exposure, ingestion, inhalation, or assimilation either directly from the environment or indirectly by ingestion through the food chains will cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations in any organism or its offspring (OAR 340-041, n.d.).

Water-quality samples collected in Brownlee Reservoir and from the discharge provide an indication of toxics within and discharging below Brownlee Reservoir in fall 2010 and 2011. In the following sections, the results are compared to water-quality criteria to provide an understanding of potential effects on aquatic organisms. Additionally, concentrations of the hypolimnetic waters within Brownlee Reservoir are compared with the water discharging from the reservoir. Thus, these data provide an indication of the potential changes in toxic levels that could occur during the time period hypolimnetic water might be used to cool discharge waters.

4.1. Temperature and DO

The temperature and DO isopleths (figures 2 and 3) show the variation in water quality within Brownlee Reservoir, including the thermally stratified structure of the reservoir. For example, the temperature levels in 2011 near the dam decrease from a high of 15°C to a low of approximately 7°C, while the DO levels decrease from a high of over 8 mg/L to a low approaching 0 mg/L (Figure 3).

The temperature and DO of the discharge water downstream of Brownlee Dam was also measured (Attachment D). Again using the 2011 data as an example, the temperature in the discharge (RM 283.9) at the time of sampling averaged just over 14°C, while the DO averaged over 6 mg/L. The relatively cool and low DO waters of the hypolimnion occur below the outlet elevation of 1,930 feet (Figure 3). This suggests that the discharge samples represent a composite of multiple depths primarily drawn from the upper strata (i.e., epilimnion and metalimnion) of Brownlee Reservoir. Counter to this, the relatively cool and low DO waters of the hypolimnion generally occur below the outlet elevation of 1,930 feet.

4.2. Inorganics

4.2.1. 2010 Inorganics

A primary focus of this study was assessing inorganic toxics in the hypolimnion of Brownlee Reservoir and comparing those levels with discharge levels to assess the potential for an increase in levels when using hypolimnion water for cooling. The discharge sample water is primarily pulled from the metalimnion and epilimnion (i.e., mid- and upper layers of the reservoir) and is assumed to represent the warmer water, which could be mixed with hypolimnion water for cooling (Figure 2). For the 2010 sampling event, hypolimnion samples were collected below the outlet level (i.e., elevation 1,930 feet) near the dam (RM 286) and 10 miles upstream (RM 296).

When comparing hypolimnetic results with the discharge results for most of the inorganic analytes, it appears that chromium, ammonia, and mercury (total and methyl) could increase if hypolimnetic waters were used to cool the discharge.

4.2.2. Chromium

Chromium can exist in oxidation states ranging from −2 to +6, but it is almost always found as trivalent (+3) or hexavalent (+6) chromium in freshwater. The laboratory reported chromium III and VI as below the LOQ of 10 and 1 µg/L, respectively (Table 6). The highest levels of total chromium observed were in the hypolimnion but were well below aquatic-life criteria for chromium III and VI.

Toxicity to aquatic biota is significantly influenced by abiotic variables, such as water hardness, temperature, pH, and salinity. Hexavalent chromium is more toxic to freshwater biota in soft and acidic waters. Chromium sensitivity is also influenced by biotic factors, such as species, life stages, and potential differences in sensitivities of local populations.

In general, younger life stages are more sensitive to chromium toxicity than older organisms. Geist et al. (1994) did not find any interruption of the fertilization process (sperm destruction) stemming from chromium. However, Chinook salmon parr *(Oncorhynchus tshawytscha)* exposed to dissolved hexavalent chromium accumulated the metal in various organs and developed deoxyribonucleic acid (DNA) damage, lipid peroxidation, microscopic lesions, gross abnormalities, reductions in weights, and reductions in survival (Farag et al. 2006). Most juvenile salmon and trout species show at least some sensitivity to hexavalent chromium.

Adult salmonids showed sensitivity to hexavalent chromium as well. Chromium accumulates in adult tissues, and these concentrations are greatest in the gills, liver, kidney, and digestive tract. In seaward-migrating coho salmon (*Oncorhynchus kisutch)*, salinity tolerance and serum osmolality were impaired during exposures to 0.23 mg/L of hexavalent chromium for 4 weeks (Sugatt 1980). Sub-lethal effects are more pronounced at high water temperatures and reduced pH.

Hexavalent chromium is more toxic than trivalent chromium because its oxidizing potential is high and it easily penetrates biological membranes. Under low pH and anoxic conditions, trivalent chromium remains in the sediments, posing little risk to aquatic organisms. However, if the sediments are oxygenated, trivalent chromium oxidizes and forms hexavalent chromium, which poses a more significant risk to aquatic species.

4.2.3. Ammonia

The toxicity of ammonia is primarily associated with un-ionized ammonia (NH3), but the more common form of ammonium (NH4+) can also affect overall toxicity levels (EPA 1999). Ammonia criteria, which are temperature and pH dependent, and the results for the sampling locations are given in total ammonia as nitrogen (Table 7). Levels of ammonia in the hypolimnion were elevated compared to discharge samples; however, both reservoir and discharge reported concentrations are below criteria. Elevated hypolimnion concentrations would be expected in the low DO water given that ammonia is a reduced from of nitrogen. Using cool hypolimnteic water to cool the discharge could possibly increase levels in the discharge. More data and analyses of ammonia are provided in IPC reports (Myers et al. 2003) and the Section 401 Certification Application for the Hells Canyon Complex (IPC 2012).

4.2.4. Total Mercury

Both Oregon (ODHS 2011) and Idaho (IDHW 2011) have issued fish-consumption advisories for mercury in Brownlee Reservoir. The SR–HC TMDL identified the primary sources of mercury as legacy mining and natural loading, both of which are associated with geological deposits within the Owyhee and Weiser river watersheds (IDEQ and ODEQ 2004). Based on these findings, data collection and a TMDL are planned, and load and wasteload allocations will be established to limit nonpoint and point sources, respectively, that are currently contributing to mercury in these waters.

The State of Oregon has established acute and chronic mercury criteria for the protection of freshwater aquatic life at 2,400 and 12 ng/L, respectively (OAR 2012). The State of Idaho has not established aquatic-life criterion for inorganic mercury. The EPA has also recommended acute and chronic mercury criteria for the protection of freshwater aquatic life at 1,400 and 770 ng/L, respectively (EPA 2009).

In 2007, the IDEQ sampled Brownlee Reservoir on a monthly basis from May through November (Stone 2008). The samples were collected in multiple locations and composited for sample analyses; thus, results provide an average for the reservoir. Total mercury levels in the water of Brownlee Reservoir averaged 4.8 ng/L, with the highest levels in September and lowest levels in June (i.e., 9.0 and 2.7 ng/L, respectively). In 2008, water samples analyzed for mercury were collected in the Snake River upstream of Brownlee Reservoir (Essig 2010). The reported total mercury level of 1.71 ng/L was well below Oregon’s chronic aquatic-life criteria of 12 ng/L.

The 2011 results indicate an average mercury level of 4.3 ng/L in the hypolimnion of Brownlee Reservoir, while the discharge averaged 0.6 ng/L. The 2011 levels are within the range of those previously reported and are below the State of Oregon’s chronic aquatic-life criteria for total mercury of 12 ng/L. However, the total mercury levels in the hypolimnion are almost an order of magnitude above those observed in the discharge. This appears to be related to levels of the MHg that are also over an order of magnitude above those observed in the discharge, as discussed in Section 4.2.5.

4.2.5. Methyl Mercury

Mercury is one of the elements that can undergo biomethylation in the natural environment. Methylation occurs through biological (e.g., bacteria reducing sulfate) or chemical (e.g., reaction with humic acid) processes under naturally occurring conditions of pH and temperature in the aquatic environment (Maier et al. 2000). Thus, all mercury entering streams and rivers as elemental (metallic) mercury, inorganic divalent mercury, phenylmercury, or alkoxyalkyl mercury can be converted into MHg compounds by natural processes. MHg is the most hazardous mercury species due to its high stability, lipid solubility, and possession of ionic properties that lead to a high ability to penetrate membranes in living organisms.

Methylation can occur under aerobic and anaerobic conditions, but rates are higher under the latter. Stratified reservoirs with low DO waters and substantial amounts of organic matter near the sediment and water interface can produce increased levels of MHg (Canavan et al. 2000). Often under these anoxia conditions, sulfate-producing bacteria generate hydrogen sulfide and can also produce MHg (Maier et al. 2000). However, Eckley et al. 2005 showed that rates of methylation and demethylation can vary as waters change from anaerobic to more aerobic conditions. And, because methylated mercury is more volatile, increased surface mixing of the waters with elevated MHg is a potential mechanism for reducing mercury levels in the water column.

Methylation produces a compound with increased lipid solubility (Maier et al. 2000), which tends to accumulate in the fat tissue of organisms, including phytoplankton, zooplankton, and fish. This bioaccumulated MHg is passed up the food web in a process referred to as biomagnification, sometimes resulting in levels of mercury that exceed health advisories for the human consumption of fish. As previously stated, mercury accumulation and cycling were identified as a primary concern in the SR–HR TDML (IDEQ and ODEQ 2004), and both Oregon (ODHS 2011) and Idaho (IDHW 2011) have issued fish-consumption advisories for mercury in Brownlee Reservoir.

MHg concentrations in the discharge were within ranges generally observed in past reservoir sampling. In 2008, water-quality samples for mercury analyses were collected in the Snake River upstream of Brownlee Reservoir, with a reported MHg concentration of 0.101 ng/L (Essig 2010). This concentration is similar to the 2011 discharge sample results averaging 0.1 ng/L (Table 8). In 2008 water-quality samples, the reported ratio of methyl to total mercury was below 0.1. In comparison, the ratio of methyl to total in the discharge was slightly elevated.

Of more interest, MHg concentrations in the hypolimnion (2.9 ng/L maximum) were substantially elevated compared to the Snake River and discharge concentrations (0.1 ng/L maximum) discussed previously. And, as would be expected, the ratio was also elevated. These results indicate a high potential for increased discharge levels of MHg if hypolimnion water is used for cooling. However, methylated mercury is relatively volatile, and increased surface mixing and discharge is a potential mechanism for reducing mercury levels in the discharge waters.

4.3. Organics

In general, laboratory results from samples collected in the hypolimnion of Brownlee Reservoir and the discharge below the dam showed relatively low levels of a few organic toxics. From the extensive list of over 470 anthropogenic organic chemicals, as provided in Attachment A, 7 organic toxics were detected. Of these 7, two were detected at or slightly above the LOQ (Table 9) and 5 were near or below the MDL (Table 8). These latter 5 toxics are considered to be present, but because levels are below those needed for quantitative analyses (i.e., LOQ), comparison between hypolimnion and discharge is not appropriate.

Organic toxics Atrazine and the degradate desethyl atrazine were reported to be above or near the LOQ (0.025 µg/L) in samples collected in the discharge below the dam (Table 9). EPA (2006) stated the “triazine” compounds share a common mechanism of toxicity (i.e., “…the ability to potentially cause neuroendocrine developmental and reproductive effects that may be relevant to humans”). However, benchmarks have not been established for this chlorinated degradate.

Atrazine is used to control broad leaf and grassy weeds in corn, wheat stubble, and fallow fields (ISDA 2010). It is also used for non-crop applications, including forest, urban landscapes, roadsides, and right-of-ways (ROW). The reported levels are well below all EPA aquatic benchmarks (EPA 2011), as shown in Table 1. While considered toxic to aquatic life and plants at relatively low levels, atrazine it is not expected to bioaccumulate (ODF 2012).

The desethyl atrazine was 1 of 13 pesticides and degradates found in a recent water-quality study conducted on lower Boise River drains (Campbell 2010). In the multiyear study, there were 39 detections of desethyl atrazine in the main stem of the Boise River (the highest number for herbicides), with the highest detected level 0.039 µg/L. Campbell stated that “Desethyl atrazine… exhibit moderate to high toxicity to aquatic species when found in water at much higher concentrations than those observed during this study.”

Atrazine and the degradate desethyl atrazine were reported in samples collected in the discharge below the Brownlee Dam. However, these toxic organics were not reported in the reservoir hypolimnion. Thus, the use of hypolimnion water for cooling would not be expected to increase concentrations of these toxics.

Five other organic toxics were reported below the LOQ but above or near the lower MDL (Table 10):

- Alpha-Chlordane—Chlordane refers to a mixture of chlordane isomers, other chlorinated hydrocarbons, and numerous other components, including cis [or alpha]-chlordane. Chlordane was first produced in 1947 and used as an insecticide for agricultural crops, including corn; used for lawns and gardens; and used for termite control. Because of the concern over the risk of cancer, the evidence of human exposure, and danger to wildlife, the EPA banned all uses after 1988. Residues still exist in soils and sediments, and chlordane bioaccumulates in the fatty tissue of fish and humans (EPA 1997).

- Chlorpyifos—An organophosphate insecticide currently used to control foliage and soilborne insect pests on a variety of food and feed crops, including corn; golf courses; as a non-structural wood treatment; and as an adult mosquitocide (EPA 2012); this pesticide is on Oregon’s 2009 to 2010 pesticide of concern list (ODA 2012).
- 44-DDE—A common breakdown product of DDT is fat soluble and can accumulate in fatty tissues of animals. It was banned in 1973 in part due to its persistence in the environment. Breakdown products of DDT include DDE and DDD.
- Dieldrin—An insecticide developed as an alternative to DDT. Aldrin, which is not toxic to insects, oxidizes in the insect to form dieldrin, which is the active compound. From 1950 to 1974, dieldrin was widely used to control insects on cotton, corn, and citrus crops. Also, dieldrin was used to control locusts and mosquitoes. Dieldrin is a persistent, bioaccumulative, and toxic (PBT) pollutant targeted by the EPA and was banned in 1987 (EPA n.d.).
- Endosulfan Sulfate—A breakdown product of endosulfan that can persist in the environment. Endosulfan is an insecticide and acaricide registered for use on a wide variety of vegetables, fruits, cereal grains, and cotton, as well as ornamental shrubs, trees, vines, and ornamentals for use in commercial agricultural settings. Chemically similar to aldrin, chlordane, and heptachlor, the EPA is taking action to end all uses of endosulfan in the U.S. (EPA 2002); enodsulfan is on Oregon’s 2009 to 2010 pesticide of concern list (ODA 2012).

As discussed previously, only 2 of the detected pesticides are in current use. The EPA is working to end use of the endosulfan (EPA 2002), while chlorphyifos is currently widely used. Chlorphyifos was also one of the organophosphate pesticides found in the Boise River pesticide study (Campbell 2010). The highest detected level was 0.095 µg/L. Chlorpyrifos is considered highly toxic to freshwater fish and aquatic invertebrates (Extoxnet 1996). However, it adsorbs strongly to soils, and, while it has a half-life of 60 to 120 days in soil, in water, concentrations generally rapidly decline.

Concentrations of the 5 toxics that were below the LOQ should not be used for quantitative analyses. However, it is appropriate to indicate presence or absence. Thus, of the 5 organic toxics detected below the LOQ in the discharge samples, only 2 were present in the hypolimnion samples.

5. CONCLUSIONS

Water-column samples were collected in 2010 and 2011 for analyses of inorganic and organic toxics. Results were compared with criteria and benchmarks established by the EPA, Oregon, and Idaho. Only a few of the organic toxics were found at levels near or above human health criteria. All organic and inorganic toxics reported in the Brownlee Reservoir hypolimnion and discharge samples were below aquatic-life criteria. However, while mercury levels are below criteria, there are fish-consumption advisories in place, indicating the relatively low levels are bioaccumulating and are of concern.

Of the samples analyzed for over 470 toxic organics, only 7 pesticides, including the isomers or degradates of pesticides, were detected, and 5 of those were below the LOQ. Concentrations of pesticides appear to be lower in the hypolimnion as compared to discharge. Other organic toxics analyzed, including semi-volatile organic compounds, individual PAHs, PCBs, and dixons, were not found at levels above the LOQ.

All organics concentrations were below criteria and benchmarks associated with aquatic life. Comparing results to the lower human-health criteria established by Oregon, dieldrin, DDE, and chlordane were above or near the criteria. These pesticides, which have been banned from use by the EPA, were detected below the LOQ, and therefore the reported concentrations are only estimates and indicate the presence of the compound.

The results from Brownlee Dam discharge samples, which are assumed to represent water primarily drawn from the upper and middle levels of the reservoir (i.e., epilimnion and metalimnion), were also compared with the results from samples collected in the lower depths of the Brownlee Reservoir (i.e., hypolimnion) to assess the potential for change in discharge concentrations if hypolimnetic water were used to cool discharge water. In general, concentrations of most inorganic toxics and all organic toxics were lower in the hypolimnion compared to the discharge. Based on the results of 2010 water samples, it appears that levels of chromium, ammonia, and mercury could increase if hypolimnetic waters are used to cool the discharge. The increase in chromium would be relatively small and the concentration would still be well below aquatic-life criteria. Considering the order of magnitude difference between ammonia levels in the hypolimnetic and discharge waters, an expected increase could be somewhat larger (on a percentage basis), however, a “mixed” concentration would also be well below aquatic-life criteria.

The results indicate total mercury concentrations in the reservoir’s hypolimnion are almost an order of magnitude above those observed in the discharge. Thus, the increased concentration could be similar to the ammonia increase. The higher concentration in the hypolimnion appears to be related to levels of MHg that are over an order of magnitude above those observed in the discharge. This potential increase is of most concern, considering MHg is the more toxic form of mercury. There are currently mercury fish-consumption advisories in place, and a mercury TMDL is currently under development.

Additional sampling has been conducted this spring to assess organic and inorganic toxics levels in reservoir sediments. Depending on how the hypolimnion water is accessed, both the water-column toxics data, as presented previously, and sediment toxics data, which should be available later this year, could be needed to fully evaluate possible downstream water-quality effects of the use of the hypolimnetic waters for cooling downstream waters.

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Attachments to the Browlnee Reservoir Hypolimnion and Discharge Water-Column Toxics Report

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ATTACHMENT A—LIST OF ANALYTES AND LIMITS OF QUANTIFICATION

2010 Analytes and Limits of Quantification

2010 inorganic toxic laboratory methods and limits of quantification (LOQ) in units of micrograms per liter (µg/L) are shown in Table A1. The laboratory reported minimum levels as practical quantification limits (PQL), but these are referred to here as LOQ for consistency in the main report.

Table A1
2010 inorganic toxic analytes, laboratory methods, and LOQ (i.e., LOQ) (17 analytes)

Parameter	Method	LOQ	Units
Arsenic	EPA 200.8	0.500	µg/L
Cadmium	EPA 200.8	0.080	µg/L
Calcium	EPA 200.8	20.000	µg/L
Chromium	EPA 200.8	0.500	µg/L
Copper	EPA 200.8	0.500	µg/L
Iron	EPA 200.8	50.000	µg/L
Lead	EPA 200.8	0.100	µg/L
Magnesium	EPA 200.8	5.000	µg/L
Nickel	EPA 200.8	0.500	µg/L
Selenium	EPA 200.8	0.500	µg/L
Silver	EPA 200.8	0.500	µg/L
Total Hardness by 2340B	EPA 200.8	71.000	µg/L
Zinc	EPA 200.8	5.000	µg/L
Nitrogen, Ammonia	EPA 350.1	20.000	µg/L
Chromium, Hexavalent	SM 3500-Cr B (Online)	1.000	µg/L
Cyanide	SM 4500-CN-E	10.000	µg/L
Chromium, Trivalent	Trivalent Chromium Calculation	10.000	µg/L

2011 Analytes and LOQ

2011 toxic laboratory methods and LOQ for approximately 473 analytes are shown in Table A2. Reporting levels (RL) provided by the various laboratories are also shown. These are given by various labs as reported detection level (RDL), pace reporting levels (PRL), RLs, quantification limits (QL), etc. In the report and attachments, these are generally referred to as LOQ for consistency. The exception is the for the lower method detection levels (MDL), which are associated equipment detection levels requested and provided by some laboratories.

Table A2
Idaho State Department of Agriculture (ISDA) pesticides requested by the Idaho Department of Environmental Quality (IDEQ) and analyzed in 2011 by the University of Idaho (U of I) (110 analytes)

Parameter	LOQ	Report. Units
Surface Water (SW)—Carbamates		
Aldicarb	0.100	µg/L
Aldicarb Sulfone	0.100	µg/L
Aldicarb Sulfoxide	0.100	µg/L
Baygon (Propoxur)	0.050	µg/L
Carbaryl	0.050	µg/L
Carbofuran	0.050	µg/L
3-Hydroxycarbofuran	0.050	µg/L
Methiocarb	0.050	µg/L
Methomyl	0.050	µg/L
Oxamyl	0.050	µg/L
Blank	–	µg/L
Spike Recovery	–	%
Surrogate Recovery	–	%
SW—Chlorinated Acids		
2,4,6-Trichlorophenol	0.100	µg/L
2,4-D	0.200	µg/L
2,4-DB	0.200	µg/L
2,4-Dichlorobenzoic acid	0.100	µg/L
3,5-Dichlorobenzoic acid	0.100	µg/L
Bentazon	0.200	µg/L
Bromoxynil	0.100	µg/L
Dacthal (DCPA)	0.080	µg/L
Dicamba	0.080	µg/L
Dichloroprop	0.250	µg/L
Diclofop methyl	0.250	µg/L
Dinoseb	0.200	µg/L
2-methyl-4-chlorophenoxyacetic acid (MCPA)	0.200	µg/L
methylchlorophenoxypropionic acid (MCPP)	0.200	µg/L
Pentachlorophenol	0.080	µg/L
Picloram	0.150	µg/L
Triclopyr	0.100	µg/L

Table A2 (cont.)

Parameter	LOQ	Report. Units
SW—Gas Chromatography–Mass Spectrometry (GCMS) Extras		
Acephate	0.500	µg/L
Bensulide	0.050	µg/L
Captan	0.100	µg/L
Coumaphos	0.050	µg/L
Diflubenzuron	0.050	µg/L
Dimethoate	0.050	µg/L
Fenthion	0.050	µg/L
Iprodione	0.100	µg/L
Methamidophos	0.050	µg/L
Naled	0.500	µg/L
Oryzalin	0.050	µg/L
Phosmet	0.050	µg/L
Blank	–	µg/L
SW—Organochlorine Pesticides		
Acetochlor	0.025	µg/L
Chlordane (alpha)	0.020	µg/L
Chlordane (gamma)	0.020	µg/L
Chloroneb	0.025	µg/L
Chlorobenzilate	0.050	µg/L
Chlorothalonil	0.025	µg/L
DCPA (parent)	0.025	µg/L
Dichlorodiphenyldichloroethane (DDD)	0.030	µg/L
Dichlorodiphenyldichloroethylene (DDE)	0.030	µg/L
Dichlorodiphenyltrichloroethane (DDT)	0.300	µg/L
Dichlobenil	0.050	µg/L
Dieldrin	0.030	µg/L
Etridiazole	0.050	µg/L
Hexachlorobenzene	0.020	µg/L
Lindane	0.015	µg/L
Oxyfluorfen	0.050	µg/L
Permethrin (cis)	0.100	µg/L
Propachlor	0.050	µg/L
Blank	–	µg/L

Table A2 (cont.)

Parameter	LOQ	Report. Units
SW—Organophosphate Organonitogen Pesticide		
Alachlor	0.050	µg/L
Ametryn	0.050	µg/L
Atrazine	0.025	µg/L
Azinphos Methyl	0.050	µg/L
Benfluralin	0.050	µg/L
Benthiocarb	0.025	µg/L
Bromacil	0.050	µg/L
Butachlor	0.050	µg/L
Butylate	0.025	µg/L
Carboxin	0.050	µg/L
Chlorpropham	0.050	µg/L
Chlorpyrifos	0.025	µg/L
Cycloate	0.050	µg/L
Desethyl Atrazine	0.025	µg/L
Di-allate	0.050	µg/L
Diazinon	0.025	µg/L
Dichlorvos	0.050	µg/L
2,6-Diethylaniline	0.050	µg/L
Disulfoton	0.050	µg/L
EPTC	0.050	µg/L
Ethalfluralin	0.050	µg/L
Ethoprop	0.025	µg/L
Fenamiphos	0.050	µg/L
Fenarimol	0.050	µg/L
Hexazinone	0.050	µg/L
Malathion	0.050	µg/L
Metalaxyl	0.050	µg/L
Methidathion	0.050	µg/L
Methyl Paraoxon	0.100	µg/L
Methyl Parathion	0.050	µg/L
Metolachlor	0.050	µg/L
Metribuzin	0.025	µg/L
MGK-264	0.050	µg/L
Napropamide	0.050	µg/L
Norflurazon	0.050	µg/L

Table A2 (cont.)

Parameter	LOQ	Report. Units
Parathion	0.050	µg/L
Pendimethalin	0.025	µg/L
Phorate	0.050	µg/L
Prometon	0.050	µg/L
Pronamide	0.050	µg/L
Propazine	0.025	µg/L
Simazine	0.025	µg/L
Stirofos	0.050	µg/L
Tebuthiuron	0.050	µg/L
Terbacil	0.050	µg/L
Terbufos	0.050	µg/L
Tri-allate	0.050	µg/L
Triadimefon	0.050	µg/L
Blank	–	µg/L
Spike Recovery	–	%
Surrogate Recovery	–	%
SW—Urea Pest		
Deisopropyl atrazine (DIA)	0.025	µg/L
Diuron	0.025	µg/L
Linuron	0.050	µg/L
Tebuthiuron	0.050	µg/L
Tralkoxydim	0.050	µg/L
Blank	–	µg/L
Spike Recovery	–	%
Surrogate Recovery	–	%

Table A3
List of parameters requested by the Oregon DEQ (ODEQ) analyzed in 2011 by Pace Analytical Services (Pace), Pacific Agricultural Laboratory (PAgL), and TDI-Brooks Laboratories

Source/Parameter	Environmental Protection Agency (EPA) Method
Oregon Department of Agriculture (ODA) Pesticides	
imidacloprid (wc)	8270D
bifenthrin	8081B
1-cyhalothrin	8081B
diflubenzuron	–
cyfluthrin	8081B
Oregon Pollutants of Interest (POI) list additions	
dimethanamid	8270D
deltamethrin	8081B
esfenvalerate	8081B
fipronil	8270D
glyphosate	–
Oregon Table 20 Organics	
acenapthene	8270
aldrin	8081
CHLOROPHENOXY HERBICIDES (2,4,5 TP)	8151
(TDE) DDT METABOLITE (DDD, DDE, DDT)	8081
DEMETON	8081
DIOXIN (2,3,7,8-TCDD)	8290
ENDOSULFAN	8081
ENDRIN	8081
FLUORANTHENE	8270
HEPTACHLOR	8081
METHOXYCHLOR	8081
MIREX	8081
NAPHTHALENE	8270
Polychlorinated Biphenyls (PCB)	8082
PHENOL	8270
POLYNUCLEAR AROMATIC HYDROCARBONS	8270 SIM
TOXAPHENE	8081
PHTHALATEs (individual)	
DIBUTYLPHTHALATE (DBP)	8270
DIETHYLPHTHALATE (DMP)	8270
DIMETHYL PHTHALATE (DEP)	8270
DI-2-ETHYLHEXYL PHTHALATE (DEHP)	8270

Table A3 (cont.)

Source/Parameter	Environmental Protection Agency (EPA) Method
Draft ODEQ priority toxics focus list	
total Polybrominated diphenyl thers (PBDE)	1614
Oregon Table 20	
MERCURY	1631E
Other	
Methyl Mercury	1630

Table A4
Semi-volatile organic compound (SVOC) parameters via EPA Method 8270 analyzed in 2011 by Pace Analytical Laboratories (66 analytes)

Analyte	MDL (µg/L)	LOQ (µg/L)
1,2,4-Trichlorobenzene	1.1	10
1,2-Dichlorobenzene	1.2	10
1,2-Diphenylhydrazine	5.0	10
1,3-Dichlorobenzene	1.1	10
1,4-Dichlorobenzene	1.2	10
1-Methylnaphthalene	1.2	10
2,4,5-Trichlorophenol	1.3	50
2,4,6-Trichlorophenol	1.1	10
2,4-Dichlorophenol	1.1	10
2,4-Dimethylphenol	1.8	10
2,4-Dinitrotoluene	5.0	10
2,4-Dinitrophenol	5.0	50
2,6-Dinitrotoluene	5.0	10
2-Chloronaphthalene	1.0	10
2-Chlorophenol	1.3	10
2-Methylnaphthalene	1.3	10
2-Methylphenol(o-Cresol)	1.1	10
2-Nitroaniline	5.0	50
2-Nitrophenol	1.0	10
3&4-Methylphenol	1.1	20
3,3'-Dichlorobenzidine	1.1	20
3-Nitroaniline	1.0	50
4,6-Dinitro-2-methylphenol	1.1	50
4-Bromophenylphenylether	5.0	10
4-Chloro-3-methylphenol	1.0	10

Table A4 (cont.)

Analyte	MDL (µg/L)	LOQ (µg/L)
4-Chloroaniline	1.4	50
4-Chlorophenylphenylether	5.0	10
4-Nitroaniline	5.0	10
4-Nitrophenol	1.3	50
Acenaphthene	5.0	10
Acenaphthylene	5.0	10
Anthracene	5.0	10
Benzo(a)anthracene	5.0	10
Benzo(a)pyrene	5.0	10
Benzo(b)fluoranthene	5.0	10
Benzo(g,h,i)perylene	5.0	10
Benzo(k)fluoranthene	5.0	10
bis(2-Chloroethoxy)methane	1.3	10
bis(2-Chloroisopropyl)ether	1.2	10
bis(2-Ethylhexyl)phthalate	1.4	10
bis(2-Chloroethyl) ether	1.3	10
Butylbenzylphthalate	1.1	10
Carbazole	5.0	10
Chrysene	5.0	10
Dibenz(a,h)anthracene	5.0	10
Dibenzofuran	5.0	10
Diethylphthalate	5.0	10
Dimethylphthalate	5.0	10
Di-n-butylphthalate	5.0	10
Di-n-octylphthalate	1.2	10
Fluoranthene	1.0	10
Fluroene	5.0	10
Hexachloro-1,3-butadiene	1.3	10
Hexachlorobenzene	5.0	10
Hexachloroethane	1.3	10
Indeno(1,2,3-cd)pyrene	5.0	10
Isophorone	1.2	10
Naphthalene	1.2	10
Nitrobenzene	1.2	10
N-Nitrosodimethylamine	1.4	10
N-Nitroso-di-n-propylamine	1.1	10

Table A4 (cont.)

Analyte	MDL (µg/L)	LOQ (µg/L)
N-Nitrosodiphenylamine	5.0	10
Pentachlorophenol	1.2	23
Phenanthrene	5.0	10
Phenol	1.2	10
Pyrene	5.0	10

Table A5
Polynuclear aromatic hydrocarbons (PAH) parameters via EPA Method 8270 PAH SIM analyzed in 2011 by Pace Analytical Laboratories (21 analytes)

Analyte	MDL (µg/L)	LOQ (µg/L)
1-Methylnaphthalene	0.009	0.04
2-Chloronaphthalene	0.005	0.04
2-Methylnaphthalene	0.012	0.04
Acenaphthene	0.006	0.04
Acenaphthylene	0.004	0.04
Anthracene	0.007	0.04
Benzo(a)anthracene	0.003	0.04
Benzo(a)pyrene	0.003	0.04
Benzo(b)fluoranthene	0.020	0.04
Benzo(e)pyrene	0.004	0.04
Benzo(g,h,i)perylene	0.005	0.04
Benzo(k)fluoranthene	0.005	0.04
Chrysene	0.003	0.04
Dibenz(a,h)anthracene	0.008	0.04
Dibenzofuran	0.004	0.04
Fluoranthene	0.004	0.04
Fluorene	0.003	0.04
Indeno(1,2,3-cd)pyrene	0.006	0.04
Naphthalene	0.006	0.04
Phenanthrene	0.006	0.04
Pyrene	0.006	0.04

Table A6
Pesticide Parameters via EPA Method 8081 analyzed in 2011 by Pace Analytical Laboratories (24 analytes)

8081 Gas Chromatograhpy (GCS) Pesticides	Chemical Abstract Services (CAS) Number	MDL (µg/L)	LOQ (µg/L)
4,4'-DDD	72-54-8	0.00190	0.01
4,4'-DDE	72-55-9	0.00090	0.01
4,4'-DDT	50-29-3	0.00360	0.01
Aldrin	309-00-2	0.00050	0.50
Chlordane	57-74-9	0.08007	0.10
Chlorobenzilate	510-15-6	0.02112	0.01
Dieldrin	60-57-1	0.00050	0.01
Endosulfan I	959-98-8	0.00070	0.01
Endosulfan II	33213-65-9	0.00070	0.01
Endosulfan Sulfate	1031-07-8	0.00060	0.01
Endrin	72-20-8	0.00170	0.01
Endrin aldehyde	7421-93-4	0.00710	0.01
Endrin Ketone	53494-70-5	0.00110	0.01
Heptachlor	76-44-8	0.00150	0.01
Heptachlor epoxide	1024-57-3	0.00040	0.01
Methoxychlor	72-43-5	0.00700	0.01
Pentachloronitrobenzene	82-68-8	0.01498	0.10
Toxaphene	8001-35-2	0.28492	0.50
alpha- Benzenehexachloride (BHC)	319-84-6	0.00030	0.01
alpha-Chlordane	5103-71-9	0.00130	0.01
beta-BHC	319-85-7	0.00050	0.01
delta-BHC	319-86-8	0.00040	0.01
gamma-BHC (Lindane)	58-89-9	0.00020	0.01
gamma-Chlordane	5103-74-2	0.00160	0.01

Table A7
Chlorinated herbicide parameters via EPA Method 8082 analyzed in 2011 by Pace Analytical Laboratories (11 analytes)

Analyte	CAS	MDL (µg/L)	LOQ (µg/L)
2,4,5-T	93-76-5	0.042	0.1895
2,4,5-TP(Silvex)	93-72-1	0.049	0.1901
2,4-D	94-75-7	0.224	0.9403
2,4-DB	94-82-6	0.509	1.8930
Bentazon	25057-89-0	0.016	0.0944
Dalapon	127-20-8	0.430	0.9112
Dicamba	1918-00-9	0.030	0.0940
Dichlorprop	120-36-5	0.191	0.6526
Dinoseb	88-85-7	0.057	0.1889
Pentachlorophenol	87-86-5	0.017	0.0284
Picloram	1918-02-1	0.019	0.0945

Table A8
PCB parameters via EPA Method 8082 analyzed in 2011 by Pace Analytical Laboratories (9 analytes)

Analyte	CAS Number	MDL (µg/L)	LOQ (µg/L)
PCB-1016 (Aroclor 1016)	12674-11-2	0.022	0.1
PCB-1221 (Aroclor 1221)	11104-28-2	0.050	0.1
PCB-1232 (Aroclor 1232)	11141-16-5	0.040	0.1
PCB-1242 (Aroclor 1242)	53469-21-9	0.034	0.1
PCB-1248 (Aroclor 1248)	12672-29-6	0.050	0.1
PCB-1254 (Aroclor 1254)	11097-69-1	0.047	0.1
PCB-1260 (Aroclor 1260)	11096-82-5	0.018	0.1
PCB-1262 (Aroclor 1262)	37324-23-5	0.034	0.1
PCB-1268 (Aroclor 1268)	11100-14-4	0.050	0.1

Table A9
Oregon pesticides analyzed in 2011 by Pacific Agricultural Laboratory (201 analytes)

Analyte	LOQ (µg/L)	Analyte	LOQ (µg/L)
Organophosphorous and Organosulfur Pesticides			
Aspon	0.30	Fensulfothion	0.30
Azinphos-methyl	0.30	Fenthion	0.30
Carbofenothion	0.30	Malathion	0.30
Chlorfenvinphos	0.30	Methidathion	0.30
Chlorpyrifos	0.30	Merphos	0.30
Chlorpyrifos-methyl	0.30	Mevinphos	0.30
Coumaphos	0.30	Monocrotophos	0.30
Demeton	0.30	Parathion	0.30
Diazinon	0.30	Parathion-methyl	0.30
Dichlorofenthion	0.30	Phorate	0.30
Dichlorvos	0.30	Phosmet	0.30
Dicrotophos	0.30	Phosphamidon	0.30
Dimethoate	0.30	Pirimiphos-methyl	0.30
Disulfoton	0.30	Propargite	0.60
EPN	0.30	Ronnel	0.30
Ethion	0.30	Sulprofos	0.30
Ethoprop	0.30	Terbufos	0.30
Famphur	0.30	Tetrachlorvinphos	0.30
Fenamiphos	0.30	Tokuthion	0.30
Fenitrothion	0.30	Tricloronate	0.30
Halogenated Pesticides			
Acetochlor	0.30	Endrin ketone	0.12
Alachlor	0.30	Esfenvalerate	0.12
Aldrin	0.12	Ethalfluralin	0.12
Benfluralin	0.12	Etridiazole	0.12
Bifenthrin	0.12	Fenarimol	0.12
á-BHC	0.12	Fenvalerate	0.12
â-BHC	0.12	Flutolanil	1.20
ä-BHC	0.12	Folpet	0.30
ã-BHC	0.12	Heptachlor	0.12
Captafol	0.12	Heptachlor epoxide	0.12
Captan	0.30	Hexachlorobenzene	0.12
Chlordane	0.60	Iprodione	0.12
Chlorobenzilate	0.30	Methoxychlor	0.12

Table A9 (cont.)

Analyte	RL (µg/L)	Analyte	LOQ (µg/L)
Chloroneb	0.30	Metolachlor	0.30
Chlorothalonil	0.12	Mirex	0.12
Cyfluthrin	0.60	Norflurazon	0.12
Cyhalothrin	0.60	Ovex	0.12
Cypermethrin	1.20	Oxadiazon	0.12
p,p'-DDD	0.12	Oxyfluorfen	0.12
p,p'-DDE	0.12	PCA	0.12
p,p'-DDT	0.12	PCNB	0.12
Dacthal	0.12	Permethrin	1.20
Deltamethrin	1.20	Prodiamine	0.12
Dichlobenil	0.12	Pronamide	0.12
Dicloran	0.12	Propachlor	0.30
Dicofol	0.30	Propanil	0.12
Dieldrin	0.12	Propiconazole	0.30
Dithiopyr	0.12	Terbacil	0.12
Endosulfan I	0.12	Toxaphene	6.00
Endosulfan II	0.12	Trifloxystrobin	0.12
Endosulfan sulfate	0.12	Triflumazole	0.12
Endrin	0.12	Trifluralin	0.12
Endrin Aldehyde	0.12	Vinclozalin	0.12
Organonitrogen Pesticides			
Amitraz	0.60	Imidacloprid	0.30
Ametryn	0.30	Isoxaben	0.12
Atrazine	0.30	Mefenoxam	0.30
Azoxystrobin	0.12	Metalaxyl	0.30
Bensulide	0.30	Metribuzin	0.60
Boscalid	0.30	Myclobutanil	0.60
Bromacil	0.30	Oryzalin	0.30
Bromopropylate	0.60	Pendimethalin	0.12
Carfentrazone-ethyl	0.30	Pirimicarb	0.30
Clothianidin	0.30	Prometon	0.60
Cyanazine	0.60	Prometryn	0.30
Diclofop-methyl	0.60	Propazine	0.30
Dimethenamid	0.30	Pyraclostrobin	0.12
Diphenylamine	0.30	Pyridaben	0.60
Ethofumesate	0.30	Pyrimethanil	0.12

Table A9 (cont.)

Analyte	RL (µg/L)	Analyte	LOQ (µg/L)
Fenbuconazole	0.60	Sethoxydim	6.00
Fenoxaprop-ethyl	0.60	Simazine	0.60
Fipronil	0.60	Simetryn	0.30
Fluazifop-P-butyl	0.60	Sulfentrazone	0.30
Fludioxanil	0.60	Tebuconazole	0.60
Flumioxazin	0.30	Tebuthiuron	0.60
Fluometuron	0.12	Thiabendazole	0.12
Fluoxypyr-meptyl	0.30	Triadimefon	0.60
Hexazinone	0.30	–	–
Phenylurea Herbicides			
Chlorpropham	0.30	Monuron	0.12
Diuron	0.12	Neburon	0.12
DCPMU	0.12	Propham	0.30
Fenuron	0.12	Siduron	0.12
Linuron	0.30	–	–
Carbamate Pesticides			
Aldicarb	0.12	3-Hydroxycarbofuran	0.12
Aldicarb sulfone	0.12	Methiocarb	0.12
Aldicarb sulfoxide	0.12	Methomyl	0.12
Bendiocarb	0.12	Oxamyl	0.12
Carbaryl	0.12	Propoxur	0.12
Carbofuran	0.12	Thiobencarb	0.30
Fenobucarb	0.12	–	–

Table A10
Selected pesticides analyzed in 2011 by TDI-Brooks Laboratories (31 analytes) and RLs in nanograms per liter (ng/L)

Target Compounds	MDL Conc. (ng/L)	LOQ Conc. (ng/L)
Aldrin	0.83	5
Dieldrin	0.77	5
Endrin	0.97	5
Heptachlor	0.65	5
Heptachlor-Epoxide	1.22	5
Oxychlordane	0.69	5
Alpha-Chlordane	0.70	5
Gamma-Chlordane	0.89	5
Trans-Nonachlor	0.68	5
Cis-Nonachlor	0.87	5
Alpha-hexachlorocyclohexane (HCH)	1.01	5
Beta-HCH	0.89	5
Delta-HCH	0.59	5
Lindane (Gamma-HCH)	0.78	5
DDMU	0.69	5
2,4'-DDD	0.63	5
4,4'-DDD	0.98	5
2,4'-DDE	0.80	5
4,4'-DDE	0.74	5
2,4'-DDT	0.66	5
4,4'-DDT	0.63	5
1,2,3,4-Tetrachlorobenzene	0.60	5
1,2,4,5-Tetrachlorobenzene	1.03	5
Hexachlorobenzene	1.04	5
Pentachloroanisole	0.90	5
Pentachlorobenzene	0.77	5
Endosulfan II	0.61	5
Endosulfan I	0.70	5
Endosulfan Sulfate	0.78	5
Mirex	0.63	5
Chlorpyrifos	0.86	5

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ATTACHMENT B—SAMPLING PROTOCOL AND QUALITY ASSURANCE PROCEDURES

2010 Brownlee Reservoir Sampling Protocols

Equipment Preparation

The preparation of field equipment followed standard cleaning protocols (Davies 1994; Wilde 2004) prior to field sampling. All tubing used to sample surface water was pre-cleaned in the laboratory using an American Chemical Society (ACS) trace-element grade (10 percent by volume in deionized water) hydrochloric acid solution and deionized water rinse. All tubing was double-bagged following laboratory cleaning for transport to the Brownlee Reservoir sampling site.

Sample Collection

All water samples were collected using a peristaltic pump and sterilized tubing that was lowered to the appropriate depth for sampling. The boat-end of the tubing was pinched, or plugged, prior to the descent of the sampling-end of the tubing to prevent inflow of water from non-sampling depths as the tubing was lowered through the water column. A weight was attached to the sampling-end of the tubing that allowed the vertical descent of the tubing and the tubing to hang perpendicular to the surface of the water. When the tubing reached the appropriate sampling depth, the tubing “plug” was removed and the peristaltic pump started. Water was allowed to purge over the side of the boat from the tubing for at least 1 minute prior to sample collection.

All water samples were collected using the “clean hands” sampling methodology developed by the Environmental Protection Agency (EPA) for sampling ambient waters for trace metals (EPA 1996). The collection of water samples was carried out by 1 individual designated as “clean hands”, 1 designated as “dirty hands”, and a third individual responsible for boat operation and other “non-clean” tasks. All operations involving contact with the sample bottle and with the transfer of the sample from the sample collection device to the sample bottle was handled by the individual designated as “clean hands.” “Dirty hands” was responsible for all activities not involving direct contact with the sample. The following steps were completed by the sampling crew to set up equipment at each sampling location prior to the sample collection:

1. When the boat arrived at each sampling location, all individuals on board put on new nitrile, powder-free gloves. Gloves were worn to set up equipment and were changed by “clean hands” prior to handling sampling containers (see the sample collection protocol below).

2. Sterilized tubing was carefully removed from each storage bag. Care was taken by all individuals to keep from touching either end of the tubing.

3. The flexible, silicon end of the tubing was folded over and tightly secured with a zip tie to act as an air-tight “plug”. The silicon tubing was inserted and locked into the peristaltic pump head.
4. The other end of the tubing was inserted into the weighted polyvinyl chloride (PVC) sampling device for deployment.
5. The PVC sampling device was attached to the downrigger and tape measure and slowly deployed to the appropriate depth.
6. When at the appropriate depth and the downrigger was locked in place, the sample collection protocols described below were followed to collect each sample.

The following protocols describe the collection of each water sample:

1. Once the sampling equipment was in place, “clean hands” put on a new set of sterile gloves.
2. “Dirty hands” opened the cooler containing the sample bottles and unzipped the outer bag; “clean hands” reached into the outer bag, opened the inner bag, and removed the bottle.
3. “Dirty hands” removed the zip tie from the end of the silicon tubing that was inserted into the pump and turned on the pump. When water began flowing from the end of the tubing in the pump, the tubing was purged for at least 1 minute.
4. “Clean hands” removed the cap to the sample container immediately prior to filling the sample container. The sample container cap was rinsed with sampling water 3 times before replacement. After the container was filled near the top, “clean hands” replaced the cap, put the bottle back into the inner bag, and zipped the inner bag. “Dirty hands” then closed the outer bag and placed it in a cooler.
5. Number 4 was repeated until all sample containers (5 containers per sampling location) were filled with the sample water.
6. The third team member was responsible for completing the necessary sample documentation (e.g., to document the sampling location, time, sample number, etc).

2011 Quality Assurance Sampling Plan Selected Sections

Prior to sampling, the 2011 Quality Assurance Sampling Plan (QAPP) was prepared collaboratively by Jack Harrison, HyQual; Kevin Masterson, Oregon Department of Environmental Quality (ODEQ) Toxics Coordinator; Marilyn Fonseca, ODEQ Hydropower Program Coordinator; Dustin Hinson, Hinson Ecological; Jesse Naymik, Idaho Power Company (IPC); Ralph Myers, IPC; and Greg Clark, U.S. Geological Survey (USGS). Most sections of the 2011 QAPP were revised to reflect actual sampling information, procedures, and protocol included in the report. The project objectives, relevant sections on quality control (QC), and reporting are presented as follows.

Project Objectives

- **Objective 1:** Measure the concentration of parameters of interest in hypolimnion in the area where the hypolimnetic pump system will be operated.

- **Objective 2:** For comparison, measure the concentration of parameters of interest in the reservoir discharge.

- **Objective 3:** Evaluate and compare data to state and federal benchmarks and criteria derived to protect human and ecological resources.

- **Objective 4:** Evaluate the change in concentration between hypolimnion and reservoir discharge.

- **Objective 5:** Evaluate and compare data to historical data collected by the Idaho State Department of Agriculture (ISDA), Idaho DEQ (IDEQ), USGS, and others.

Quality Objectives and Criteria

Environmental data is assumed to be acceptable for use when associated QC data is within established control limits. Therefore, it is important to define appropriate QC data and how to interpret the QC data as it applies to the reported environmental data. Specific QC objectives for this project are as follows:

- Collect a sufficient number of samples, sample duplicates, and field blanks to evaluate the sampling and measurement error.

- Analyze a sufficient number of QC standards, blanks, and duplicate samples in the laboratory environment to effectively evaluate results against numerical QA goals established for precision and accuracy.

- Implement sampling techniques in such a manner that the analytical results are representative of the media and conditions being sampled.

Data quality shall be evaluated through the use of the traditional Data Quality Indicators:

- Precision

- Accuracy/bias

- Sensitivity

- Representativeness

- Comparability

- Completeness

QC Samples

Field QC samples will include the following:

- Replicate (all parameters)
- Equipment blank at discharge site (all parameters)
- Field blanks (mercury [Hg] only), 1 each at a discharge and hypolimnion site
- Temperature blank (Pace/ Pacific Agricultural Laboratory [PAgL] and TDI-Brooks Laboratories shipment)

QC samples will be collected following procedures discussed previously. Replicate and equipment blank QC samples with be numbers such that laboratories are unaware of the source.

Analytical Method Requirements

Laboratory QC will include the following:

- Standard package (with QC on batch, not specific to Brownlee samples) includes method blanks, laboratory control spikes, sample duplicates, and matrix spikes and matrix spike duplicates (MS/MSD), along with the accuracy and precision data.
- Standard reporting includes a copy of the Chain of Custody, a Sample Condition Upon Receipt report, and a batch QC cross-reference table. In addition, the QC results for the method blanks, laboratory control spikes, sample duplicates, and MS/MSD are provided, along with the accuracy and precision data.

Data Reporting

The contract lab will follow routine data review, verification, and validation procedures. All data verification, validation, and assessment activities for project purposes are the responsibility of the project manager. Reports will be sent to the personnel listed for review. As soon as possible after each sampling event, calculations and determinations for precision, completeness, and laboratory accuracy will be made. If data quality indicators do not meet the project's specifications, data may be discarded or flagged. The cause of the failure will be evaluated. Any limitations on data use will be detailed in interim and final reports, and other documentation will be provided as needed.

ATTACHMENT C—QUALITY CONTROL RESULTS

Relevant field and laboratory quality control (QC) results for the 2010 and 2011 sampling events are presented as follows. Additional QC results and information are provided in the laboratory reports available from Idaho Power Company (IPC) upon request.

QC Results for 2010 Event

Field QC samples in 2010 included the collection of a replicate and field blank (Table C1 and C2). As discussed below, replicate results did not meet QC criteria for cyanide. However, results for the field sample were below reporting levels (RL) limits of quantification (LOQ) except for nickel.

Table C1
Estimated laboratory reported values for cyanide and nickel

Sample ID	Results	Units	LOQ	Sample ID	Results	Units	LOQ
Cyanide				**Nickel**			
BLANK	ND	µg/L[1]	10.0	BLANK	0.68	µg/L	0.50
RM 283.9	ND	µg/L	10.0	RM 283.9	0.52	µg/L	0.50
RM 286 EPI1	10.6	µg/L	10.0	RM 286 EPI1	1.10	µg/L	0.50
RM 286 EPI2	ND	µg/L	10.0	RM 286 EPI2	0.76	µg/L	0.50
RM 286 HYPO1	ND	µg/L	10.0	RM 286 HYPO1	1.20	µg/L	0.50
RM296MC 50 meters (m)	ND	µg/L	10.0	RM296MC 50 m	0.87	µg/L	0.50
RM326MC 5 feet (ft)	ND	µg/L	10.0	RM326MC 5 ft	0.78	µg/L	0.50

[1] Micrograms per liter

A field replicate was sampled consecutively (i.e., one after the other) to limit temporal variability (the total collection time was a few minutes) and used to assess precision. However, because the replicate was not an exact duplicate, the precision estimate has less precision. The control limit for the replicate samples collected in the field are +/-20 percent relative percent difference for samples >5 times the LOQ or +/- the LOQ for the difference between replicates when the concentrations are <5 times the LOQ.

A cyanide concentration of 10.6 µg/L, which was near the LOQ of 10.0 µg/L, was reported in only 1 of the 2 replicates of the epilimnion samples collected near the dam (Table C2). The single cyanide result was flagged as an estimate because 1 of the reported replicates was below detection and the QC control limit could not be calculated.

The nickel results were also flagged because the field blank concentration was just above the LOQ (i.e., 0.68 and 0.5 µg/L, respectively). Also, all nickel results are estimates because reported concentrations are within 10 times the blank concentration (i.e., 6.8 µg/L) (Pace 2011, pers. comm.).

Table C2
Summary of 2010 Brownlee Reservoir flagged inorganic toxics sampling results (cyanide and nickel), along with Idaho and Oregon aquatic-life criteria (Idaho Administrative Procedures Act [IDAPA] and Oregon Administrative Rules [OAR], respectively) and laboratory LOQ (all units are µg/L)

	Idaho		Oregon			Flagged Results			
	Acute	Chronic	Acute	Chronic	Note	Maximum	Flag	Count	LOQ
Cyanide (WAD)	22	5.2	22	5.2	W	10.60	X	1	10.00
Nickel	470	52.0	1,400	160.0	(+)	1.20	XX	7	0.50

Notes:
Most criteria for Idaho and Oregon are "dissolved" levels.
Results are shown as reported total levels (i.e., more conservative).
(+) = Hardness-dependent criteria (100 milligrams per liter [mg/L] used); with higher hardness, criteria would be higher.
W = Weak acid dissociable.
Flag X = Questionable result reported in only 1 replicate of the epilimnion samples.
Flag XX = Questionable results due to levels in the field blank (i.e., 0.68).

QC Results for 2011 Event

A field replicate sample and equipment and field blanks were collected to assess 2011 sampling procedures (Table C3). The replicate sample was collected using the same sampling apparatus as the previous sample. The replicate sample bottles were filled one after the other to limit possible temporal variability. This produced 2 sample results for 1 location and allowed for an estimate of sample precision. However, because this was not an exact duplicate, the precision estimate will be flagged.

Table C3
Sample QC information for 2011 sampling

ID	Date	Time	Site Name
IPC-7	26-Oct	8:30	Replicate of IPC-3
IPC-8	26-Oct	11:30	Equipment Blank (at IPC-4)
IPC-9	25-Oct	13:10	Field Blanks (mercury [Hg] only) (at IPC-2)
IPC-10	26-Oct	14:30	Field Blanks (Hg only) (at IPC-5)

The equipment blank was collected at IPC-4 to assess the potential for field contamination. The sample was generated in the field by filling sample bottles with laboratory-provided reagent-grade water using sampling equipment pre-conditioned using ultra-clean methods. The equipment blank was processed just before the environmental sample was collected using the same equipment.

The field blanks for mercury were collected at 2 sites to assess ambient conditions. The primary purpose of these blanks is to assess exposure to the air and any background contamination that can diffuse into the water during the transfer of the sample into the bottles.

Field QC Results

Results for field and equipment blank samples were below RLs of 0.5 and 0.1 nanograms per liter (ng/L) for total mercury and methyl mercury, respectively, which indicates no background or transfer contamination.

Results for replicates indicate acceptable precision (Table C4). Precision was estimated by measuring the variability of the replicate measurements, which were sampled consecutively (i.e., one after the other) to limit temporal variability (the total collection time was a few minutes). However, because the replicate was not an exact duplicate, the precision estimate has less precision.

The control limit for the replicate samples collected in the field are +/-20 percent relative percent difference for samples >5 times the LOQ or +/- the LOQ for the difference between replicates when the concentrations are <5 times the LOQ. The precision of the samples was within the control limits (Table C4).

Table C4
Replicate mercury sample results and control limits

	Mercury (ng/L)	
	Total	**Methyl**
Date	25-Oct	25-Oct
IPC-3 (ng/L)	4.8	2.9
IPC-3 Replicate (ng/L)	4.1	3.1
Difference (ng/L)	0.7	0.2
(Minimum) RL(ng/L)	0.5	0.1
RL times 5 (ng/L)	2.5	0.5
Relative Percent Difference (RPD)	15%	7%
Within Control Limit: RPD +/- 20%	Yes	Yes

Note:
Locations are hypolimnion.
IPC-3 R is replicate collected consecutively with IPC-3; labeled as IPC-7.
The control limit is +/-20% RPD for results >5 times the RL.

Selected 2011 Laboratory QC Results

Laboratory QC included method blanks, laboratory control spikes, sample duplicates, and matrix spikes and matrix spike duplicates (MS/MSD), along with the accuracy and precision data. The results were provided by the laboratories in a standard reporting that included a copy of the Chain of Custody, a Sample Condition Upon Receipt report, and batch QC information.

University of Idaho

The narrative report stated the following:

> Organophosphate and Organonitrogen Pesticides: samples 1243 and 1244 each contained 0.030 µg/L desethyl atrazine. Samples 1243 and 1244 also contained atrazine concentrations of 0.014 µg/L. Note: these atrazine concentrations are flagged as semi-quantitative since the results are below the reporting limit of 0.025 µg/L.

Pace Analytical Services, Inc.

Mercury. Results reported herein conform to the most current TNI standards, where applicable, unless otherwise noted in the body of the report.

Dioxin (2,3,7,8-TCDD). The recoveries of the isotopically-labeled TCDD internal standard in the sample extracts ranged from 34 to 60 percent. Except for 2 low values, which were flagged "R" on the results tables, the labeled standard recoveries obtained for this project were within the 40 to 135-percent target range specified in Method 8290. Also, since the quantification of the native TCDD was based on isotope dilution, the data were automatically corrected for recovery and accurate values were obtained.

A laboratory method blank was prepared and analyzed with the sample batch as part of routine QC procedures. The results show that 2,3,7,8-TCDD was not detected, indicating that the sample processing steps were free of background levels of this congener.

Organics Project Report #10174208. Results reported herein conform to the most current TNI standards and the laboratory's *Quality Assurance Manual*, where applicable. In some laboratory control samples and duplicates, results were flagged with "J - Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit."

For 2 analytes (4,4'-DDE and Dieldrin) in 2 samples (IPC-4 and 5), the results were flagged as "J", indicating the estimated concentration was above the adjusted method detection level (MDL) and below the adjusted reporting limit." The RL for each is 0.010RL.

TDI-Brooks Laboratories

There were no QC results reported to be outside the corresponding QC criteria discussed in the QC variance section of this report. This includes analytical interferences detected in the sample that would be qualified with an "I". However, two analytes, Hexachlorobenzene and Pentachloroanisole, were detected below the MDL (qualified as "J") in the procedural blank.

Table C5
Levels reported in TDI blanks (units in ng/L)

	Equipment Blank	Lab Blank	MDL
Hexachlorobenzene	0.56	0.16	1.04
Pentachloroanisole	0.08	0.05	0.90

Table C6
Flagged (questionable) TDI reported results due to levels reported in blanks (units in ng/L)

	IPC-1	IPC-2	IPC-3	IPC-3rep	IPC-4	IPC-5	IPC-6	MDL
Hexachlorobenzene	na	na	na	na	na	na	0.17	1.04
Pentachloroanisole	0.05	0.07	0.06	0.05	0.46	0.46	0.38	0.90

Notes:
All units in ng/L, Actual MDL.
LOQs are 5 ng/L for all analytes.
na = Analyte not detected.

Table C7
Criteria for the flagged (questionable) TDI results

	Oregon Water-Quality Standards Human Health Criteria	
	Water and Fish Ingestion (unit/L)	Fish Consumption Only (unit/L)
Hexachlorobenzene	0.029 ng	0.029 ng
Pentachloroanisole	–	–

Notes:
LOQs are 5 ng/L for all analytes.
JX = Questionable analyte detected below the MDL.

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ATTACHMENT D—SAMPLING LOCATIONS AND FIELD PARAMETERS

2010 Selected Field Parameters

Table D shows selected field data collected during the 2010 inorganic sampling event.

Table D1
Temperature and pH of water at sampling locations

Sample ID	Temperature (degrees Celsius [°C])	pH
RM 283.9	16.4	7.71
RM 286 EPI1	17.1	8.50
RM 286 EPI2	17.1	8.50
RM 286 HYPO1	5.9	7.90
RM296MC 50 meters (m)	6.1	8.00
RM326MC 5 feet (ft)	14.0	8.60

2011 Sampling Information and Field Parameters

Table D2 provides sampling locations and depth/elevation for the samples collected in 2011. Table D3 shows selected field data collected during the 2011 organic and mercury sampling event.

Table D2
2011 sample location and information

ID	Date	Time	Site Name	Latitude	Longitude
IPC 1	25-Oct	10:30	Hypolimnion—286	44.82	-116.92
IPC-2	25-Oct	13:10	Hypolimnion—286.5	44.82	-116.92
IPC-3	26-Oct	8:30	Hypolimnion—287	44.81	-116.93
IPC-4	26-Oct	12:30	Brownlee Discharge—Right channel (RC)	44.85	-116.90
IPC-5	26-Oct	14:30	Brownlee Discharge—Middle Channel (MC)	44.85	-116.90
IPC-6	26-Oct	15:30	Brownlee Discharge—Left Channel (LC)	44.85	-116.90

Table D3
Field data summary for samples collected from hypolimnion (hypo) and discharge (disc). Reservoir discharge collected from the left, middle, and right channel of the (i.e., LC, MC and RC, respectively).

Site ID	Location	River Mile (RM)	Date	Time	Sample Elevation (ft)	Sample Depth (ft)	Temperature (°C)	DO (mg/L[1])	Conductivity (mS/com)	pH (S.U.)
IPC-1[2]	Hypo	286.0	25-Oct	9:17	1,822.7	212.8	7.20	0.15	0.268	7.37
IPC-2[3]	Hypo	286.5	–	–	1,823.2	212.4	7.25	0.14	0.268	7.36
IPC-3[2]	Hypo	287.0	25-Oct	10:48	1,823.5	212.0	7.29	0.14	0.269	7.35
IPC-4[4]	Right-disc	283.8	26-Oct	12:30	1,803.0	5.0	14.34	6.73	0.410	8.07
IPC-5[4]	Mid-disc.	283.8	26-Oct	14:30	1,803.0	5.0	14.22	5.87	0.400	7.86
IPC-6[4]	Left-disc	283.8	26-Oct	15:30	1,803.0	5.0	14.09	5.94	0.400	7.98

Notes:

[1] Milligrams per liter

[2] Raw Aquatics Database (ADB) export data from the seabird instrument; water surface elevation based on Idaho Power Company (IPC) database;

[3] IPC-2 estimated as average of IPC-1 and 3.

[4] Data from Jesse Naymik, IPC, field notebook.

IPC-2 is estimated because no profile data were collected at the IPC-2 location and, therefore, an average of IPC-1 and IPC-3 was used.

Discharge samples IPC-4 and 6 were collected from the right and left bank, respectively.

Discharge water flows through the turbines and is drawn from upper and mid-reservoir strata just upstream of the dam.

ATTACHMENT E—SAMPLING RESULTS AS REPORTED

2010 Results for Inorganics

The following table provides results for inorganic toxics used to the calculate maximums presented in the main report. Parameter results provided in Attachment C are not included.

Table E1
Inorganic toxic results as reported by Pace Analytical Laboratories in 2010

Sample ID	Results	Units	LOQ[1]	Sample ID	Results	Units	LOQ
Arsenic				**Iron**			
BLANK	0.00	µg/L[2]	0.50	BLANK	ND	µg/L	50.00
RM 283.9	6.10	µg/L	0.50	RM 283.9	ND	µg/L	50.00
RM 286 EPI1	6.40	µg/L	0.50	RM 286 EPI1	ND	µg/L	50.00
RM 286 EPI2	6.30	µg/L	0.50	RM 286 EPI2	ND	µg/L	50.00
RM 286 HYPO1	4.80	µg/L	0.50	RM 286 HYPO1	ND	µg/L	50.00
RM296MC 50 meters (m)	5.10	µg/L	0.50	RM296MC 50 m	ND	µg/L	50.00
RM326MC 5 feet (ft)	6.30	µg/L	0.50	RM326MC 5 ft	221.00	µg/L	50.00
Chromium				**Lead**			
BLANK	ND	µg/L	0.50	BLANK	ND	µg/L	0.10
RM 283.9	0.63	µg/L	0.50	RM 283.9	ND	µg/L	0.10
RM 286 EPI1	1.30	µg/L	0.50	RM 286 EPI1	ND	µg/L	0.10
RM 286 EPI2	0.80	µg/L	0.50	RM 286 EPI2	ND	µg/L	0.10
RM 286 HYPO1	2.10	µg/L	0.50	RM 286 HYPO1	ND	µg/L	0.10
RM296MC 50 m	0.86	µg/L	0.50	RM296MC 50 m	ND	µg/L	0.10
RM326MC 5 ft	1.30	µg/L	0.50	RM326MC 5 ft	0.14	µg/L	0.10
Copper				**Selenium**			
BLANK	ND	µg/L	0.50	BLANK	ND	µg/L	0.50
RM 283.9	0.77	µg/L	0.50	RM 283.9	0.55	µg/L	0.50
RM 286 EPI1	0.86	µg/L	0.50	RM 286 EPI1	0.70	µg/L	0.50
RM 286 EPI2	0.85	µg/L	0.50	RM 286 EPI2	0.64	µg/L	0.50
RM 286 HYPO1	ND	µg/L	0.50	RM 286 HYPO1	ND	µg/L	0.50
RM296MC 50 m	ND	µg/L	0.50	RM296MC 50 m	ND	µg/L	0.50
RM326MC 5 ft	1.10	µg/L	0.50	RM326MC 5 ft	0.68	µg/L	0.50

[1] Limits of quantification

[2] Micrograms per liter

Table E2
Total hardness results used to calculate inorganic toxic criteria

Sample ID	Results	Units	LOQ
BLANK	76.0	µg/L	71.0
RM 283.9	167,000.0	µg/L	355.0
RM 286 EPI1	171,000.0	µg/L	355.0
RM 286 EPI2	174,000.0	µg/L	355.0
RM 286 HYPO1	180,000.0	µg/L	355.0
RM296MC 50 m	188,000.0	µg/L	355.0
RM326MC 5 ft	201,000.0	µg/L	355.0

2011 Results for Organics

Table E3 provides a more complete list of the organic results summarized in the report. Included is the narrative from the University of Idaho (U of I) for parameters reported below the limits of quantification (LOQ). Also provided are results for the organic toxics used to calculate the maximums presented in the main report. For the parameters requested by Oregon, some of which were not discussed in the report, the criteria and reporting levels (RL) (LOQ) are also provided to allow comparison of criteria with the LOQ.

Criteria given in the report were updated to more current and generally lower levels. However, because criteria and benchmarks are revised regularly, not all of criteria given below have been reviewed and updated at the time of this publication.

University of Idaho Analytical Sciences Laboratory provided the following narrative:

> The concentrations of the following pesticides did not exceed the limit of detection (0.02 µg/L): DDT, Dieldrin, Hexachlorobenzene, Permethrin, Azinphos Methyl, Dichlorvos, and Terbufos. The limits of detection were lower than the reporting levels.

Table E3
TDI-Brooks Laboratories results (in nanograms per liter [ng/L]) for all sample locations with results reported

	IPC-1		IPC-2		IPC-3		IPC-3rep		IPC-4		IPC-5		IPC-6		3X MDL[1]	Actual MDL
Dieldrin	0.00	U	0.00	U	0.00	U	0.00	U	0.00	U	0.00	U	**0.16**	**J**	2.32	0.77
Alpha-Chlordane	0.00	U	0.00	U	0.00	U	0.00	U	**0.82**		0.00	U	0.00	U	2.11	0.70
4,4'-DDE	0.00	U	**0.07**	**J**	**0.11**	**J**	**0.09**	**J**	0.00	U	0.00	U	**0.15**	**J**	2.22	0.74
Endosulfan Sulfate	0.00	U	0.00	U	0.00	U	0.00	U	0.10	J	0.00	U	**0.10**	**J**	2.35	0.78
Chlorpyrifos	**0.67**	**J**	**0.94**	–	0.00	U	**0.89**	**J**	**0.50**	**J**	**0.55**	**J**	**0.67**	**J**	2.57	0.86

Notes:
[1] Method detection level = MDL
Units in µg/L and ng/L as indicated.
LOQs are 5 ng/L for all analytes.
J = Analyte detected below the MDL.

Data reported by TDI-Brooks Laboratories is as follows:

> Analytes that are detected below the method detection limit are qualified as “J”. Analytes that are detected in the procedural blanks greater than 3X MDL are qualified with a “B”. Analytical interference’s that are detected in the sample are qualified with an “I”. Analytes not detected in the samples are qualified with a “U”. The RPD for analytes in duplicate samples that are <3X MDL are qualified with a “X”.

Table E4
Criteria and TDI maximum estimated concentrations (all in µg/L)

	OR WQS Aquatic-Life Criteria		OR WQS HH Criteria		Maximum TDI Concentration				
	Fresh Acute Criteria (µg/L)	Fresh Chronic Criteria (µg/L)	Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)	Hypo (µg/L)		Disc (µg/L)		Actual MDL (µg/L)
Aldrin	3.000	–	0.0000050	0.0000050	nd	–	nd	–	0.00083
Dieldrin	2.500	0.0019	0.0000053	0.0054000	nd	–	0.00016	J	0.00077
Alpha-Chlordane	–	–	–	–	nd	–	0.00082	–	0.00070
4,4'-DDE (DDE)	–	–	0.000022	0.0000220	0.00011	J	0.00015	J	0.00074
2,4'-DDT (DDT)	–	–	0.000022	0.0000220	nd	–	nd	–	0.00066
Endosulfan	0.220	0.0560	–	–	nd	–	nd	–	0.00061
Endosulfan Sulfate	–	–	8.500000	8.9000000	nd	–	0.00010	J	0.00078
Mirex	–	0.0010	–	–	nd	–	nd	–	0.00063
Chlorpyrifos	0.083	0.0410	–	–	0.00094	–	0.00067	J	0.00086
Total Chlordane	2.400	0.0043	0.000081	0.000081	nd	–	0.00082	–	–
Total DDT	1.100	0.0010	–	–	0.00011	J	0.00015	J	–

Notes:
Units in µg/L.
LOQs are 5 ng/L for all analytes.
J = Analyte detected below the MDL.

Table E5
Oregon Table 20 organic criteria and Pacific Agricultural Laboratory (PAgL) and Pace Analytical Laboratories' RLs. All results were reported below LOQ and MDL.

	OR WQS Aquatic-Life Criteria (µg/L)		OR WQS HH Criteria (µg/L)		PAgL (µg/L)	Pace (µg/L except as noted)
Oregon Table 20 Organics	**Fresh Acute Criteria**	**Fresh Chronic Criteria**	**Water and Fish Ingestion**	**Fish Consumption Only**	**LOQ**	**MDL/LOQ**
acenapthene	–	–	95.00000000000	99.00000000000	–	5/10
aldrin	3.00	–	0.00000500000	0.00000500000	0.12	0.0005/0.01
CHLOROPHENOXY HERBICIDES (2,4,5 TP)	–	–	10.00000000000	–	–	0.049/0.1901
DEMETON	–	0.1000	–	–	0.03	–
DIOXIN (2,3,7,8-TCDD)	–	–	0.00000000051	0.00000000051	–	5/10 (pg/L)
ENDOSULFAN	0.22	0.0560	–	–	0.12	0.0007/0.01
ENDRIN	0.18	0.0023	0.02400000000	0.02400000000	0.12	0.0017/0.01
FLUORANTHENE	–	–	14.00000000000	14.00000000000	–	1/10
HEPTACHLOR	0.52	0.0038	0.00000790000	0.00000790000	0.12	0.0015/0.01
METHOXYCHLOR	–	0.0300	100.00000000000	–	0.12	0.007/0.01
MIREX	–	0.0010	–	–	0.12	–
NAPHTHALENE	–	–	–	–	–	1.2/10
Polychlorinated Biphenyls (PCB)	2.00	0.0140	0.00000640000	0.00000640000	–	–/0.1
PHENOL	–	–	9,400.00000000000	86,000.00000000000	–	1.2/10
POLYAROMATIC HYDROCARBONS (PAH)	–	–	–	–	–	varies
TOXAPHENE	0.73	0.0002	0.00002800000	0.00002800000	6.00	–

Table E6
Oregon Table 20 organic and other criteria and Pace Analytical Laboratories' estimated results for the discharge samples (Disc) above RLs. All other sample site results were "nd," indicating parameter concentrations below RLs.

	OR WQS Aquatic-Life Criteria (µg/L)		OR WQS HH Criteria		Pace Results		
Oregon Table 20 Organics	**Fresh Acute Criteria**	**Fresh Chronic Criteria**	**Water and Fish Ingestion**	**Fish Consumption Only**	**Disc 4**	**Disc 5**	**LOQ (MDL)**
DDT METABOLITE (DDD, DDE, DDT[1])							
4,4'-DDD	–	–	0.0000310	0.0000310	nd	nd	0.01
4,4'-DDE	–	–	0.0000220	0.0000220	nd	0.0015J	0.01
4,4'-DDT	–	–	0.0000220	0.0000220	nd	nd	0.01

Table E6 (cont.)

	OR WQS Aquatic-Life Criteria (µg/L)		OR WQS HH Criteria		Pace Results		
Oregon Table 20 Organics	**Fresh Acute Criteria**	**Fresh Chronic Criteria**	**Water and Fish Ingestion**	**Fish Consumption Only**	**Disc 4**	**Disc 5**	**LOQ (MDL)**
DDT	1.10	0.0010	–	–	–	–	–
PHTHALATEs (individual)							
DIBUTYLPHTHALATE (DBP)	–	–	35 mg	154.0 mg	nd	nd	10 (5)
DIETHYLPHTHALATE (DMP)	–	–	350 mg	1.8 g	nd	nd	10 (5)
DIMETHYL PHTHALATE (DEP)	–	–	313 mg	2.9 g	nd	nd	10 (5)
DI-2-ETHYLHEXYL PHTHALATE (DEHP)	–	–	15 mg	50.0 mg	nd	nd	10 (5)
Other Reported Results							
Dieldrin	2.50	0.0019	0.0000053	0.0000054	0.00093J	0.00071J	0.01

Notes:

[1] DDD = dichlorodiphenyldichloroethane, DDE = dichlorodiphenyldichloroethylene, and DDT = dichlorodiphenyltrichloroethane

Units in µg/L.

J = Analyte detected below the LOQ.

Table E7

Oregon Department of Agriculture (ODA) pesticides and pollutants of interest (POI) organic criteria and PAgL RLs. All results were reported below RL and the MDL.

	EPA OPM Benchmarks (µg/L)						PAgL
Parameter	**Acute Fish^2**	**Chronic Fish^2**	**Acute Invert.^{4}**	**Chronic Invert.^{4}**	**Non-Vascular Plants Acute**	**Vascular Plants Chronic**	**RL (µg/L)**
ODA Pesticides							
imidacloprid (wc)	>41,500.000	1,200.000	35.0000	1.05000	>10,000	–	0.30
bifenthrin	0.075	0.040	0.8000	0.00130	–	–	0.12
1-cyhalothrin	–	–	–	–	–	–	0.60
diflubenzuron	64,500.000	100.000	0.0014	0.00025	200	190.0	10.00
cyfluthrin	0.034	0.010	0.0125	0.00700	–	–	0.60
Oregon POI List Additions							
dimethanamid	3,150.000	300.000	6,000.0000	1,020.00000	14	8.9	0.30
deltamethrin	0.290	0.017	0.0550	0.00410	–	–	1.20
esfenvalerate	0.035	0.035	0.0250	0.01700	–	–	0.12
fipronil	41.500	6.600	0.1100	0.01100	140	>100.0	0.60
glyphosate	21,500.000	1,800.000	26,600.0000	49,900.00000	12,100	11,900.0	10.00

Notes:

Benchmarks from http://www.epa.gov/oppefed1/ecorisk_ders/aquatic_life_benchmark.htm.

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ODEQ Request #1

Water Column Toxics:

DEQ has been reviewing the information on toxic pollutants provided in the December 1, 2015 application for Section 401 certification. DEQ has been unable to reconcile results in various tables in Exhibit 6.6-1. For example, Table 10 lists endosulfan as a parameter that was evaluated in the 2010 and 2011 sampling events in Brownlee Reservoir. Table 10 notes the maximum concentrations and MDL for endosulfan with a "dash." No Note is provided to explain the meaning of the dash symbol. Further, on Table E4, endosulfan is listed with non-detect results and an MDL recorded.

Please provide a table of the results for the toxic parameters listed below, including site name (include data for each location sampled), parameter name, detection limit (MDL), limit of quantification (LOQ), result and any flags. Results should be summarized as follows:

Parameter not detected below the detection level (MDL) = ND
Values between the MDL and LOQ = flag as an estimate
Values above the LOQ = Validated results

Please provide this information for the following parameters:

Atrazine
Desethyl atrazine
Chlordane
Chlorpyrifos
Dieldrin
DDT
4,4' DDE
Endosulfan
Endosulfan Alpha (reported as endosulfan I)
Endosulfan Beta (reported as endosulfan II)
Endosulfan sulfate
Dioxin (2,3,7,8-TCDD)
Polychlorinated Biphenyls (PCBs)

IPC Response

This Revised Table 1 replaces the draft Table 1 in IPCs response to this request on 04/15/2016

Table 1 incorporates ODEQ's request to use specific flags and notations (listed below). In order to match with the results reported by the laboratory, IPC included one additional flag to the requested items from ODEQ. Therefore the results in Table 1 are summarized as:

- Parameter not detected below the detection level (MDL) = "ND"
- Parameter detected below the detection level (MDL) = flag as "J"
- Values between the MDL and LOQ = flag as an estimate "E"
- Values above the LOQ = Validated results "V"

Table 1. Summarized results (in ng/L, unless otherwise noted) for selected toxic organic compounds requested by ODEQ via email on April 5, 2016. Parameters were measured in 2011 in the Brownlee Reservoir hypolimnion (IPC-1, IPC-2, IPC-3 and IPC-3 replicate) and Brownlee Reservoir Discharge (IPC-4, IPC-5 and IPC-6).

Result by TDI-Brooks [except as noted]	IPC-1	Flag	IPC-2	Flag	IPC-3	Flag	IPC-3 rep	Flag	IPC-4	Flag	IPC-5	Flag	IPC-6	Flag	MDL[1]	LOQ[2]
Atrazine [UI][3]	ND		ND		ND		ND		ND		14	E	14	E	--	25
Desethyl atrazine [UI]	ND		ND		ND		ND		ND		30	V	30	V	--	25
Chlordane[4]	ND		ND		ND		ND		0.82		ND		ND		--	--
Alpha-Chlordane	ND		ND		ND		ND		0.82	E	ND		ND		0.70	5
Gamma-Chlordane	ND		ND		ND		ND		ND		ND		ND		0.89	5
Chlorpyrifos	0.67	J	0.94	E	ND		0.89	E	0.5	J	0.55	J	0.67	J	0.86	5
Dieldrin	ND		ND		ND		ND		ND		ND		ND		0.77	5
Dieldrin [Pace][5]	ND		ND		ND		ND		0.93	E	0.71	E	ND		0.52	10
DDT[6]	ND		0.07		0.11		0.09		ND		ND		0.15		--	--
2,4'-DDT	ND		ND		ND		ND		ND		ND		ND		0.80	5
4,4'-DDT	ND		ND		ND		ND		ND		ND		ND		0.63	5
4,4'-DDE	ND		0.07	J	0.11	J	0.09	J	ND		ND		0.15	J	0.74	5
4,4'-DDE [Pace]	ND		ND		ND		ND		ND		1.5	E	ND		0.94	10
Endosulfan	---		--		--		--		--		--		--		--	--
Endosulfan Alpha (reported as endosulfan I)	ND		ND		ND		ND		ND		ND		ND		0.70	5
Endosulfan Beta (reported as endosulfan II)	ND		ND		ND		ND		ND		ND		ND		0.61	5
Endosulfan sulfate	ND		ND		ND		ND		0.10	J	ND		0.10	J	0.78	5
Dioxin (2,3,7,8-TCDD) [Pace]	ND		ND		ND		ND		ND		ND		ND		--	10pg/L
Polychlorinated Biphenyls (PCBs) [Pace]	ND		ND		ND		ND		ND		ND		ND		--	100

Notes: [1]MDL is the lower method detection level provided by the laboratory. [2]LOQ is the Limit of Quantification reported by the lab. [3]UI is University of Idaho Analytical Sciences Laboratory, Moscow, Idaho. [4]Chlordane was reported by TDI-Brooks as "Total Chlordane" as the sum of Alpha-Chlordane and Gamma-Chlordane. No flags or MDL/LOQ values were included with the Total Chlordane result from TDI-Brooks. [5]Pace is Pace Analytical Services, Inc. Minneapolis, Minnesota. [6]DDT was reported by TDI-Brooks as "Total DDT" as the sum of all DDT and DDT breakdown products (DDE and DDD). No flags or LOQ/MDL values were included with the Total DDT result from TDI-Brooks. A dash (--) in the result columns indicates the analysis for that specific compound requested by ODEQ was not run or reported by any laboratory. A dash (--) in the LOQ/MDL columns indicates no values were provided by laboratory because the result was reported as the sum of other analyses. ND indicates "non-detect" meaning the parameter was not detected below the MDL, as requested by ODEQ. A Flag of "E" indicates an estimated value detected above the MDL but below the LOQ, as requested by ODEQ. A Flag of J indicates the parameter was detected below the MDL.

As shown in Table 1, estimated concentrations for Deildrin and DDE were reported by both TDI-Brooks and Pace Analytical, and all reported results are provided. Where multiple labs reported “non-detects” only the lowest reporting limits are provided in the table. Three different Endosulfan parameters were analyzed by multiple laboratories. Unlike DDT and Chlordane, the three parameters were not summed by the laboratories, and therefore are not summed in this table.

Exhibit 6.6-2

Water column and bed-sediment core samples collected from Brownlee Reservoir near Oxbow, Oregon, 2012

Prepared in cooperation with Idaho Power Company

Water Column and Bed-Sediment Core Samples Collected from Brownlee Reservoir near Oxbow, Oregon, 2012

Data Series 809

U.S. Department of the Interior
U.S. Geological Survey

Water Column and Bed-Sediment Core Samples Collected from Brownlee Reservoir near Oxbow, Oregon, 2012

By Ryan L. Fosness, U.S. Geological Survey; Jesse Naymik, Idaho Power Company; Candice B. Hopkins, U.S. Geological Survey; and John F. DeWild, U.S. Geological Survey

Prepared in cooperation with Idaho Power Company

Data Series 809

U.S. Department of the Interior
U.S. Geological Survey

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SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2013

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Conversion Factors, Datums, and Abbreviations and Acronyms

Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Volume	
liter (L)	33.82	ounce, fluid (fl. oz)
liter (L)	61.02	cubic inch (in^3)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)

Concentrations of chemical constituents in water are given in either milligrams or micrograms per liter (mg/L or µg/L) or milligrams or micrograms per kilogram (mg/kg or µg/kg). Units in nanograms per liter (ng/L) are approximately equivalent to parts per trillion (10^{12}).

Datums

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Conversion Factors, Datums, and Abbreviations and Acronyms—Continued

Abbreviations and Acronyms

DO	dissolved oxygen
IDEQ	Idaho Department of Environmental Quality
IPC	Idaho Power Company
HCC	Hells Canyon Complex
MRL	USGS Mercury Research Laboratory
ODEQ	Oregon Department of Environmental Quality
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEC	probable effect concentration
SVOC	semi-volatile organic compound
TEC	threshold effect concentration
TOC	total organic carbon
USGS	U.S. Geological Survey

Water Column and Bed-Sediment Core Samples Collected from Brownlee Reservoir near Oxbow, Oregon, 2012

By Ryan L. Fosness[1], Jesse Naymik[2], Candice B. Hopkins[1], and John F. DeWild[1]

Abstract

The U.S. Geological Survey, in cooperation with Idaho Power Company, collected water-column and bed-sediment core samples from eight sites in Brownlee Reservoir near Oxbow, Oregon, during May 5–7, 2012. Water-column and bed-sediment core samples were collected at each of the eight sites and analyzed for total mercury and methylmercury. Additional bed-sediment core samples, collected from three of the eight sites, were analyzed for pesticides and other organic compounds, trace metals, and physical characteristics, such as particle size.

Total mercury and methylmercury were detected in each of the water column and bed-sediment core samples. Only 17 of the 417 unique pesticide and organic compounds were detected in bed-sediment core samples. Concentrations of most organic wastewater compounds detected in bed sediment were less than the reporting level. Trace metals detected were greater than the reporting level in all the bed-sediment core samples submitted for analysis. The particle size distribution of bed-sediment core samples was predominantly clay mixed with silt.

Introduction

Idaho Power Company (IPC) owns and operates Brownlee Dam, which forms Brownlee Reservoir (____), the farthest upstream and largest in area and volume within IPC's Hells Canyon Hydroelectric Project (Brownlee, Oxbow, and Hells Canyon Reservoirs), commonly referred to as the Hells Canyon Complex (HCC). Brownlee Dam was completed in May 1959, and along with the Oxbow and Hells Canyon Dams, effectively blocked the upstream

,

2003). A

by IPC was adopted in 1991 to protect salmonid spawning areas downstream of the HCC. This plan called for constant

early part of the salmonid (including fall Chinook) spawning period in late October (Idaho Power Company, 1991). However, water temperatures in the Snake River downstream of the Hells Canyon Hydroelectric Project are warmer than the temperature criteria set for salmonid spawning by the Idaho Department of Environmental Quality (IDEQ) and Oregon Department of Environmental Quality (IDEQ and ODEQ; 2004). IPC is researching strategies to comply with the set temperature criteria during the salmonid spawning period. One potential strategy involves pumping hypolimnetic (cooler water from the deepest areas of the reservoir) into the Brownlee Dam powerhouse intake and downstream to the Snake River. A concern associated with accessing the deep, cool water is re-suspending and transporting potentially contaminated water and bed-sediment.

Purpose and Scope

This report documents the methods used to collect and analyze the water column and bed-sediment core samples from Brownlee Reservoir, and presents the results of the analyses. Characterization of the water column and bed-sediment chemistry in the reservoir provides data to better understand the potential effects of transporting potentially contaminated water from the hypolimnetic zone downstream.

Description of the Study Area

Brownlee Reservoir forms a part of the Idaho-Oregon border along the Snake River (____). The reservoir is about 92

less than 1 km wide, and reaches depths exceeding 90 m near Brownlee Dam. gins and a

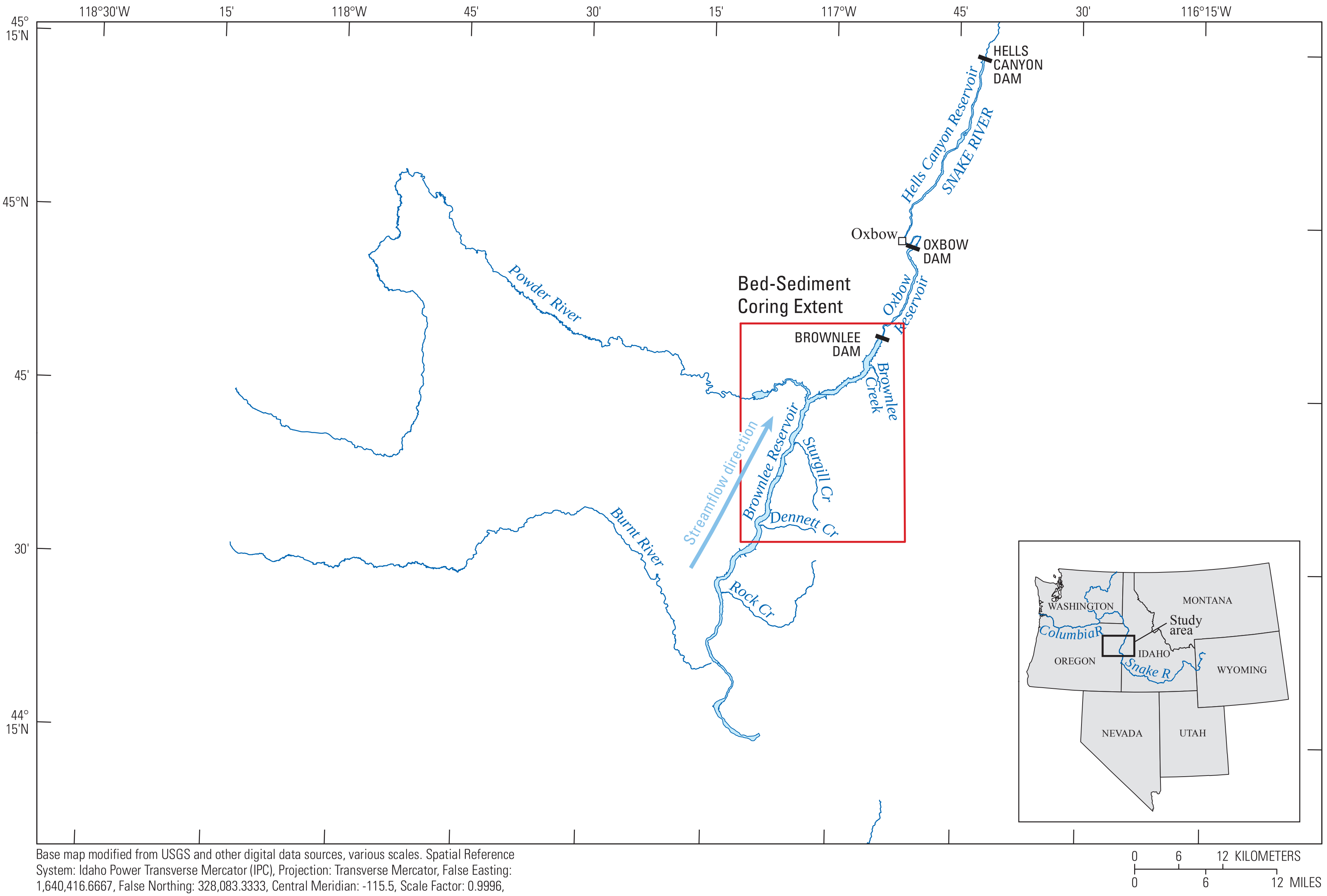
-impoundment thalweg. The mean pool elevation for Brownlee Reservoir for water years 2010–11 ranged from 614 to 633 m above the NGVD 29 datum. Typically, IPC draws the reservoir down (about 12–18 m during 2010 and 2011) in the early spring to create storage capacity for snowmelt runoff.

to Brownlee Reservoir, but the Burnt and Powder Rivers, and Dennett, Sturgill, and Brownlee Creeks discharge directly to the reservoir (____). Wood and Etheridge (2011) provide a more comprehensive description of land use, drainage area, and other characteristics of the Snake River watershed upstream of Brownlee Reservoir.

---

[1] U.S. Geological Survey.

[2] Idaho Power Company.



Base map modified from USGS and other digital data sources, various scales. Spatial Reference System: Idaho Power Transverse Mercator (IPC), Projection: Transverse Mercator, False Easting: 1,640,416.6667, False Northing: 328,083.3333, Central Meridian: -115.5, Scale Factor: 0.9996, Latitude Of Origin: 42, Horizontal Datum: North American Datum of 1983.

Figure 1. Lower Snake River drainage basin and tributary subbasins to Brownlee Reservoir near Oxbow, Oregon.

Previous Investigations

Although numerous water-quality and sediment studies have been completed in Brownlee Reservoir, most previous

not included the wide array of constituents that may be present in the water column and bed-sediment.

In 1998, the U.S. Geological Survey (USGS), in

-tissue samples at two sites in an upstream part of Brownlee Reservoir near the Burnt River and Dennett Creek. The sediment samples were collected and analyzed for organochlorine compounds and trace elements. Bed-sediment samples collected at the Burnt River contained the largest concentration of detected organochlorine compounds (Dacthal, p,p'-DDD, p,p'-DDE, p,p'-DDT, and Hexachlorobenzene) in the Snake River Basin. However, the concentrations of the or

downstream site near Dennett Creek where the only detected compounds were p,p'-DDD and p,p'- DDE. Concentrations of trace metals including arsenic, cadmium, chromium, copper, nickel, and zinc in the bed sediment collected near Dennett Creek were the largest in the Snake River Basin. The concentration of the trace elements generally increased from the site at Burnt River to the site near Dennett Creek (Clark and Maret, 1998).

In a follow-up study done in 1998 and 1999, CH2M HILL (2000) did sediment coring throughout Brownlee Reservoir, including sites near those sampled by Clark and Maret (1998). The objective of the CH2M HILL study was to determine the physical and mineralogical characteristics of sediment along the thalweg of the channel through Brownlee Reservoir. As part of the study, CH2M HILL analyzed the bed sediment for selected organochlorine and trace elements. Generally, organochlorine and trace element concentrations (including total mercury) in the bed sediment increased in a northerly direction toward Brownlee Dam (CH2M HILL, 2000). Physical and mineralogical results from the study provided insight into the sedimentation patterns in the reservoir; silt and clay-sized-sediment accounted for more than 99 percent of the total particle-size distribution near Brownlee Dam.

In June and September 2006, Brandt (2007) collected water samples upstream and downstream of Brownlee Reservoir to determine the concentration and load of total mercury into and out of Brownlee Reservoir. The results were used to estimate a mass balance for total mercury and to identify the major sources of mercury to Brownlee Reservoir. Findings from the study indicated relatively low concentrations and loadings of total mercury to the reservoir. However, the reservoir seemed to be acting as a mercury sink; less than 50 percent of the total mercury entering Brownlee Reservoir was transported through the reservoir.

In October of 2010 and 2011, Harrison and others (2012) collected water samples from the hypolimnion and discharge waters of Brownlee Reservoir, and analyzed the samples for selected organic and inorganic compounds (including mercury). Seventeen inorganic constituents were analyzed in 2010, and 470 organic constituents were analyzed in 2011 along with total mercury and methylmercury. Of the 470 organic constituents analyzed in 2011, only 7 pesticides, including the isomers or degradates of pesticides, were detected in the water column. Other organic compounds, including semi-volatile organic compounds (SVOCs), individual polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and dioxins, were detected

All concentrations were less than the aquatic-life criteria and benchmarks established by the U.S. Environmental Protection Agency (EPA) (Stephan and others, 1985). However consumption advisories based on mercury are in place for Brownlee Reservoir, and the relatively high methylmercury concentrations detected in the hypolimnion of Brownlee Reservoir (2.5–2.9 ng/L) were noted by Harrison and others (2012) as a human health concern.

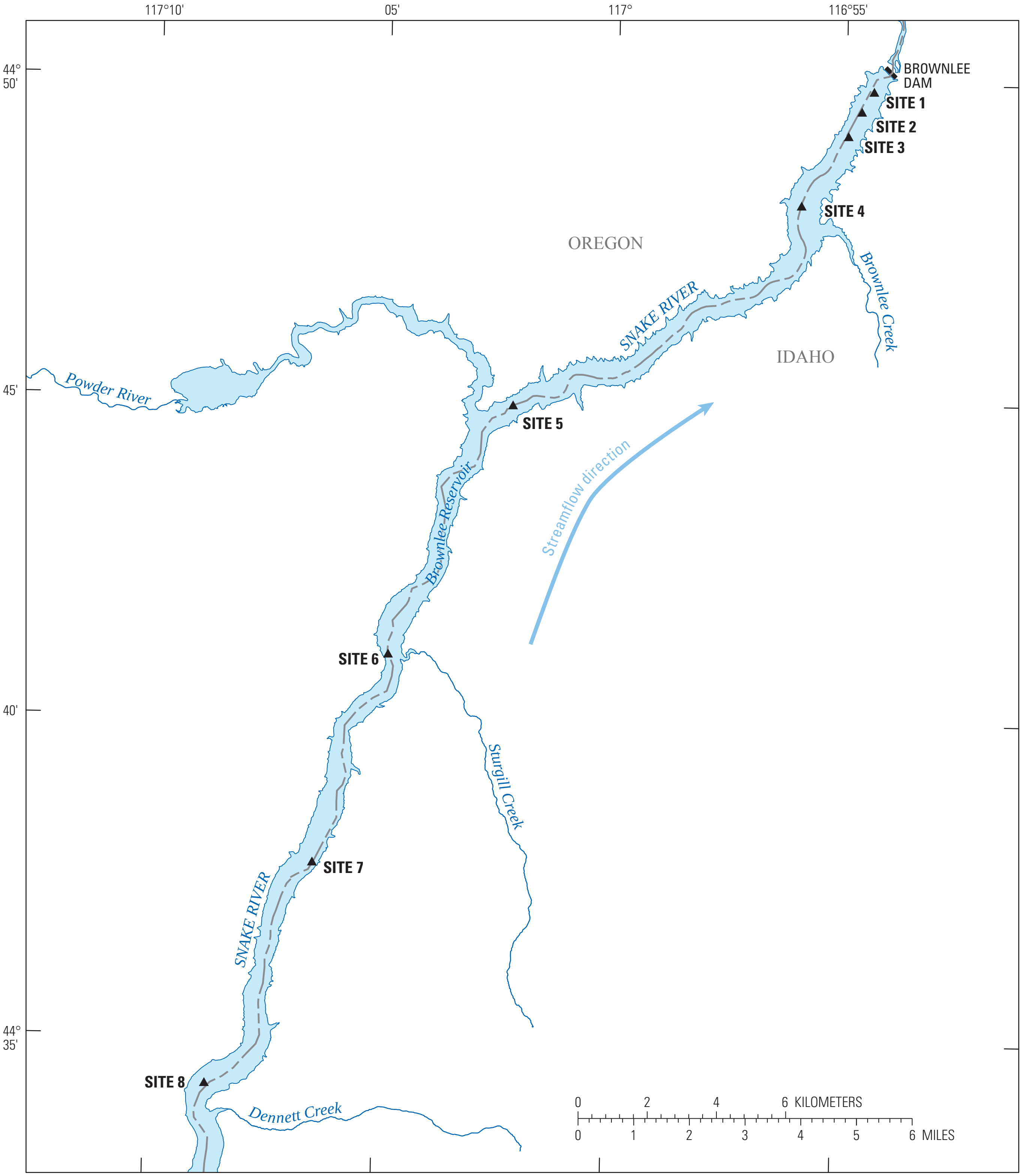
Methods

Sampling Methods

Water-column sampling and bed-sediment coring were done during the week of May 7–11, 2012. Field personnel from the USGS Idaho Water Science Center in Boise and the USGS Mercury Research Laboratory (MRL) in Madison, Wisconsin collected samples from eight sites (____, table 1) to provide a spatial representation of the northern half of the reservoir. Sites 1–3 were slightly upstream of the deepest part of the reservoir near Brownlee Dam. Sites 4–8 were located

All of the sites were within the pre-impoundment thalweg to target

(less than 0.063 mm) bed sediment (van Metre and others, 2004). High-resolution bathymetry provided by IPC was used to identify the pre-impoundment thalweg at each of the sites.



Base map modified from USGS and other digital data sources, various scales. Streamflow vector lines from National Hydrography Dataset. Spatial Reference System: Idaho Power Transverse Mercator (IPC), Projection: Transverse Mercator, False Easting: 1,640,416.6667, False Northing: 328,083.3333, Central Meridian: -115.5, Scale Factor: 0.9996, Latitude Of Origin: 42, Horizontal Datum: North American Datum of 1983.

Figure 2. Locations where water-column samples and bed-sediment core samples were collected from Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

Table 1. Description of sites and number of water-column and bed-sediment core samples collected from Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

[**NWIS site**: All sites are in Snake River upstream of Brownlee Dam, Idaho. **River mile designation**: Designations are commonly referenced locations, so a conversion to kilometers was not made or recommended. Online data can be viewed at http://waterdata.usgs.gov/nwis/inventory by entering the National Water Information System (NWIS) site No. for each site using a multiple site numbers search criteria. –, no sample]

NWIS site name	NWIS site No.	River mile designation	Water-column mercury samples	Bed-sediment cores			
				Mercury (total and methylmercury)	Organics and trace elements	Description and particle size	Replicates
Site 1	444954116542400	285.1	3	1	4	1	2
Site 2	444935116544000	285.5	3	1	–	–	2
Site 3	444912116545700	286.0	3	1	–	–	2
Site 4	444807116555700	287.6	3	1	–	–	2
Site 5	444455117021200	295.1	3	1	4	1	2
Site 6	444101117045000	300.7	3	1	–	–	2
Site 7	443745117062500	305.1	3	1	–	–	2
Site 8	443416117084000	310.0	3	1	4	1	2

Water Column Profiles

collected at each site using a Sea-Bird Electronics, Inc. SeaCAT T) (____).

from which to collect water samples for analysis of total mercury and methylmercury. The SEACAT is designed to drift slowly (approximately 0.5 m per second) downward through the water column, continuously collecting data four times per second. Post-processed readings provided data at intervals of about 0.5 m within the water column. The SEACAT was calibrated by the manufacturer prior to the

probe (Hydrolab® multiprobe).

Water-Column Samples

Three zones were targeted for water-column sampling based on the information collected from the water column

water surface in the upper part of the epilimnion (warmer upper zone), near the bottom of the metalimnion (middle zone) where the temperature and DO sharply decreased, and in the hypolimnion (bottom zone) slightly above the reservoir bed. Water column samples were collected at sites 1–8 for mercury analysis using the methods described in Lewis and Brigham (2004). A horizontally oriented Niskin point-sampler (____) was used to collect samples from each of the three targeted zones in the water column. The pre-cleaned Niskin sampler was lowered in the “open” position, and a triggering device was used to collect the sample at the desired depth. Each water sample was transferred to a separate pre-cleaned container and stored on ice.

Figure 3. Sea-Bird Electronics, Inc. SEACAT Profiler CTD SBE-19plus, used to collect water column profiles of temperature, dissolved oxygen, and specific conductance in Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

Figure 4. Niskin point-sampler used to collect water column samples in Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

Bed-Sediment Core Samples

Bed-sediment core samples were collected at each of the eight sites for analysis of total mercury and methylmercury. Additional bed-sediment core samples were collected at sites 1, 5, and 8 for analysis of organics and trace metals, description of particle size, and replicates (table 1).

A lightweight gravity core sampler was determined to be the most appropriate device for the bed-sediment coring. Two types of gravity core samplers were used.
lightweight 5.1 cm (inside diameter) Ballchek™ Corer ( )

The Ballchek™

bed-sediment upon collection. The second core sampler was a K-B™ Corer, which is a heavier version of the Ballchek™ Corer. The K-B™ Corer was used only at site 8 where the bed sediment was more consolidated. A 5.1-cm-diameter, 91.4-cm-long stainless-steel core barrel was threaded to the selected core sampler, and a plastic (cellulose acetate butyrate) liner was placed in the core barrel. The bed-sediment was cohesive and easily retained in the core barrel, negating the need for a core catcher at the bottom of the barrel. A nose piece made of Lexan® was attached to the bottom of the core barrel to hold the core liner in place and to prevent the stainless steel core barrel from contacting the sediment. A hand-winch was used to lower and raise the core barrel from the coring vessel. After each core was captured and brought to the surface, the liner was removed from the core barrel, and was capped, labeled, measured, and photographed (6). After all the cores were collected at the site, they were transferred to shore for subsampling. All equipment used to collect the bed-sediment core samples was decontaminated prior to sampling using methods described in Shelton and Capel (1994) and in chapter 8 of the USGS National Field Manual (Radtke, 2005).

Underwater Videography

The physical composition of the bed sediment collected from Brownlee Reservoir caused little resistance to core penetration. To ensure that a consistent core length was collected and that disturbance to the sample was minimized, an underwater video camera was used to monitor the core-barrel penetration. The camera was mounted above the bottom of the core barrel and oriented to look downward (7*A*). The transmitted video (*B*
personnel to monitor the position of the core barrel as it was lowered into the sediment to obtain a consistent core length of about 75 cm.

Sample Processing

Following collection, water column and bed-sediment core samples were transferred to a mobile laboratory on shore and prepared for subsampling. Water samples were

Figure 5. Ballchek™ bed-sediment core sampler used in Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

A description of the processing, preservation, storage, and shipment of the samples for mercury analysis is available in Lewis and Brigham (2004). Bed-sediment cores were subsampled and prepared for mercury analysis using methods described by Lewis and Brigham (2004) and by Radtke (2005). A core pusher was used to extrude each core ( ). The minimum core length for mercury analysis was 30 cm; the subsampling interval was based on sediment layering, but generally was 2 cm or less. From each core, 8 to 10 subsamples were taken. A minimum of 2 g of sediment (dry weight) were required from each subsample for mercury analysis.

Bed-sediment cores from sites 1, 5, and 8 were subsampled for pesticides and organic compounds, trace metals, and physical characteristics. Four cores were collected

sediment for laboratory analyses. A core pusher was used to extrude each core into a top sample designated “a” (0–30 cm), and a bottom sample designated “b” (30–75 cm). The respective top and bottom samples from each of the four cores were homogenized into a single top and bottom sample prior to subsampling for laboratory analysis. This was necessary to ensure enough material was available for all laboratory analyses and to maintain consistency between the sites.

Figure 6. Typical (*A*) core recovery and (*B*) close-up of organic material on top of core sample collected from site 2 at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

Figure 7. Underwater video camera system used to assist with sediment coring showing (*A*) components of camera mounted on core barrel, and (*B*) example image of collection of bed-sediment core sample in Brownlee Reservoir, Oregon, May 7–9, 2012.

Figure 8. Extraction process used to subsample bed-sediment cores collected from Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

Laboratory Methods

Water column and bed-sediment core samples were analyzed at seven laboratories based on the constituents of interest (table 2). Water column and bed-sediment core samples were analyzed for total mercury and methylmercury at the MRL. Core samples were analyzed for selected pesticides, organic compounds, trace metals, and physical characteristics at the University of Idaho-Analytical Sciences Laboratory (UI-ASL), Pace Analytical Services, Inc. (Pace), Agriculture Laboratory (PacAg), USGS National Water Quality Laboratory (NWQL), USGS Pesticide Fate Research Group Production Laboratory (PFRG), and the USGS Kansas Water Science Center Organic Geochemistry Research Laboratory (OGRL).

Laboratory methods and abbreviated descriptions of the techniques used to analyze samples are described in table 2. A listing of all EPA methods and documentation is available at ALS Environmental (2013). A list of standard methods is available at American Public Health Association (2006). American Society for Testing and Materials (ASTM) methodology is available at American Society for Testing and Materials (2013).

Mercury in Water and Sediment

The MRL analyzed water column and bed-sediment core samples using methods described in table 2. Water samples , , and dissolved organic carbon. At each of the 8 sites, 8 to 10 subsamples of bed sediment from cores were collected and analyzed for total mercury, methylmercury, percentage of dry weight, and percentage of loss on ignition. Additional information about laboratory procedures can be accessed at U.S. Geological Survey (2013).

Pesticides and Other Organic Compounds

Bed-sediment core samples were analyzed for pesticides and organic compounds using the methods listed in table 2. The UI-ASL in Moscow, Idaho, analyzed bed-sediment core samples for selected herbicides and carbamate insecticides A methods. The Pace Analytical Laboratory in Minneapolis, Minnesota, followed EPA methods to analyze bed-sediment core samples for SVOCs, PAHs, organochlorine pesticides, PCBs, chlorinated herbicides, and dioxin. The PacAg Laboratory in Portland, Oregon, followed EPA methods to analyze bed-sediment core samples for halogenated pesticides, organophosphorus and organosulfur pesticides, phenylurea herbicides, and carbamate insecticides. The PacAg laboratory also processed bed-sediment core samples for the herbicide glyphosate and its breakdown product aminomethylphosphonic acid (AMPA). The NWQL in Lakewood, Colorado, analyzed bed-sediment core samples for wastewater compounds using methods listed in table 2. The PFRG laboratory in Sacramento, California, analyzed bed-sediment core samples for current-use pesticides, their degradation products, and organochlorine insecticides. The Kansas Water Science Center Organic Geochemistry Research Laboratory in Lawrence, Kansas, analyzed bed-sediment core samples for glyphosate, AMPA, and the herbicide glufosinate.

Physical Characteristics and Trace Metals

Bed-sediment core samples were analyzed for physical characteristics and trace metals using methods listed in table 2. The Pace Analytical Laboratory in Minneapolis, Minn., analyzed physical characteristics (total solids, total organic carbon (TOC), grain size, pH, and redox state) using EPA methods, standard methods, and ASTM methods. The NWQL in Lakewood, Colo., analyzed bed-sediment core samples for trace metals in sediment.

Table 2. Techniques and associated methodologies used by laboratories to analyze water and bed-sediment core samples collected from Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

[**Abbreviations:** ASTM, American Society for Testing and Materials; CF

chromatography; HR-GC-MS, high resolution-gas chromotography-mass spectrometry; HPLC/ICP-MS, high performance liquid chromatography inductively coupled plasma-mass spectrometry; ICP-MS, inductively coupled plasma-mass spectrometry; LC/MS/MS, liquid chromatography coupled to a tandem mass spectrometer; PCB, polychlorinated biphenyls; SIM, selective ion monitoring; TOC, total organic carbon; EPA, U.S. Environmental Protection Agency; USGS, U.S. Geological Survey; cm, centimeter; °C, degrees Celsius]

Chemical or method name	Method	Techniques used for analysis	Method citation
USGS—Mercury Research Laboratory (water column)			
Filtered total mercury	EPA Method 1631, Rev. E	Oxidation, purge and trap, and CVAFS	U.S. Environmental Protection Agency (2002)
Filtered methylmercury	USGS Open-File Report 01-445	Aqueous phase ethylation and chromatographic separation with CVAFD	DeWild and others (2002)
Particulate total mercury	USGS Techniques and Methods Report 5A-8	Oxidation, CVAFS	Olund and others (2004)
Particulate methylmercury	USGS Techniques and Methods Report 5A-7	Filtration, reaction and distillation, CVAFS	DeWild and others (2004)
Dissolved organic carbon	Shimadzu TOC	Catalytically-aided platinum 680°C combustion technique	Shimadzu (2013)
USGS—Mercury Research Laboratory (bed sediment)			
Sediment total mercury	USGS Techniques and Methods 5A-8 - acid digestion	Acid digestion, oxidation, and CVAFS	Olund and others (2004)
	EPA Method 7473 (SW-846) Rev. 0 - direct combustion	Dry, chemical decomposition, amalgamation, and GC-MS	U.S. Environmental Protection Agency (2007a)
Sediment methylmercury	USGS Techniques and Methods 5A-7	Reaction, ethylation, GC, and CVAFS	DeWild and others (2004)
Dry weight percent (percent solids)	USGS Techniques of Water-Resources Investigations 5-A1, 3rd ed., p. 48	Dry, weight	Fishman and Freidman (1989)
Percent loss on ignition	USGS Techniques of Water-Resources Investigations 5-A1, 3rd ed., p. 451	Dry, weight	Fishman and Freidman (1989)
University of Idaho—Analytical Sciences Laboratory			
Carbamates	EPA	Extraction, dry, and HPLC	U.S. Environmental Protection Agency (1993)
Chlorinated acid herbicides	EPA		U.S. Environmental Protection Agency (1996a)
GC/MS extras	EPA	Extraction, exchange, and GC-FPD	U.S. Environmental Protection Agency (2000)
Organochlorine pesticides	EPA	Extraction, neutralization, and GC-ECD	U.S. Environmental Protection Agency (1996b)
Organophosphate and organonitrogen pesticides	EPA	Extraction, exchange, and GC-FPD	U.S. Environmental Protection Agency (2000)
Urea pesticides	EPA	Extraction, dry, and HPLC	U.S. Environmental Protection Agency (1993)
Pace Analytical Services, Inc.			
Semivolatile organics	EPA 8270 (GC-MS)	Preparation and GC-MS	U.S. Environmental Protection Agency (1996c)
Polynuclear aromatic hydrocarbons PAH (low level)	EPA 8270(GC-MS, SIM mode)	Preparation and GC-MS	U.S. Environmental Protection Agency (1996c)
Organochlorine pesticides	EPA 8081 (GC-ECD)	Extraction, cleanup, and GC-ECD	U.S. Environmental Protection Agency (1996b)
PCBs	EPA 8082 (GC-ECD)	Extraction, cleanup, and GC-ECD	U.S. Environmental Protection Agency (1996d)
Chlorinated herbicides	EPA 8151		U.S. Environmental Protection Agency (1996a)

Table 2. Techniques and associated methodologies used by laboratories to analyze water and bed-sediment core samples collected from Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

[**Abbreviations:** ASTM, American Society for Testing and Materials; CF

chromatography; HR-GC-MS, high resolution-gas chromotography-mass spectrometry; HPLC/ICP-MS, high performance liquid chromatography inductively coupled plasma-mass spectrometry; ICP-MS, inductively coupled plasma-mass spectrometry; LC/MS/MS, liquid chromatography coupled to a tandem mass spectrometer; PCB, polychlorinated biphenyls; SIM, selective ion monitoring; TOC, total organic carbon; EPA, U.S. Environmental Protection Agency; USGS, U.S. Geological Survey; cm, centimeter; °C, degrees Celsius]

Chemical or method name	Method	Techniques used for analysis	Method citation
		Pace Analytical Services, Inc.—Continued	
Dioxin (2,3,7,8-TCDD)	EPA 1613 (HR-GC-MS)	, and HR-GC-MS	U.S. Environmental Protection Agency (1994)
Total solids	SM 2540B	Dry, weigh	American Public Health Association (1999)
TOC	SW 9060 mod.	Carbonaceous analysis	U.S. Environmental Protection Agency (1986)
Grain size	ASTM D422	Sieve and weigh	American Society for Testing and Materials (1998)
pH	EPA 9045	Mix with reagent, measure pH	U.S. Environmental Protection Agency (2004)
Redox	ASTM D1498	Reduction-oxidation potential measurement	American Society for Testing and Materials (1990)
		Pacific Agricultural Laboratory	
Aminomethylphosphonic acid (AMPA) Glyphosate	Monsanto FLP Method (HPLC-FLD)	Preparation, extraction, and HPLC	M.E. Oppenhuizen, Monsanto Corporation, unpub. data (1993)
Halogenated pesticides	EPA 8081B (GC-ECD)	Extraction, cleanup,and GC-ECD	U.S. Environmental Protection Agency (1996b)
Organophosphorous and organosulfur pesticides	EPA 8141B (GC-FPD)	Extraction, exchange, and GC-FPD	U.S. Environmental Protection Agency (2000)
Organonitrogen pesticides	EPA 8270D (GC-MS, SIM mode)	Preparation and GC-MS	U.S. Environmental Protection Agency (1996c)
Phenylurea herbicides	EPA 8321B (HPLC-MS)	Direct injection, HPLC-MS	U.S. Environmental Protection Agency (2007b)
Carbamate pesticides	EPA 8321B (HPLC-MS)	Direct injection, HPLC-MS	U.S. Environmental Protection Agency (2007b)
		USGS—National Water Quality Laboratory	
Wastewater compounds in sediment	USGS Techniques and Methods Report 5-B2	Extraction, isolation, dry, and GC-MS	Burkhardt and others (2006)
Routine metals in sediment	USGS Techniques and Methods Report 5-B1	Digestion, HPLC/ICP-MS	Garbarino and others (2006)
		USGS—Pesticide Fate Research Group Production Laboratory	
Current-use pesticides Organochlorine pesticides	Multi-residue method (GC-MS)	Extraction, cleanup, GC-MS	Smalling and Kuivila (2008)
		USGS—Kansas Water Science Center Organic Geochemistry Research Laboratory	
Glyphosate	USGS O-2141-09	Derivatization, extraction, elution, LC/MS/MS	Meyer and others (2009)
Aminomethylphosphonic acid (AMPA) Glufosinate			

Quality Assurance and Quality Control

This study followed the USGS Idaho Water Science Center's quality-assurance plan for the collection of water-quality samples (Mark Hardy, U.S. Geological Survey, written commun., 2008). Quality-control and environmental samples were collected. Quality control for bed-sediment

each laboratory analysis. The split replicate samples from the laboratory were reviewed to ensure no major discrepancies between the environmental and split replicate samples. Sample blinds or blank samples were not submitted as part of this study. However, all laboratory methods and internal quality-control standards for each laboratory included in this study were reviewed and approved by the USGS. Two core samples from each of the 8 sites (16 samples) were collected concurrently as replicate core samples, but were not submitted for analysis. The replicate core samples were frozen immediately after being transferred to the on-site sample preparation area and were subsequently transferred to an IPC storage facility for long-term storage.

Water Column and Sediment Core Samples

Total Mercury and Methylmercury in Water and Sediment

The MRL and particulate total mercury methylmercury, and dissolved organic carbon (table 3). Filtered total mercury concentrations in water ranged from 0.38 to 1.3 ng/L. Filtered methylmercury concentrations generally increased with depth and were less than 0.13 ng/L, with the exception of the outlier at site 8 (0.61 ng/L). Particulate total mercury concentrations also increased with depth and ranged from 0.287 to 1.89 ng/L. Particulate methylmercury concentrations ranged from 0.027 to 0.312 ng/L. Dissolved organic carbon concentrations ranged from 1.8 to 2.8 mg/L.

Total mercury and methylmercury were detected in all bed-sediment core samples (table 4). Total mercury concentrations in sediment ranged from 51.4 to 112 µg/kg. Methylmercury concentrations ranged from 0.36 to 18 µg/kg, with the highest concentrations occurring near the sediment-water interface. Percentage of dry weight from bed-sediment core samples ranged from 5.52 to 31.53 percent. The measured percentage of loss on ignition ranged from 6.68 to 17.28 percent.

Pesticides and Organic Compounds

Bed-sediment core samples collected at sites 1, 5, and 8 were analyzed for 417 pesticides and other organic compounds. Concentrations of pesticides and other organic compounds are listed by the laboratory in which they were analyzed.

University of Idaho-Analytical Sciences Laboratory

Bed-sediment core samples from sites 1, 5, and 8 were analyzed at UI-ASL for selected herbicides and carbamate pesticides (table 5). The carbamate pesticide baygon (propoxur) was detected in cores 5b, 8a, and 8b at concentrations of 6.1, 6.1, and 7.3 µg/kg, respectively. The chlorinated acid herbicide 2,4-dichlorobenzoic acid was present at concentrations less than the reporting level of 10 µg/kg in core samples 1a, 1b, 5a, 5b, and 8a, and the chlorinated acid herbicide pentachlorophenol was less than the reporting level of 8 µg/kg in core 8b. The organochlorine pesticide compound dichlorodiphenyldichloroethylene (DDE), a breakdown product of dichlorodiphenyltrichloroethane (DDT), was less than the reporting level of 3 µg/kg in cores 5b, 8a, and 8b. The pesticide prometon was less than the reporting level of 5 µg/kg in cores 5b, 8a, and 8b. No urea pesticides were detected in the bed-sediment core samples.

Pace Analytical Services Laboratory

Bed-sediment core samples at sites 1, 5, and 8 were analyzed by the Pace Analytical Services Laboratory for SVOCs, PAHs, organochlorine pesticides, PCBs, chlorinated herbicides, and dioxin. SVOCs, chlorinated herbicides, or PAHs were not detected (table 11; at back of report). The breakdown product 4,4'-DDE was the only organochlorine pesticide detected; however, the concentrations were less than the adjusted reporting limit (but greater than the detection limit) in every sample analyzed. Cores 5a, 8a, and 8b were not analyzed for PCBs due to miscommunications with the laboratory, but PCBs were not detected in samples collected from the three remaining core samples (1a, 1b, and 5b). Chlorinated herbicides were analyzed for bed-sediment core samples collected at site 1 due to a miscommunication at the laboratory; no chlorinated herbicides were detected in either of the cores collected at site 1. Dioxin was not detected in any of the bed-sediment core samples.

Table 3. Total mercury, methylmercury, and dissolved organic carbon concentrations in water-column samples collected from Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

[Samples analyzed at U.S. Geological Survey Mercury Research Laboratory according to laboratory methodologies listed in table 2. **Abbreviations:** m, meter; ng/L, nanogram per liter; mg/L, milligram per liter; USGS, U.S. Geological Survey; –, no data available]

Sample collection			Total mercury (filtered) (ng/L)	Methylmercury (filtered) (ng/L)	Total mercury (particulate) (ng/L)	Methylmercury (particulate) (ng/L)	Dissolved organic carbon (mg/L)
Date	Time	Depth in water column (m)					
USGS 444954116542400–Site 1							
05-07-12	1300	0.50	1.03	0.07	0.540	0.034	2.7
	1318	47.0	0.38	0.06	0.374	0.027	1.9
	1330	76.7	0.45	0.12	0.457	0.167	1.9
USGS 444935116544000–Site 2							
05-08-12	1225	0.50	1.29	0.05	0.424	0.054	2.7
	1220	47.0	0.48	0.06	0.397	0.043	2.0
	1215	81.3	0.48	0.10	0.461	0.229	1.9
USGS 444912116545700–Site 3							
05-08-12	1610	0.50	1.05	0.09	0.413	0.050	2.7
	1605	47.0	0.45	0.04	0.359	0.031	1.9
	1550	83.6	1.19	0.10	1.89	0.224	1.9
USGS 444807116555700–Site 4							
05-08-12	1425	0.50	1.08	0.08	0.602	0.061	2.8
	1420	47.0	0.42	0.06	0.470	0.031	2.0
	1415	79.3	0.49	0.12	0.755	0.265	1.9
USGS 444455117021200–Site 5							
05-09-12	0818	0.50	1.05	0.08	0.441	0.038	2.4
	0828	47.0	0.46	0.07	0.484	0.054	2.0
	0833	65.6	0.41	0.12	0.953	0.178	1.8
USGS 444101117045000–Site 6							
05-08-12	1210	0.50	1.14	0.08	0.287	0.035	2.5
	1235	43.0	0.64	0.10	0.505	–	2.2
	1220	57.0	0.48	0.10	0.960	0.140	2.0
USGS 443745117062500–Site 7							
05-09-12	1030	0.50	1.09	0.06	0.618	0.048	2.4
	1025	10.0	1.15	0.08	1.08	0.040	2.4
	1020	47.3	0.91	0.11	1.79	0.312	2.3
USGS 443416117084000–Site 8							
05-08-12	0907	0.50	1.27	0.08	0.673	0.036	2.4
	0930	10.3	1.26	0.08	1.10	0.050	2.8
	0913	32.3	1.01	0.61	1.38	0.106	2.4

Table 4. Total mercury and methylmercury concentrations and selected physical characteristics of bed-sediment samples collected from Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

[Samples analyzed at U.S. Geological Survey Mercury Research Laboratory according to laboratory methodologies listed in table 2. **Abbreviations:** m, meter; µg/kg, microgram per kilogram; USGS, U.S. Geological Survey]

Sample date	Time	Sample interval (m)	Total mercury (µg/kg)	Methylmercury (µg/kg)	Dry weight percent solids (percent)	Loss on ignition (percent)
USGS 444954116542400—Site 1						
05-07-12	1351	0–0.01	98.2	15	8.58	17.28
	1352	0.01–0.02	64.5	6.1	9.32	15.66
	1353	0.02– 0.05	86.1	2.8	11.88	9.29
	1354	0.05–0.1	96.3	3.1	11.11	12.98
	1355	0.1–0.15	99.6	1.2	10.22	13.47
	1356	0.15–0.25	100	0.94	14.01	13.45
	1357	0.25–0.3	91.7	0.88	16.28	9.65
	1358	0.3–0.35	110	0.6	21.18	6.95
	1350	0.35–0.4	84.6	0.73	19.97	8.59
USGS 444935116544000—Site 2						
05-09-12	1240	0–0.01	99.2	18	8.7	15.36
	1241	0.01–0.02	61	5.2	9.11	15.14
	1242	0.02–0.05	97.7	5.3	8.21	11.27
	1243	0.05–0.1	90.9	2.4	12.2	11.95
	1244	0.1–0.15	100	1.3	9.74	14.03
	1245	0.15–0.25	105	1.1	14.44	11.77
	1246	0.25–0.3	98.2	1.1	12.95	11.37
	1247	0.3–0.35	97	0.58	21.62	8.47
	1248	0.35–0.4	80.3	0.64	19.11	8.48
USGS 444912116545700—Site 3						
05-08-12	1630	0–0.01	103	18	8.13	13.84
	1631	0.01–0.03	77.9	7.7	8.39	15.57
	1632	0.03–0.07	83.3	4.2	8.82	9.51
	1633	0.07–0.12	93.6	3.2	13.34	11.23
	1634	0.12–0.17	98.4	1.5	10.7	16
	1635	0.17–0.22	112	1	15.86	8.98
	1636	0.22–0.32	104	2	11.81	16.03
	1637	0.32–0.42	101	0.74	17.62	9.55
USGS 444807116555700—Site 4						
05-08-12	1440	0–0.01	81.8	13	6.75	14.16
	1441	0.01–0.03	74.2	5.3	8.53	14.91
	1442	0.03–0.05	77.6	8.5	5.52	13.74
	1443	0.05–0.07	88.4	2.4	9.84	9.97
	1444	0.07–0.09	84.9	4.6	7.59	13.16
	1445	0.09–0.11	80.2	7.2	7.42	11.62
	1446	0.11–0.21	74.2	2.1	15.38	10.73
	1447	0.21–0.31	84.8	1.7	15.00	12.25
	1448	0.31–0.41	96.3	0.86	16.83	11.08

Table 4. Total mercury and methylmercury concentrations and selected physical characteristics of bed-sediment samples collected from Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

[Samples analyzed at U.S. Geological Survey Mercury Research Laboratory according to laboratory methodologies listed in table 2. **Abbreviations:** m, meter; µg/kg, microgram per kilogram; USGS, U.S. Geological Survey]

Sample date	Time	Sample interval (m)	Total mercury (µg/kg)	Methylmercury (µg/kg)	Dry weight percent solids (percent)	Loss on ignition (percent)
USGS 444455117021200—Site 5						
05-09-12	0850	0–0.02	75.1	7.3	6.44	12.56
	0851	0.02–0.04	74.1	5.7	8.06	11.22
	0852	0.04–0.06	70.8	3	11.16	11.43
	0853	0.06–0.08	71.1	4.1	9.16	12.22
	0854	0.08–0.1	78.2	2	17.58	7.88
	1440	0.1–0.2	75.9	1.7	19.62	11.02
	1441	0.2–0.3	82.5	1.2	13.98	12.34
	1442	0.3–0.4	78.6	0.54	25.05	7.95
USGS 444101117045000—Site 6						
05-08-12	1250	0–0.01	99.2	12	6.86	12.25
	1251	0.01–0.03	91.7	12	11.02	10.52
	1252	0.03–0.05	81.1	11	12.26	11.87
	1253	0.05–0.07	73.4	5.5	13.52	12.53
	1254	0.07–0.09	73.1	2.2	16.07	8.8
	1255	0.09–0.11	75.8	2	17.18	8.75
	1256	0.11–0.21	73.6	1.8	17.24	9.61
	1257	0.21–0.31	68.2	1.8	21.57	7.35
	1258	0.31–0.41	77.2	1.4	20.09	10.15
USGS 443745117062500—Site 7						
05-09-12	1045	0–0.02	84.9	12	15.29	10.71
	1046	0.02–0.04	71.4	6.3	16.5	10.43
	1047	0.04–0.06	62.2	1.6	20.18	8.14
	1048	0.06–0.08	65.4	2	20.42	8.84
	1049	0.08–0.11	67.4	1.6	19.85	8.59
	1050	0.11–0.23	64.1	1.4	19.89	9.54
	1051	0.23–0.33	65.4	1.4	24.86	14.4
	1052	0.33–0.43	67.8	0.72	19.93	10.5
USGS 443416117084000—Site 8						
05-08-12	0945	0–0.01	75.9	10	12.84	10.48
	0946	0.01–0.03	72.7	8.1	20.68	8.82
	0947	0.03–0.05	74.7	4.2	22.19	8.21
	0948	0.05–0.1	57.8	1.2	23.66	8.72
	0949	0.1–0.12	60.6	1.8	27.03	7.16
	0950	0.12–0.14	51.4	1.1	28.53	7.87
	0951	0.14–0.18	56.8	0.78	26.25	6.68
	0952	0.18–0.24	54.3	0.52	22.51	8.95
	0953	0.24–0.28	55.8	0.36	23.62	9.41
	0954	0.28–0.29	54.7	0.46	31.53	7.06

Table 5. Selected herbicide and carbamate insecticide concentrations in bed-sediment core samples collected at selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

[Samples analyzed at University of Idaho-Analytical Sciences Laboratory according to laboratory methodologies listed in table 2. All values are in micrograms per kilogram (wet weight). **NWIS site name**: Top subsample designated “a” (0–30 cm), and a bottom subsample designated “b” (30–75 cm). **CASRN**: Chemical Abstracts Service (CAS) Registry Number®, a registered trademark of the American Chemical Society. CAS recommends th
through CAS Client Services^{SM}. **Abbreviations:** NWIS, National Water Information System; GC/MC, gas chromatography/mass spectometry; cm, centimeter; ND, not detected; <, less than]

Parameter	CASRN	Reporting level	NWIS site name with sample date and time					
			Site 1a	Site 1b	Site 5a	Site 5b	Site 8a	Site 8b
			05-07-12 1400	05-07-12 1415	05-09-12 0900	05-09-12 0915	05-08-12 0900	05-08-12 0915
Carbamates								
Aldicarb	00116-06-3	10	ND	ND	ND	ND	ND	ND
Aldicarb Sulfone	01646-88-4	10	ND	ND	ND	ND	ND	ND
Aldicarb Sulfoxide	01646-87-3	10	ND	ND	ND	ND	ND	ND
Baygon (Propoxur)	00114-26-1	5	ND	ND	ND	6.1	6.1	7.3
Carbaryl	00063-25-2	5	ND	ND	ND	ND	ND	ND
Carbofuran	01563-66-2	5	ND	ND	ND	ND	ND	ND
Methiocarb	02032-65-7	5	ND	ND	ND	ND	ND	ND
Methomyl	16752-77-5	5	ND	ND	ND	ND	ND	ND
Oxamyl	23135-22-0	5	ND	ND	ND	ND	ND	ND
Chlorinated acid herbicides								
2,4,6-Trichlorophenol	00088-06-2	10	ND	ND	ND	ND	ND	ND
2,4-D	00094-75-7	20	ND	ND	ND	ND	ND	ND
2,4-DB	00094-82-6	20	ND	ND	ND	ND	ND	ND
2,4-Dichlorobenzoic acid	000-50-84-0	10	<10	<10	<10	<10	<10	ND
3,5-Dichlorobenzoic acid	00051-36-5	10	ND	ND	ND	ND	ND	ND
Bentazon	25057-89-0	20	ND	ND	ND	ND	ND	ND
Bromoxynil	01689-84-5	10	ND	ND	ND	ND	ND	ND
Dacthal (DCPA)	02136-79-0	8	ND	ND	ND	ND	ND	ND
Dicamba	01918-00-9	8	ND	ND	ND	ND	ND	ND
Dichloroprop	00120-36-5	25	ND	ND	ND	ND	ND	ND
Diclofop methyl	51338-27-3	25	ND	ND	ND	ND	ND	ND
Dinoseb	00088-85-7	20	ND	ND	ND	ND	ND	ND
MCPA	00094-74-6	20	ND	ND	ND	ND	ND	ND
MCPP	07085-19-0	20	ND	ND	ND	ND	ND	ND
Pentachlorophenol	00087-86-5	8	ND	ND	ND	ND	ND	<8
Picloram	01918-02-1	15	ND	ND	ND	ND	ND	ND
Triclopyr	55336-06-3	10	ND	ND	ND	ND	ND	ND
GC/MS extras								
Acephate	30560-19-1	50	ND	ND	ND	ND	ND	ND
Bensulide	00741-58-2	5	ND	ND	ND	ND	ND	ND
Captan	00133-06-2	10	ND	ND	ND	ND	ND	ND
Coumaphos	00056-72-4	5	ND	ND	ND	ND	ND	ND
	35367-38-5	5	ND	ND	ND	ND	ND	ND
Dimethoate	00060-51-5	5	ND	ND	ND	ND	ND	ND
Fenthion	00055-38-9	5	ND	ND	ND	ND	ND	ND
Iprodione	36734-19-7	10	ND	ND	ND	ND	ND	ND
Methamidophos	10265-92-6	5	ND	ND	ND	ND	ND	ND
Naled	00300-76-5	50	ND	ND	ND	ND	ND	ND
Oryzalin	19044-88-3	5	ND	ND	ND	ND	ND	ND
Phosmet	00732-11-6	5	ND	ND	ND	ND	ND	ND

Table 5. Selected herbicide and carbamate insecticide concentrations in bed-sediment core samples collected at selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

[Samples analyzed at University of Idaho-Analytical Sciences Laboratory according to laboratory methodologies listed in table 2. All values are in micrograms per kilogram (wet weight). **NWIS site name**: Top subsample designated "a" (0–30 cm), and a bottom subsample designated "b" (30–75 cm). **CASRN**: Chemical Abstracts Service (CAS) Registry Number®, a registered trademark of the American Chemical Society. CAS recommends th
through CAS Client Services^{SM}. **Abbreviations:** NWIS, National Water Information System; GC/MC, gas chromatography/mass spectometry; cm, centimeter; ND, not detected; <, less than]

Parameter	CASRN	Reporting level	NWIS site name with sample date and time					
			Site 1a	Site 1b	Site 5a	Site 5b	Site 8a	Site 8b
			05-07-12 1400	05-07-12 1415	05-09-12 0900	05-09-12 0915	05-08-12 0900	05-08-12 0915
Organochlorine pesticides								
Acetochlor	34256-82-1	2.5	ND	ND	ND	ND	ND	ND
Chlordane (alpha)	00319-84-6	2	ND	ND	ND	ND	ND	ND
Chlordane (gamma) (Lindane)	00058-89-9	2	ND	ND	ND	ND	ND	ND
Chlorobenzilate	00510-16-6	5	ND	ND	ND	ND	ND	ND
Chloroneb	02675-77-6	2.5	ND	ND	ND	ND	ND	ND
Chlorothalonil	01897-45-6	2.5	ND	ND	ND	ND	ND	ND
DCPA (parent)	01861-32-1	2.5	ND	ND	ND	ND	ND	ND
DDD	00072-54-8	3	ND	ND	ND	ND	ND	ND
DDE	00072-55-9	3	ND	ND	ND	<3	<3	<3
DDT	00050-29-3	30	ND	ND	ND	ND	ND	ND
Dichlobenil	01194-65-6	5	ND	ND	ND	ND	ND	ND
Dieldrin	00060-57-1	3	ND	ND	ND	ND	ND	ND
Etridiazole	02593-15-9	5	ND	ND	ND	ND	ND	ND
Hexachlorobenzene	00118-74-1	2	ND	ND	ND	ND	ND	ND
	42874-03-3	5	ND	ND	ND	ND	ND	ND
Permethrin (cis)	52645-53-1	10	ND	ND	ND	ND	ND	ND
Propachlor	01918-16-7	5	ND	ND	ND	ND	ND	ND
Organophosphate and organonitrogen pesticides								
Alachlor	15972-60-8	5	ND	ND	ND	ND	ND	ND
Ametryn	00834-12-8	5	ND	ND	ND	ND	ND	ND
Atrazine	01912-24-9	2.5	ND	ND	ND	ND	ND	ND
	01861-40-1	5	ND	ND	ND	ND	ND	ND
Benthiocarb	28249-77-6	2.5	ND	ND	ND	ND	ND	ND
Bromacil	00314-40-9	5	ND	ND	ND	ND	ND	ND
Butachlor	23184-66-9	5	ND	ND	ND	ND	ND	ND
Butylate	02008-41-5	2.5	ND	ND	ND	ND	ND	ND
Carboxin	05234-68-5	5	ND	ND	ND	ND	ND	ND
Chlorpropham	00101-21-3	5	ND	ND	ND	ND	ND	ND
Chlorpyrifos	02921-88-2	2.5	ND	ND	ND	ND	ND	ND
Cycloate	01134-23-2	5	ND	ND	ND	ND	ND	ND
Desethyl Atrazine	06190-65-4	2.5	ND	ND	ND	ND	ND	ND
Di-allate	02303-16-4	5	ND	ND	ND	ND	ND	ND
Diazinon	00333-41-5	2.5	ND	ND	ND	ND	ND	ND
Dichlorvos	00062-73-7	5	ND	ND	ND	ND	ND	ND
Disulfoton	00298-04-4	5	ND	ND	ND	ND	ND	ND
EPTC	00759-94-4	5	ND	ND	ND	ND	ND	ND
	55283-68-6	5	ND	ND	ND	ND	ND	ND

Table 5. Selected herbicide and carbamate insecticide concentrations in bed-sediment core samples collected at selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

[Samples analyzed at University of Idaho-Analytical Sciences Laboratory according to laboratory methodologies listed in table 2. All values are in micrograms per kilogram (wet weight). **NWIS site name**: Top subsample designated “a” (0–30 cm), and a bottom subsample designated “b” (30–75 cm). **CASRN**: Chemical Abstracts Service (CAS) Registry Number®, a registered trademark of the American Chemical Society. CAS recommends th
through CAS Client Services^{SM}. **Abbreviations:** NWIS, National Water Information System; GC/MC, gas chromatography/mass spectometry; cm, centimeter; ND, not detected; <, less than]

Parameter	CASRN	Reporting level	NWIS site name with sample date and time					
			Site 1a	Site 1b	Site 5a	Site 5b	Site 8a	Site 8b
			05-07-12 1400	05-07-12 1415	05-09-12 0900	05-09-12 0915	05-08-12 0900	05-08-12 0915
Organophosphate and organonitrogen pesticides—Continued								
Ethoprop	13194-48-4	2.5	ND	ND	ND	ND	ND	ND
Fenamiphos	22224-92-6	5	ND	ND	ND	ND	ND	ND
Fenarimol	60168-88-9	5	ND	ND	ND	ND	ND	ND
Hexazinone	51235-04-2	5	ND	ND	ND	ND	ND	ND
Malathion	00121-75-5	5	ND	ND	ND	ND	ND	ND
Metalaxyl	57837-19-1	5	ND	ND	ND	ND	ND	ND
Methidathion	00950-37-8	5	ND	ND	ND	ND	ND	ND
Methyl Paraoxon	00950-35-6	10	ND	ND	ND	ND	ND	ND
Methyl Parathion	00298-00-0	5	ND	ND	ND	ND	ND	ND
Metolachlor	51218-45-2	5	ND	ND	ND	ND	ND	ND
Metribuzin	21087-64-9	2.5	ND	ND	ND	ND	ND	ND
Napropamide	15299-99-7	5	ND	ND	ND	ND	ND	ND
	27314-13-2	5	ND	ND	ND	ND	ND	ND
Parathion	00056-38-2	5	ND	ND	ND	ND	ND	ND
Pendimethalin	40487-42-1	2.5	ND	ND	ND	ND	ND	ND
Phorate	00298-02-2	5	ND	ND	ND	ND	ND	ND
Prometon	01610-18-0	5	ND	ND	ND	<5	<5	<5
Pronamide	23950-58-5	5	ND	ND	ND	ND	ND	ND
Propazine	00139-40-2	2.5	ND	ND	ND	ND	ND	ND
Simazine	00122-34-9	2.5	ND	ND	ND	ND	ND	ND
Terbacil	05902-51-2	5	ND	ND	ND	ND	ND	ND
Terbufos	13071-79-9	5	ND	ND	ND	ND	ND	ND
Triallate	02303-17-5	5	ND	ND	ND	ND	ND	ND
Triadimefon	43121-43-3	5	ND	ND	ND	ND	ND	ND
Urea pesticides								
Deisopropyl atrazine (DIA)	01007-28-9	2.5	ND	ND	ND	ND	ND	ND
Diuron	00330-54-1	2.5	ND	ND	ND	ND	ND	ND
Linuron	00330-55-2	5	ND	ND	ND	ND	ND	ND
Tebuthiuron	34014-18-1	5	ND	ND	ND	ND	ND	ND
Tralkoxydim	87820-88-0	5	ND	ND	ND	ND	ND	ND

Pacific Agriculture Laboratory

Pesticide and herbicide concentrations from the bed-sediment core samples from sites 1, 5, and 8 were Agriculture Laboratory (PacAg) (table 12; at back of report). One halogenated pesticide, p,p'-DDE, was detected at a concentration of 0.03 µg/kg in the core samples collected at site 5b. Organophosphorus and organosulfur pesticides, organonitrogen pesticides, phenylurea herbicides, and carbamate insecticides were not detected in any of the bed-sediment core samples.

The concentrations in the initial bed-sediment core samples analyzed at PacAg for the glyphosate and AMPA were higher than expected. Based on the initial results, follow-up analysis of glyphosate and AMPA was requested. Concentrations from the subsequent analyses at PacAg from core samples 1b and 8a were much lower than the original results. The herbicide glyphosate was detected in one sample and the concentration was close to the reporting level. AMPA, the breakdown product of glyphosate, was not detected in any of the bed-sediment core samples. Additionally, a split core was sent to the OGRL for analysis. The OGRL analyzed for glyphosate, AMPA, and glufosinate, and all results were less than the reporting limit of 20 µg/kg. Results for glyphosate, AMPA, and glufosinate sent to PacAg and OGRL laboratories for analysis on bed-sediment core samples are listed in table 6.

U.S. Geological Survey National Water Quality Laboratory

The NWQL analyzed bed-sediment core samples from sites 1, 5, and 8 for wastewater compounds (table 7). Due to method performance variability, an analyte could have multiple reporting levels in some cases. Concentrations of most wastewater compounds in bed sediment were less than the method reporting levels. Some compound detections are reported at an estimated (“E”) level; estimated values may

Estimated concentration values were considered detections for the bed-sediment samples in this study. The analytes 2,6-Dimethylnaphthalene, 3-Methyl-1(H)-indole (Skatole) (except 1b), 3-beta-Coprostanol, beta-Sitosterol, beta-Stigmastanol, Cholesterol, Indole, Isophorone (except 1a and 5a), and p-Cresol were detected in all samples. Carbazole was detected in samples 5b, 8a, and 8b; 4-Nonylphenol (sum of all isomers) was detected in samples 1b, 5a, and 5b.

U.S. Geological Survey Pesticide Fate Research Group

The USGS-Pesticide Fate Research Group analyzed bed-sediment core samples for an array of pesticides, herbicides, and fungicides. Only samples from the top (0–30 cm) of the bed-sediment cores at sites 1a, 5a, and 8b (table 7) were submitted for analysis. Of the 90 analytes, 2 were detected in the bed-sediment core samples (table 8). One analyte, p,p'-DDE, was detected in samples from sites 1 and 8 at concentrations of 3.2 and 2.1 µg/kg (based on dry weight), respectively. Pendimethalin was detected at a concentration of 24.7 µg/kg in a single core sample collected at site 8.

Physical Characteristics and Trace Metals

The Pace Analytical Laboratory analyzed selected bed-sediment core samples for physical characteristics (table 9). Total organic carbon in bed sediment ranged from 12,400 to 16,800 mg/kg. Grain-size results for samples collected from sites 5 and 8 ranged from 66.0 to 75.8 percent clay and 24.2 to 34.0 percent silt. The pH of the sediment ranged from 7.0 to 7.9, and reduction-oxidation (redox) potential in core samples from sites 5 and 8 ranged from 89.3 to 1,200 millivolts, decreasing both with depth and in a downstream direction. Because of a miscommunication with the analyzing laboratory, no data are available for total solids (all sites), grain-size analysis (sites 1a and 1b), pH (site 1b), and redox (sites 1a and 1b).

Trace metals in bed sediment samples were analyzed by the NWQL (table 10) and were greater than the reporting level in all the samples submitted for analysis. According to sediment quality guidelines published by MacDonald and others (2000), results for arsenic, copper, and nickel were between the consensus-based threshold effect concentration (TEC) and probable effect concentration (PEC) for freshwater ecosystems. The TEC indicates a concentration where adverse effects rarely occur, whereas the PEC indicates a concentration where adverse effects occur more often than not. Because the samples were neither less than the TEC nor greater than the PEC, the samples cannot be determined to be nontoxic or toxic based on these sediment quality guidelines.

Table 6. Laboratory results for glyphosate and breakdown product concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

Agricultural Laboratory and USGS Organic Geochemistry Research Laboratory. Multiple analyses completed for quality assurance/quality control purposes. **NWIS site name**: Top subsample designated “a” (0–30 cm), and a bottom subsample designated “b” (30–75 cm). **CASRN**: Chemical Abstracts Service (CAS) Registry Number®, a registered trademark of the American Chemical Society ^{SM}. **Analysis date:** Additional samples analyzed on 12-14-12 were subsampled from frozen cores and sent to laboratory to compare against data from 05-26-12. **Abbreviations:** cm, centimeter; µg/kg, microgram per kilogram; ND, not detected; <, less than]

NWIS site No.			**444954116542400**				**444455117021200**			
NWIS site name			**Site 1a**		**Site 1b**		**Site 5a**		**Site 5b**	
Sample date / time			**05-07-12 1400**		**05-07-12 1415**		**05-09-12 0900**		**05-09-12 0915**	
Parameter	**CASRN No.**	**Analysis date**	**Reporting level (µg/kg)**	**Detection (µg/kg)**	**Reporting level (µg/kg)**	**Detection (µg/kg)**	**Reporting level (µg/kg)**	**Detection (µg/kg)**	**Reporting level (µg/kg)**	**Detection (µg/kg)**
Pacific Agricultural Laboratory: Glyphosate-Monsanto Method (HPLC-FLD)										
Aminomethylphosphonic acid (AMPA)	1066-51-9	05-26-12	94	ND	49	100	33	43	32	44
Glyphosate	1071-83-6		94	130	490	13,000	33	390	32	70
Aminomethylphosphonic acid (AMPA)	1066-51-9	12-14-12	34	ND	36	ND	34	ND	34	ND
Glyphosate	1071-83-6		34	ND	36	39	34	ND	34	ND
USGS-OGRL Laboratory: LCGS Method 0-2141-09										
Glyphosate	1071-83-6	12-14-12	20	<	20	<	20	<	20	<
Aminomethylphosphonic acid (AMPA)	1066-51-9		20	<	20	<	20	<	20	<
Glufosinate	51276-47-2		20	<	20	<	20	<	20	<

NWIS site No.			**443416117084000**			
NWIS site name			**Site 8a**		**Site 8b**	
Sample date / time			**05-08-12 0900**		**05-08-12 0915**	
Parameter	**CASRN No.**	**Analysis date**	**Reporting level (µg/kg)**	**Detection (µg/kg)**	**Reporting level (µg/kg)**	**Detection (µg/kg)**
Pacific Agricultural Laboratory: Glyphosate-Monsanto Method (HPLC-FLD)						
Aminomethylphosphonic acid (AMPA)	1066-51-9	05-26-12	50	ND	33	35
Glyphosate	1071-83-6		50	210	33	750
Aminomethylphosphonic acid (AMPA)	1066-51-9	12-14-12	34	ND	34	ND
Glyphosate	1071-83-6		34	34	34	ND
USGS-OGRL Laboratory: LCGS Method 0-2141-09						
Glyphosate	1071-83-6	12-14-12	20	<	20	<
Aminomethylphosphonic acid (AMPA)	1066-51-9		20	<	20	<
Glufosinate	51276-47-2		20	<	20	<

Table 7. Wastewater compound concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

[Samples analyzed at the U.S. Geological Survey National Water Quality Laboratory according to laboratory methodologies listed in table 2. **Parameter:** Waste indicators of solids in bottom material, pressurized solvent extraction-solid-phase extraction, by gas chromatography/mass spectrometry. **NWIS site name**: Top subsample designated “a” (0–30 cm), and a bottom subsample designated “b” (30–75 cm). **CASRN**: Chemical Abstracts Service (CAS) Registry Number®, a registered trademark of the American Chemical Society. CAS recommends th^{SM}]

NWIS site No.		444954116542400				444455117021200				443416117084000			
NWIS site name		Site 1a		Site 1b		Site 5a		Site 5b		Site 8a		Site 8b	
Sample date / time		05-07-12 1400		05-07-12 1415		05-09-12 0900		05-09-12 0915		05-08-12 0900		05-08-12 0915	
Parameter	CASRN	Remark code	Detection (µg/kg)	Remark code	Detection (µg/kg)	Remark code	Detection (µg/kg)	Remark code	Detection (µg/kg)	Remark code	Detection (µg/kg)	Remark code	Detection (µg/kg)
Wastewater compounds													
1,4-Dichlorobenzene	106-46-7	<	32	<	130	<	34	<	120	<	128	<	130
1-Methylnaphthalene	90-12-0	<	30	<	130	<	30	<	120	<	128	<	130
2,2',4,4'-Tetrabromodiphenylether (PBDE 47)	5436-43-1	<	32	<	127	<	34	<	123	<	128	<	131
2,6-Dimethylnaphthalene	581-42-0	E	100	E	390		150		650		342		340
2-Methylnaphthalene	91-57-6	<	30	<	130	<	30	<	120	<	128	<	130
3-beta-Coprostanol	360-68-9	E	2,900	E	3,600	E	1,700	E	7,900	E	3,900	E	2,200
3-Methyl-1(H)-indole (Skatole)	83-34-1	E	20	<	130		30		130		14		130
3-tert-Butyl-4-hydroxy anisole (BHA)	121-00-6	<	100	<	380	<	100	<	370	<	384	<	390
4-Cumylphenol	599-64-4	<	30	<	130	<	30	<	120	<	128	<	130
4-n-Octylphenol	1806-26-4	<	30	<	130	<	30	<	120	<	128	<	130
4-Nonylphenol (sum of all isomers)	104-40-5	<	480	E	280	E	70	E	230	<	1,920	<	2,000
4-tert-Octylphenol	140-66-9	<	30	<	130	<	30	<	120	<	128	<	130
Acetophenone	98-86-2	<	100	<	380	<	100	<	370	<	384	<	390
Acetyl hexamethyl tetrahydronaphthalene (AHTN)	21145-77-7	<	30	<	130	<	30	<	120	<	128	<	130
Anthracene	120-12-7	<	30	<	130	<	30	<	120	<	128	<	130
Anthraquinone	84-65-1	<	32	<	130	<	34	<	120	<	128	<	130
Atrazine	1912-24-9	<	60	<	250	<	70	<	250	<	256	<	260
Benzo[a]pyrene	50-32-8	<	30	<	130	<	30	<	120	<	128	<	130
Benzophenone	119-61-9	<	30	<	130	<	30	<	120	<	128	<	130
beta-Sitosterol	83-46-5	E	5,600	E	9,600	E	5,700	E	18,000	E	11,400	E	12,000
beta-Stigmastanol	19466-47-8	E	2,100	E	5,500	E	1,500	E	8,500	E	3,500	E	6,400
bis(2-Ethylhexyl) phthalate	117-81-7	<	160	<	640	<	170	<	620	<	640	<	660
Bisphenol A	80-05-7	<	30	<	130	<	30	<	120	<	128	<	130
Bromacil	314-40-9	<	320	<	1,300	<	340	<	1,200	<	1,280	<	1,300
Camphor	76-22-2	<	30	<	130	<	30	<	120	<	128	<	130
Carbazole	86-74-8	<	30	<	130	<	30	E	20	E	7	E	10
Chlorpyrifos	2921-88-2	<	30	<	130	<	30	<	120	<	128	<	130
Cholesterol	57-88-5	E	7,900	E	10,000	E	7,000	E	21,000	E	15,600	E	8,300
Diazinon	333-41-5	<	30	<	130	<	30	<	120	<	128	<	130
4-Nonylphenol diethoxylate, (sum of all isomers) also known as NP2EO	–	<	640	<	2,500	<	680	<	2,500	<	2,560	<	2,600

Table 7. Wastewater compound concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

[Samples analyzed at the U.S. Geological Survey National Water Quality Laboratory according to laboratory methodologies listed in table 2. **Parameter:** Waste indicators of solids in bottom material, pressurized solvent extraction-solid-phase extraction, by gas chromatography/mass spectrometry. **NWIS site name**: Top subsample designated "a" (0–30 cm), and a bottom subsample designated "b" (30–75 cm). **CASRN**: Chemical Abstracts Service (CAS) Registry Number®, a registered trademark of the American Chemical Society. CAS recommends th ^{SM}]

NWIS site No.		444954116542400				444455117021200				443416117084000			
NWIS site name		Site 1a		Site 1b		Site 5a		Site 5b		Site 8a		Site 8b	
Sample date / time		05-07-12 1400		05-07-12 1415		05-09-12 0900		05-09-12 0915		05-08-12 0900		05-08-12 0915	
Parameter	CASRN	Remark code	Detection (µg/kg)	Remark code	Detection (µg/kg)	Remark code	Detection (µg/kg)	Remark code	Detection (µg/kg)	Remark code	Detection (µg/kg)	Remark code	Detection (µg/kg)
Wastewater compounds—Continued													
4-tert-Octylphenol diethoxylate, also known as OP2EO	2315-61-9	<	30	<	130	<	30	<	120	<	128	<	130
Diethyl phthalate	84-66-2	<	60	<	250	<	70	<	250	<	256	<	260
d-Limonene	5989-27-5	<	30	<	130	<	30	<	120	<	128	<	130
4-tert-Octylphenol monoethoxylate, also known as OP1EO	2315-67-5	<	160	<	640	<	170	<	620	<	640	<	660
Fluoranthene	206-44-0	<	30	<	130	<	30	<	120	<	128	<	130
Hexahydrohexamethyl-cyclopentabenzopyran (HHCB)	1222-05-5	<	30	<	130	<	30	<	120	<	128	<	130
Indole	120-72-9	E	160	E	90	E	50	E	660	E	232	E	200
Isoborneol	124-76-5	<	30	<	130	<	30	<	120	<	128	<	130
Isophorone	78-59-1	<	30	E	20	<	30	E	20	E	15	E	20
Isopropylbenzene	98-82-8	<	60	<	250	<	70	<	250	<	256	<	260
Isoquinoline	119-65-3	<	60	<	250	<	70	<	250	<	256	<	260
Menthol	89-78-1	<	30	<	130	<	30	<	120	<	128	<	130
Metolachlor	51218-45-2	<	30	<	130	<	30	<	120	<	128	<	130
N,N-diethyl-meta-toluamide (DEET)	134-62-3	<	60	<	250	<	70	<	250	<	256	<	260
Naphthalene	91-20-3	<	30	<	130	<	30	<	120	<	128	<	130
4-Nonylphenol monoethoxylate, (sum of all isomers) also known as NP1EO	104-35-8	<	320	<	1,300	<	340	<	1,200	<	1,280	<	1,300
p-Cresol	106-44-5	E	10	E	40		20		60		106		60
Phenanthrene	85-01-8	<	30	<	130	<	30	<	120	<	128	<	130
Phenol	108-95-2	<	50	<	130	<	40	<	120	<	128	<	140
Prometon	1610-18-0	<	30	<	130	<	30	<	120	<	128	<	130
Pyrene	129-00-0	<	30	<	130	<	30	<	120	<	128	<	130
Tris(2-butoxyethyl)phosphate	78-51-3	<	100	<	380	<	100	<	370	<	354	<	390
Tris(2-chloroethyl)phosphate	115-96-8	<	60	<	250	<	70	<	250	<	256	<	260
Tributyl phosphate	126-73-8	<	30	<	130	<	30	<	120	<	128	<	130
Triclosan	3380-34-5	<	32	<	127	<	34	<	123	<	128	<	131
Triphenyl phosphate	115-86-6	<	30	<	130	<	30	<	120	<	128	<	130
Tris(dichloroisopropyl)phosphate	13674-87-8	<	60	<	250	<	70	<	250	<	256	<	260

Table 8. Pesticide concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

[Samples analyzed by the U.S. Geological Survey Pesticide Fate Research Group according to laboratory methodologies listed in table 2. **NWIS site name:** Top subsample designated “a” (0–30 cm). **CASRN**: Chemical Abstracts Service (CAS) Registry Number®, a registered trademark of the American Chemical Society. ^{SM}. **Detection limit:** Sediment method detection limit. **Abbreviations:** NWIS, National Water Information System; µg/kg, microgram per kilogram; cm, centimeter; ND, not detected]

NWIS site No.			**444954116542400**	**444455117021200**	**443416117084000**
NWIS site name			**Site 1a**	**Site 5a**	**Site 8a**
Sample date / time			**05-07-12 1405**	**05-09-12 0905**	**05-08-12 0905**
Parameter	**CASRN**	**Detection limit (µg/kg)**		**Result (µg/kg)**	
			Current-use pesticides		
3,5-Dichloroaniline	626-43-7	3.0	ND	ND	ND
Boscalid	188425-85-6	1.7	ND	ND	ND
Clomazone	81777-89-1	2.5	ND	ND	ND
Cyhalothrin (all isomers)	68085-85-8	2.4	ND	ND	ND
Cyprodinil	121522-61-2	2.4	ND	ND	ND
Difenoconazole	119446-68-3	0.6	ND	ND	ND
Dimethomorph	110488-70-5	2.0	ND	ND	ND
Etofenprox	80844-07-1	2.5	ND	ND	ND
Famoxadone	131807-57-3	2.4	ND	ND	ND
Fenarimol	60168-88-9	1.5	ND	ND	ND
Fenbuconazole	114369-43-6	2.2	ND	ND	ND
Fenhexamid	126833-17-8	3.2	ND	ND	ND
Fludioxonil	131341-86-1	3.7	ND	ND	ND
Fluoxastrobin	361377-29-9	1.8	ND	ND	ND
Flusilazole	85509-19-9	3.0	ND	ND	ND
Flutriafol	76674-21-0	1.3	ND	ND	ND
Imazalil	35554-44-0	2.5	ND	ND	ND
Kresoxim-methyl	143390-89-0	0.6	ND	ND	ND
Prometon	1610-18-0	3.4	ND	ND	ND
Propanil	709-98-8	3.2	ND	ND	ND
Propyzamide	23950-58-5	1.5	ND	ND	ND
Pyraclostrobin	175013-18-0	1.6	ND	ND	ND
Pyrimethanil	53112-28-0	1.2	ND	ND	ND
T	79538-32-2	1.1	ND	ND	ND
Triadimefon	43121-43-3	3.8	ND	ND	ND
Triadimenol	55219-65-3	1.6	ND	ND	ND
T	68694-11-1	0.6	ND	ND	ND
Triticonazole	131983-72-7	2.4	ND	ND	ND
Vinclozolin	50471-44-8	1.8	ND	ND	ND
Zoxamide	156052-68-5	1.1	ND	ND	ND
3,4-Dichloroaniline	95-76-1	2.5	ND	ND	ND
Alachlor	15972-60-8	0.96	ND	ND	ND
Allethrin	584-79-2	1.46	ND	ND	ND
Atrazine	1912-24-9	1.7	ND	ND	ND
Azoxystrobin	131860-33-8	1.1	ND	ND	ND
Bifenthrin	82657-04-3	2.21	ND	ND	ND
Butylate	2008-41-5	1.58	ND	ND	ND
Carbaryl	63-25-2	1.8	ND	ND	ND
Carbofuran	1563-66-2	1.5	ND	ND	ND
Chlorothalonil	1897-45-6	1.2	ND	ND	ND
Chlorpyrifos	2921-88-2	2.04	ND	ND	ND
Cycloate	1134-23-2	0.96	ND	ND	ND
	68359-37-5	1.96	ND	ND	ND
Cypermethrin	52315-07-8	2.55	ND	ND	ND
Cyproconazole	94361-06-5	1.5	ND	ND	ND
Dacthal (DCPA)	1861-32-1	2.46	ND	ND	ND
Deltamethrin	52918-63-5	2.52	ND	ND	ND

Table 8. Pesticide concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

[Samples analyzed by the U.S. Geological Survey Pesticide Fate Research Group according to laboratory methodologies listed in table 2. **NWIS site name:** Top subsample designated "a" (0–30 cm). **CASRN**: Chemical Abstracts Service (CAS) Registry Number®, a registered trademark of the American Chemical Society. ^{SM}. **Detection limit:** Sediment method detection limit. **Abbreviations:** NWIS, National Water Information System; µg/kg, microgram per kilogram; cm, centimeter; ND, not detected]

NWIS site No.			**444954116542400**	**444455117021200**	**443416117084000**
NWIS site name			**Site 1a**	**Site 5a**	**Site 8a**
Sample date / time			**05-07-12 1405**	**05-09-12 0905**	**05-08-12 0905**
Parameter	**CASRN**	**Detection limit (µg/kg)**		**Result (µg/kg)**	
Current-use pesticides—Continued					
	205650-65-3	2.76	ND	ND	ND
Diazinon	333-41-5	1.95	ND	ND	ND
EPTC	759-94-4	0.88	ND	ND	ND
Esfenvalerate	66230-04-4	2.13	ND	ND	ND
	55283-68-6	1.34	ND	ND	ND
Fenpropathrin	39515-41-8	2.12	ND	ND	ND
Fipronil	120068-37-3	1.86	ND	ND	ND
	120067-83-6	2.22	ND	ND	ND
Fipronil sulfone	120068-36-2	1.09	ND	ND	ND
Hexazinone	51235-04-2	1.2	ND	ND	ND
Iprodione	36734-19-7	0.9	ND	ND	ND
Malathion	121-75-5	1.09	ND	ND	ND
Metconazole	125116-23-6	0.7	ND	ND	ND
Methidathion	950-37-8	2.9	ND	ND	ND
Methoprene	40596-69-8	2.36	ND	ND	ND
Methyl parathion	298-00-0	1.21	ND	ND	ND
Metolachlor	51218-45-2	1.31	ND	ND	ND
Molinate	2212-67-1	1.09	ND	ND	ND
Myclobutanil	88671-89-0	2.9	ND	ND	ND
Napropamide	15299-99-7	1.28	ND	ND	ND
	42874-03-3	3.64	ND	ND	ND
Pebulate	1114-71-2	1.38	ND	ND	ND
Pendimethalin	40487-42-1	0.99	ND	ND	24.7
Permethrin	52645-53-1	0.98	ND	ND	ND
Phenothrin	26002-80-2	1.25	ND	ND	ND
Phosmet	732-11-6	1.37	ND	ND	ND
Piperonyl butoxide	51-03-6	1.64	ND	ND	ND
Prometryn	7287-19-6	2.8	ND	ND	ND
Propiconazole	60207-90-1	1.6	ND	ND	ND
Resmethrin	10453-86-8	1.89	ND	ND	ND
Simazine	122-34-9	1.5	ND	ND	ND
tau-Fluvalinate	102851-06-9	2.6	ND	ND	ND
Tebuconazole	107534-96-3	1.6	ND	ND	ND
Tetraconazole	112281-77-3	1.3	ND	ND	ND
Tetramethrin	7696-12-0	1.36	ND	ND	ND
Thiobencarb	28249-77-6	0.59	ND	ND	ND
T	141517-21-7	1.4	ND	ND	ND
T	1582-09-8	1.71	ND	ND	ND
Organochlorine pesticides					
p,p'-DDD	72-54-8	1.26	ND	ND	ND
p,p'-DDE	72-55-9	1.4	3.2	ND	2.1
p,p'-DDT	50-29-3	1.4	ND	ND	ND
Pentachloroanisole (PCA)	1825-21-4	1.4	ND	ND	ND
Pentachloronitrobenzene (PCNB)	82-68-8	1.15	ND	ND	ND

Table 9. Physical characteristics of bed-sediment cores collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

[Samples analyzed at the Pace Analytical Laboratory according to laboratory methodologies listed in table 2. **NWIS site name**: Top subsample designated "a" (0–30 cm), and a bottom subsample designated "b" (30–75 cm). **CASRN**: Chemical Abstracts Service (CAS) Registry Number®, a registered trademark of the American Chemical Society
Client Services^{SM}. **MDL:** method detection limit; **Abbreviations:** NA, not applicable; SU, standard unit; mV, millivolt; TOC, total organic carbon, Redox, reduction oxidation potential; ASTM, American Society for Testing and Materials; EPA, U.S. Environmental Protection Agency; cm, centimeter; mg/kg, milligram per kilogram; –, no data available]

NWIS site No.				444954116542400		444455117021200		443416117084000	
NWIS site name				Site 1a	Site 1b	Site 5a	Site 5b	Site 8a	Site 8b
Sample date / time				05-07-12 1400	05-07-12 1415	05-09-12 0900	05-09-12 0915	05-08-12 09:00	05-08-12 0915
Parameter	CASRN	Method	MDL (units)	Detection (units vary, noted in MDL)					
TOC	7440-44-0	EPA 9060 mod.	250 (mg/kg)	16,800	13,500	15,500	12,400	13,700	12,900
Grain size	NA	ASTM D422	clay / silt (percent)	–	–	75.8 / 24.2	66.0 / 34.0	68.4 / 31.6	66.4 / 33.6
pH	NA	EPA 9045	0.1 (SU)	7.9	–	7.0	7.1	7.0	7.2
Redox	NA	ASTM D1498	1.0 (mV)	–	–	1,200	673	109	89.3

Table 10. Trace metal concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

[Samples analyzed at the U.S. Geological Survey National Water Quality Laboratory according to laboratory methodologies listed in table 2. **NWIS site name**: Top subsample designated "a" (0–30 cm), and a bottom subsample designated "b" (30–75 cm). **CASRN**: Chemical Abstracts Service (CAS) Registry Number®, a registered trademark of the American Chemical Society. CAS ^{SM}. Shaded values exceed threshold effect limits (TEC) but are less than the probable effect limit (PEC) (MacDonald and others, 2000). **Abbreviations:** NWIS, National Water Information System; CAS, Chemical Abstracts Service; cm, centimeter; mg/kg, milligram per kilogram]

NWIS site No.			444954116542400		444455117021200		443416117084000	
NWIS site name			Site 1a	Site 1b	Site 5a	Site 5b	Site 8a	Site 8b
Sample date / time			05-07-12 1500	05-07-12 1515	05-09-12 1500	05-09-12 1515	05-08-12 1500	05-08-12 1515
Trace metal	CASRN	Reporting level (mg/kg)	Detection (mg/kg)					
Aluminum	7429-90-5	25	56,300	36,200	34,400	25,400	24,300	22,000
Arsenic	7440-38-2	0.10	16.8	15.4	13.2	14	12.5	11.3
Boron	7440-42-8	2.4	11.8	9.0	12.4	10.9	9.8	9.7
Cadmium	7440-43-9	0.10	0.56	0.69	0.61	0.65	0.71	0.64
Chromium	7440-47-3	0.10	31.3	33.3	35.4	31.1	29.3	24
Cobalt	7440-48-4	0.10	16.6	15.6	16.3	12.8	10.7	8.52
Copper	7440-50-8	0.10	40.2	41	43.7	38.7	35.3	28.4
Iron	7439-89-6	4.6	34,400	42,300	42,400	35,200	29,500	27,400
Lead	7439-92-1	0.10	13.2	17.5	14.9	13.6	13.4	11.2
Manganese	7439-96-5	0.20	3,160	2,420	1,710	1,440	888	846
Molybdenum	7439-98-7	0.10	1.2	0.33	0.52	0.77	0.37	0.44
Nickel	7440-02-0	0.10	23.7	27.6	29.2	23.1	22.5	18.4
Selenium	7782-49-2	0.10	2.5	1.8	1.79	2.29	1.74	1.67
Vanadium	7440-62-2	0.10	91.3	63.1	73.5	67.7	53.2	46.7
Zinc	7440-66-6	0.10	89.1	113	99.1	90.7	100	86.7

Summary

Total mercury and methylmercury were collected from water column and bed-sediment core samples at eight sites at Brownlee Reservoir near Oxbow, Oregon. Total methylmercury concentrations in the water column increased with depth. Total methylmercury in the bed sediment was largest near the sediment-water interface and decreased substantially with depth.

The bed-sediment core samples from sites 1, 5, and 8 were analyzed for 417 pesticides and other organic compounds. Only 17 of the 417 analytes were detected at or greater than the reporting level, and 11 of the detected analytes were wastewater compounds. Other organics detected in the bed sediment cores included the herbicides 2,4-Dichlorobenzoic acid and pentachlorphenol along with the pesticides 4,4'-DDE, pendimethalin, prometon, and propoxur; 4,4'-DDE was detected in all sediment samples that were analyzed. Initially, glyphosate (and AMPA) analysis indicated an anomalously high concentration of glyphosate, but further

samples were not accurate.

The physical characteristic analyses included total organic carbon, grain size, pH, and redox. Total organic carbon was consistent throughout the reservoir ranging from 12,400 to 16,800 milligrams per kilogram. The grain size ranged from about 66 to 75.8 percent clay, and about 24 to 34 percent silt. The highest pH was 7.9 and occurred in the northern part of the reservoir at site 1; all other pH samples ranged from 7.0 to 7.2. Redox was not analyzed at site 1; however, redox decreased with depth at sites 5 and 8 and decreased in a downstream direction.

Trace metals were detected at greater than the reporting level in all bed-sediment core samples submitted for analysis. Three trace metals exceeded the sediment quality guidelines. Arsenic (all sites), copper (sites 1a and 1b, 5a and 5b, and 8a), and nickel (sites 1a and 1b and 5a and 5b) each exceeded the threshold effect concentration (TEC), but were less than the probable effect concentration (PEC) for freshwater ecosystem. Because the concentrations were between the TEC and PEC, a determination of toxicity could not be determined.

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Table 11. Organic compound concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

[Samples analyzed at Pace Analytical Services, Inc. according to laboratory methodologies listed in table 2. All values are in micrograms per kilogram (wet weight). **NWIS site name**: Top subsample designated “a” (0–30 cm), and a bottom subsample designated “b” (30–75 cm). **CASRN:** Chemical Abstracts Service (CAS) Registry Number®, a registered trademark of the American Chemical Society. CAS recommends th
Client Services℠. **MDL:** method detection limit. **RL:** reporting level. **Abbreviations:** NWIS, National Water Information System; EPA, U.S. Environmental Protection Agency; SIM, selected ion monitoring; PCBs, polychlorinated biphenyls; TCDD,Tetrachlorodibenzo-p-dioxin; ND, not detected; cm centimeter; µg/kg, microgram per kilogram; –, no data available]

NWIS site No.		**444954116542400**					
NWIS site name		**Site 1a**			**Site 1b**		
Sample date and time		**05-07-12 1400**			**05-07-12 1415**		
Compound	**CASRN**	**Detection (µg/kg)**	**MDL (µg/kg)**	**RL (µg/kg)**	**Detection (µg/kg)**	**MDL (µg/kg)**	**RL (µg/kg)**
Semivolatile organics (SVOC)—EPA 8270							
1,2,4-Trichlorobenzene	120-82-1	ND	630	3,040	ND	312	1,510
1,2-Dichlorobenzene	95-50-1	ND	652	3,040	ND	323	1,510
1,2-Diphenylhydrazine	122-66-7	ND	358	15,600	ND	177	7,760
1,3-Dichlorobenzene	541-73-1	ND	695	3,040	ND	344	1,510
1,4-Dichlorobenzene	106-46-7	ND	647	3,040	ND	321	1,510
1-Methylnaphthalene	90-12-0	ND	439	3,040	ND	218	1,510
2,4,5-Trichlorophenol	95-95-4	ND	521	15,600	ND	258	7,760
2,4,6-Trichlorophenol	88-06-2	ND	450	3,040	ND	223	1,510
2,4-Dichlorophenol	120-83-2	ND	455	3,040	ND	225	1,510
2,4-Dimethylphenol	105-67-9	ND	1,520	3,040	ND	753	1,510
2.4-Dinitrophenol	51-28-5	ND	435	15,600	ND	216	7,760
2,4-Dinitrotoluene	121-14-2	ND	424	3,040	ND	210	1,510
2.6-Dinitrotoluene	606-20-2	ND	424	3,040	ND	210	1,510
2-Chloronaphthalene	91-58-7	ND	366	3,040	ND	182	1,510
2-Chlorophenol	95-57-8	ND	667	3,040	ND	331	1,510
2-Methylnaphthalene	91-57-6	ND	449	3,040	ND	223	1,510
2-Methylphenol(o-Cresol)	95-48-7	ND	465	3,040	ND	230	1,510
2-Nitroaniline	88-74-4	ND	422	15,600	ND	209	7,760
2-Nitrophenol	88-75-5	ND	504	3,040	ND	250	1,510
3&4-Methylphenol	108-39-4 [3] and 106-44-5 [4]	ND	408	6,080	ND	202	3,010
3,3’-Dichlorobenzidine	91-94-1	ND	3,080	6,170	ND	1,530	3,060
3-Nitroaniline	99-09-2	ND	597	15,600	ND	296	7,760
4,6-Dinitro-2-methylphenol	534-52-1	ND	2,560	15,600	ND	1,270	7,760
4-Bromophenylphenyl ether	101-55-3	ND	463	3,040	ND	229	1,510
4-Chloro-3-methylphenol	59-50-7	ND	356	3,040	ND	177	1,510
4-Chloroaniline	106-47-8	ND	1,520	3,040	ND	753	1,510
4-Chlorophenylphenyl ether	7005-72-3	ND	409	3,040	ND	203	1,510
4-Nitroaniline	100-01-6	ND	2,220	15,600	ND	1,100	7,760
4-Nitrophenol	100-02-7	ND	7,820	15,600	ND	3,880	7,760
Acenaphthene	[1]83-32-9	ND	360	3,040	ND	178	1,510
Acenaphthylene	[1]208-96-8	ND	352	3,040	ND	174	1,510
Anthracene	[1]120-12-7	ND	390	3,040	ND	193	1,510
Benzo(a)anthracene	[1]56-55-3	ND	429	3,040	ND	213	1,510
Benzo(a)pyrene	[1]50-32-8	ND	434	3,040	ND	215	1,510
	[1]205-99-2	ND	434	3,040	ND	215	1,510
Benzo(g,h,i)perylene	[1]191-24-2	ND	462	3,040	ND	229	1,510
	[1]207-08-9	ND	423	3,040	ND	209	1,510
Butylbenzylphthalate	85-68-7	ND	413	3,040	ND	205	1,510
Carbazole	86-74-8	ND	397	3,040	ND	197	1,510
Chrysene	[1]218-01-9	ND	434	3,040	ND	215	1,510
Di-n-butylphthalate	84-74-2	ND	313	3,040	ND	155	1,510
Di-n-octylphthalate	117-84-0	ND	444	3,040	ND	220	1,510
Dibenz(a,h)anthracene	[1]53-70-3	ND	472	3,040	ND	234	1,510
Dibenzofuran	132-64-9	ND	370	3,040	ND	183	1,510

Table 11. Organic compound concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

NWIS site No.		**444954116542400**					
NWIS site name		**Site 1a**			**Site 1b**		
Sample date and time		**05-07-12 1400**			**05-07-12 1415**		
Compound	**CASRN**	**Detection (µg/kg)**	**MDL (µg/kg)**	**RL (µg/kg)**	**Detection (µg/kg)**	**MDL (µg/kg)**	**RL (µg/kg)**
Semivolatile organics (SVOC)—EPA 8270—Continued							
Diethylphthalate	84-66-2	ND	399	3,040	ND	198	1,510
Dimethylphthalate	131-11-3	ND	423	3,040	ND	210	1,510
Fluoranthene	[1]206-44-0	ND	371	3,040	ND	184	1,510
Fluorene	[1]86-73-7	ND	390	3,040	ND	193	1,510
Hexachloro-1,3-butadiene	87-68-3	ND	755	3,040	ND	374	1,510
Hexachlorobenzene	118-74-1	ND	427	3,040	ND	212	1,510
Hexachloroethane	67-72-1	ND	718	3,040	ND	356	1,510
Indeno(1,2,3-cd)pyrene	[1]193-39-5	ND	445	3,040	ND	220	1,510
Isophorone	78-59-1	ND	365	3,040	ND	181	1,510
N-Nitroso-di-n-propylamine	621-64-7	ND	472	3,040	ND	234	1,510
N-Nitrosodimethylamine	62-75-9	ND	487	3,040	ND	241	1,510
N-Nitrosodiphenylamine	86-30-6	ND	440	3,040	ND	218	1,510
Naphthalene	[1]91-20-3	ND	591	3,040	ND	293	1,510
Nitrobenzene	98-95-3	ND	610	3,040	ND	302	1,510
Pentachlorophenol	[1]87-86-5	ND	3,080	6,170	ND	1530	3,060
Phenanthrene	[1]85-01-8	ND	406	3,040	ND	201	1,510
Phenol	108-95-2	ND	552	3,040	ND	274	1,510
Pyrene	[1]129-00-0	ND	423	3,040	ND	209	1,510
bis(2-Chloroethoxy)methane	111-91-1	ND	515	3,040	ND	255	1,510
bis(2-Chloroethyl) ether	111-44-4	ND	622	3,040	ND	308	1,510
bis(2-Chloroisopropyl)ether	108-60-1	ND	725	3,040	ND	360	1,510
bis(2-Ethylhexyl)phthalate	117-81-7	ND	712	3,040	ND	353	1,510
Polyaromatic hydrocarbons (PAH) (low level)—EPA 8270(SIM)							
Acenaphthene	[2]83-32-9	ND	42.5	85	ND	22.8	45.6
Acenaphthylene	[2]208-96-8	ND	42.5	85	ND	22.8	45.6
Anthracene	[2]120-12-7	ND	42.5	85	ND	22.8	45.6
Benzo(a)anthracene	[2]56-55-3	ND	2.9	85	ND	1.6	45.6
Benzo(a)pyrene	[2]50-32-8	ND	2.5	85	ND	1.4	45.6
	[2]205-99-2	ND	13.1	85	ND	7	45.6
Benzo(g,h,i)perylene	[2]191-24-2	ND	2.8	85	ND	1.5	45.6
	[2]207-08-9	ND	10	85	ND	5.3	45.6
Chrysene	[2]218-01-9	ND	2.8	85	ND	1.5	45.6
Dibenz(a,h)anthracene	[2]53-70-3	ND	2.9	85	ND	1.6	45.6
Fluoranthene	[2]206-44-0	ND	42.5	85	ND	22.8	45.6
Fluorene	[2]86-73-7	ND	3.2	85	ND	1.7	45.6
Indeno(1,2,3-cd)pyrene	[2]193-39-5	ND	2.4	85	ND	1.3	45.6
Naphthalene	[2]91-20-3	ND	1.6	85	ND	0.84	45.6
Phenanthrene	[2]85-01-8	ND	2.4	85	ND	1.3	45.6
Pyrene	[2]129-00-0	ND	3.2	85	ND	1.7	45.6
Organochlorine pesticides—EPA 8081							
4,4’-DDD	72-54-8	ND	30.5	395	ND	16.3	212
4,4’-DDE	72-55-9	19.4	14.2	395	16.2	7.6	212
4,4’-DDT	50-29-3	ND	22.3	395	ND	11.9	212
Aldrin	309-00-2	ND	13.5	395	ND	7.2	212
Chlordane (technical)	57-74-9	ND	3,690	3,950	ND	1,980	2,120
Dieldrin	60-57-1	ND	9.3	395	ND	5	212
Endosulfan I	959-98-8	ND	5.8	395	ND	3.1	212

Table 11. Organic compound concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

NWIS site No.		444954116542400					
NWIS site name		**Site 1a**			**Site 1b**		
Sample date and time		**05-07-12 1400**			**05-07-12 1415**		
Compound	**CASRN**	**Detection (µg/kg)**	**MDL (µg/kg)**	**RL (µg/kg)**	**Detection (µg/kg)**	**MDL (µg/kg)**	**RL (µg/kg)**
Organochlorine pesticides—EPA 8081—Continued							
Endosulfan II	33213-65-9	ND	13.3	395	ND	7.1	212
Endosulfan sulfate	1031-07-8	ND	10	395	ND	5.4	212
Endrin	72-20-8	ND	12.1	395	ND	6.5	212
Endrin aldehyde	7421-93-4	ND	15.4	395	ND	8.2	212
Endrin ketone	53494-70-5	ND	18.6	395	ND	10	212
Heptachlor	76-44-8	ND	9.1	395	ND	4.9	212
Heptachlor epoxide	1024-57-3	ND	25.8	395	ND	13.8	212
Methoxychlor	72-43-5	ND	244	395	ND	131	212
Toxaphene	8001-35-2	ND	1710	3,950	ND	914	2,120
alpha-BHC	319-84-6	ND	16.1	395	ND	8.6	212
beta-BHC	319-85-7	ND	17.9	395	ND	9.6	212
delta-BHC	319-86-8	ND	20.2	395	ND	10.8	212
gamma-BHC (lidane)	58-89-9	ND	34.4	395	ND	18.4	212
Polychlorinated biphenyls (PCBs)—EPA 8082							
PCB-1016 (Aroclor 1016)	12674-11-2	ND	1,020	2,810	ND	547	1,510
PCB-1221 (Aroclor 1221)	11104-28-2	ND	1,110	2,810	ND	593	1,510
PCB-1232 (Aroclor 1232)	11141-16-5	ND	1,190	2,810	ND	639	1,510
PCB-1242 (Aroclor 1242)	53469-21-9	ND	682	2,810	ND	365	1,510
PCB-1248 (Aroclor 1248)	12672-29-6	ND	597	2,810	ND	319	1,510
PCB-1254 (Aroclor 1254)	11097-69-1	ND	768	2,810	ND	411	1,510
PCB-1260 (Aroclor 1260)	11096-82-5	ND	1,020	2,810	ND	547	1,510
PCB-1262 (Aroclor 1262)	37324-23-5	ND	341	2,810	ND	182	1,510
PCB-1268 (Aroclor 1268)	11100-14-4	ND	512	2,810	ND	274	1,510
Chlorinated herbicides—EPA 8151							
2,4,5-T	93-76-5	ND	28.2	158	ND	15.1	84.8
2,4,5-TP (Silvex)	93-72-1	ND	19.9	159	ND	10.7	85
2,4-D	94-75-7	ND	190	786	ND	102	421
2,4-DB	94-82-6	ND	423	1,580	ND	226	847
Bentazon	25057-89-0	ND	48.3	78.9	ND	25.9	42.2
Dalapon	75-99-0	ND	153	762	ND	81.9	408
Dicamba	1918-00-9	ND	31.9	78.6	ND	17.1	42
Dichlorprop	120-36-5	ND	215	546	ND	115	292
Dinoseb	88-85-7	ND	37.2	158	ND	19.9	84.5
Pentachlorophenol	[3]87-86-5	ND	20.3	23.7	ND	10.9	12.7
Picloram	1918-02-1	ND	13.4	79	ND	7.2	42.3
Dioxin (2,3,7,8-TCDD)—EPA 1613							
2,3,7,8-TCDD	1746-01-6	ND	–	1	ND	–	1

Table 11. Organic compound concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

NWIS site No.		444455117021200					
NWIS site name		Site 5a			Site 5b		
Sample date and time		05-09-12 0900			05-09-12 0915		
Compound	CASRN	Detection (μg/kg)	MDL (μg/kg)	RL (μg/kg)	Detection (μg/kg)	MDL (μg/kg)	RL (μg/kg)
Semivolatile organics (SVOC)—EPA 8270							
1,2,4-Trichlorobenzene	120-82-1	ND	441	2,130	ND	317	1,530
1,2-Dichlorobenzene	95-50-1	ND	456	2,130	ND	328	1,530
1,2-Diphenylhydrazine	122-66-7	ND	251	11,000	ND	180	7,880
1,3-Dichlorobenzene	541-73-1	ND	487	2,130	ND	350	1,530
1,4-Dichlorobenzene	106-46-7	ND	453	2,130	ND	326	1,530
1-Methylnaphthalene	90-12-0	ND	307	2,130	ND	221	1,530
2,4,5-Trichlorophenol	95-95-4	ND	365	11,000	ND	262	7,880
2,4,6-Trichlorophenol	88-06-2	ND	315	2,130	ND	227	1,530
2,4-Dichlorophenol	120-83-2	ND	318	2,130	ND	229	1,530
2,4-Dimethylphenol	105-67-9	ND	1,060	2,130	ND	765	1,530
2.4-Dinitrophenol	51-28-5	ND	305	11,000	ND	219	7,880
2,4-Dinitrotoluene	121-14-2	ND	297	2,130	ND	214	1,530
2.6-Dinitrotoluene	606-20-2	ND	297	2,130	ND	214	1,530
2-Chloronaphthalene	91-58-7	ND	257	2,130	ND	184	1,530
2-Chlorophenol	95-57-8	ND	467	2,130	ND	336	1,530
2-Methylnaphthalene	91-57-6	ND	315	2,130	ND	226	1,530
2-Methylphenol(o-Cresol)	95-48-7	ND	325	2,130	ND	234	1,530
2-Nitroaniline	88-74-4	ND	295	11,000	ND	212	7,880
2-Nitrophenol	88-75-5	ND	353	2,130	ND	254	1,530
3&4-Methylphenol	108-39-4 [3] and 106-44-5 [4]	ND	286	4,250	ND	205	3,060
3,3'-Dichlorobenzidine	91-94-1	ND	2,160	4,320	ND	1,550	3,110
3-Nitroaniline	99-09-2	ND	418	11,000	ND	301	7,880
4,6-Dinitro-2-methylphenol	534-52-1	ND	1,790	11,000	ND	1,290	7,880
4-Bromophenylphenyl ether	101-55-3	ND	324	2,130	ND	233	1,530
4-Chloro-3-methylphenol	59-50-7	ND	249	2,130	ND	179	1,530
4-Chloroaniline	106-47-8	ND	1,060	2,130	ND	765	1,530
4-Chlorophenylphenyl ether	7005-72-3	ND	286	2,130	ND	206	1,530
4-Nitroaniline	100-01-6	ND	1,550	11,000	ND	1,120	7,880
4-Nitrophenol	100-02-7	ND	5,480	11,000	ND	3,940	7,880
Acenaphthene	[1]83-32-9	ND	252	2,130	ND	181	1,530
Acenaphthylene	[1]208-96-8	ND	246	2,130	ND	177	1,530
Anthracene	[1]120-12-7	ND	273	2,130	ND	197	1,530
Benzo(a)anthracene	[1]56-55-3	ND	300	2,130	ND	216	1,530
Benzo(a)pyrene	[1]50-32-8	ND	304	2,130	ND	219	1,530
	[1]205-99-2	ND	304	2,130	ND	219	1,530
Benzo(g,h,i)perylene	[1]191-24-2	ND	324	2,130	ND	233	1,530
	[1]207-08-9	ND	296	2,130	ND	213	1,530
Butylbenzylphthalate	85-68-7	ND	289	2,130	ND	208	1,530
Carbazole	86-74-8	ND	278	2,130	ND	200	1,530
Chrysene	[1]218-01-9	ND	304	2,130	ND	219	1,530
Di-n-butylphthalate	84-74-2	ND	219	2,130	ND	158	1,530
Di-n-octylphthalate	117-84-0	ND	311	2,130	ND	223	1,530
Dibenz(a,h)anthracene	[1]53-70-3	ND	331	2,130	ND	238	1,530
Dibenzofuran	132-64-9	ND	259	2,130	ND	186	1,530

Table 11. Organic compound concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

NWIS site No.		**444455117021200**					
NWIS site name		**Site 5a**			**Site 5b**		
Sample date and time		**05-09-12 0900**			**05-09-12 0915**		
Compound	**CASRN**	**Detection (µg/kg)**	**MDL (µg/kg)**	**RL (µg/kg)**	**Detection (µg/kg)**	**MDL (µg/kg)**	**RL (µg/kg)**
Semivolatile organics (SVOC)—EPA 8270—Continued							
Diethylphthalate	84-66-2	ND	279	2,130	ND	201	1,530
Dimethylphthalate	131-11-3	ND	296	2,130	ND	213	1,530
Fluoranthene	[1]206-44-0	ND	260	2,130	ND	187	1,530
Fluorene	[1]86-73-7	ND	273	2,130	ND	197	1,530
Hexachloro-1,3-butadiene	87-68-3	ND	528	2,130	ND	380	1,530
Hexachlorobenzene	118-74-1	ND	299	2,130	ND	215	1,530
Hexachloroethane	67-72-1	ND	503	2,130	ND	362	1,530
Indeno(1,2,3-cd)pyrene	[1]193-39-5	ND	311	2,130	ND	224	1,530
Isophorone	78-59-1	ND	256	2,130	ND	184	1,530
N-Nitroso-di-n-propylamine	621-64-7	ND	331	2,130	ND	238	1,530
N-Nitrosodimethylamine	62-75-9	ND	341	2,130	ND	245	1,530
N-Nitrosodiphenylamine	86-30-6	ND	308	2,130	ND	222	1,530
Naphthalene	[1]91-20-3	ND	414	2,130	ND	298	1,530
Nitrobenzene	98-95-3	ND	427	2,130	ND	307	1,530
Pentachlorophenol	[1]87-86-5	ND	2,160	4,320	ND	1,550	3,110
Phenanthrene	[1]85-01-8	ND	284	2,130	ND	204	1,530
Phenol	108-95-2	ND	387	2,130	ND	278	1,530
Pyrene	[1]129-00-0	ND	296	2,130	ND	213	1,530
bis(2-Chloroethoxy)methane	111-91-1	ND	361	2,130	ND	260	1,530
bis(2-Chloroethyl) ether	111-44-4	ND	436	2,130	ND	313	1,530
bis(2-Chloroisopropyl)ether	108-60-1	ND	508	2,130	ND	365	1,530
bis(2-Ethylhexyl)phthalate	117-81-7	ND	499	2,130	ND	359	1,530
Polyaromatic hydrocarbons PAH (low level)—EPA 8270(SIM)							
Acenaphthene	[2]83-32-9	ND	32.9	65.8	ND	23.2	46.4
Acenaphthylene	[2]208-96-8	ND	32.9	65.8	ND	23.2	46.4
Anthracene	[2]120-12-7	ND	32.9	65.8	ND	23.2	46.4
Benzo(a)anthracene	[2]56-55-3	ND	2.2	65.8	ND	1.6	46.4
Benzo(a)pyrene	[2]50-32-8	ND	2	65.8	ND	1.4	46.4
	[2]205-99-2	ND	10.1	65.8	ND	7.1	46.4
Benzo(g,h,i)perylene	[2]191-24-2	ND	2.2	65.8	ND	1.5	46.4
	[2]207-08-9	ND	7.7	65.8	ND	5.4	46.4
Chrysene	[2]218-01-9	ND	2.1	65.8	ND	1.5	46.4
Dibenz(a,h)anthracene	[2]53-70-3	ND	2.2	65.8	ND	1.6	46.4
Fluoranthene	[2]206-44-0	ND	32.9	65.8	ND	23.2	46.4
Fluorene	[2]86-73-7	ND	2.5	65.8	ND	1.7	46.4
Indeno(1,2,3-cd)pyrene	[2]193-39-5	ND	1.9	65.8	ND	1.3	46.4
Naphthalene	[2]91-20-3	ND	1.2	65.8	ND	0.86	46.4
Phenanthrene	[2]85-01-8	ND	1.9	65.8	ND	1.3	46.4
Pyrene	[2]129-00-0	ND	2.5	65.8	ND	1.7	46.4
Organochlorine pesticides—EPA 8081							
4,4’-DDD	72-54-8	ND	23.5	305	ND	16.6	215
4,4’-DDE	72-55-9	14.3	10.9	305	14.3	7.7	215
4,4’-DDT	50-29-3	ND	17.2	305	ND	12.1	215
Aldrin	309-00-2	ND	10.4	305	ND	7.3	215
Chlordane (technical)	57-74-9	ND	2,850	3,050	ND	2,010	2,150
Dieldrin	60-57-1	ND	7.2	305	ND	5.1	215
Endosulfan I	959-98-8	ND	4.5	305	ND	3.2	215

Table 11. Organic compound concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

NWIS site No.		444455117021200					
NWIS site name		Site 5a			Site 5b		
Sample date and time		05-09-12 0900			05-09-12 0915		
Compound	CASRN	Detection (µg/kg)	MDL (µg/kg)	RL (µg/kg)	Detection (µg/kg)	MDL (µg/kg)	RL (µg/kg)
Organochlorine pesticides—EPA 8081—Continued							
Endosulfan II	33213-65-9	ND	10.2	305	ND	7.2	215
Endosulfan sulfate	1031-07-8	ND	7.7	305	ND	5.4	215
Endrin	72-20-8	ND	9.3	305	ND	6.6	215
Endrin aldehyde	7421-93-4	ND	11.8	305	ND	8.3	215
Endrin ketone	53494-70-5	ND	14.3	305	ND	10.1	215
Heptachlor	76-44-8	ND	7	305	ND	4.9	215
Heptachlor epoxide	1024-57-3	ND	19.9	305	ND	14	215
Methoxychlor	72-43-5	ND	188	305	ND	133	215
Toxaphene	8001-35-2	ND	1,320	3,050	ND	929	2,150
alpha-BHC	319-84-6	ND	12.4	305	ND	8.7	215
beta-BHC	319-85-7	ND	13.8	305	ND	9.7	215
delta-BHC	319-86-8	ND	15.6	305	ND	11	215
gamma-BHC (lidane)	58-89-9	ND	26.5	305	ND	18.7	215
Polychlorinated biphenyls (PCBs)—EPA 8082							
PCB-1016 (Aroclor 1016)	12674-11-2	–	–	–	ND	556	1,530
PCB-1221 (Aroclor 1221)	11104-28-2	–	–	–	ND	603	1,530
PCB-1232 (Aroclor 1232)	11141-16-5	–	–	–	ND	649	1,530
PCB-1242 (Aroclor 1242)	53469-21-9	–	–	–	ND	371	1,530
PCB-1248 (Aroclor 1248)	12672-29-6	–	–	–	ND	324	1,530
PCB-1254 (Aroclor 1254)	11097-69-1	–	–	–	ND	417	1,530
PCB-1260 (Aroclor 1260)	11096-82-5	–	–	–	ND	556	1,530
PCB-1262 (Aroclor 1262)	37324-23-5	–	–	–	ND	185	1,530
PCB-1268 (Aroclor 1268)	11100-14-4	–	–	–	ND	278	1,530
Chlorinated herbicides—EPA 8151							
2,4,5-T	93-76-5	–	–	–	–	–	–
2,4,5-TP (Silvex)	93-72-1	–	–	–	–	–	–
2,4-D	94-75-7	–	–	–	–	–	–
2,4-DB	94-82-6	–	–	–	–	–	–
Bentazon	25057-89-0	–	–	–	–	–	–
Dalapon	75-99-0	–	–	–	–	–	–
Dicamba	1918-00-9	–	–	–	–	–	–
Dichlorprop	120-36-5	–	–	–	–	–	–
Dinoseb	88-85-7	–	–	–	–	–	–
Pentachlorophenol	[3]87-86-5	–	–	–	–	–	–
Picloram	1918-02-1	–	–	–	–	–	–
Dioxin (2,3,7,8-TCDD)—EPA 1613							
2,3,7,8-TCDD	1746-01-6	ND	–	1	ND	–	1

Table 11. Organic compound concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

NWIS site No.		**443416117084000**					
NWIS site name		**Site 8a**			**Site 8b**		
Sample date and time		**05-08-12 0900**			**05-08-12 0915**		
Compound	**CASRN**	**Detection (μg/kg)**	**MDL (μg/kg)**	**RL (μg/kg)**	**Detection (μg/kg)**	**MDL (μg/kg)**	**RL (μg/kg)**
Semivolatile organics (SVOC)—EPA 8270							
1,2,4-Trichlorobenzene	120-82-1	ND	295	1,420	ND	258	1,250
1,2-Dichlorobenzene	95-50-1	ND	305	1,420	ND	267	1,250
1,2-Diphenylhydrazine	122-66-7	ND	168	7,320	ND	147	6,420
1,3-Dichlorobenzene	541-73-1	ND	325	1,420	ND	285	1,250
1,4-Dichlorobenzene	106-46-7	ND	303	1,420	ND	265	1,250
1-Methylnaphthalene	90-12-0	ND	205	1,420	ND	180	1,250
2,4,5-Trichlorophenol	95-95-4	ND	244	7,320	ND	214	6,420
2,4,6-Trichlorophenol	88-06-2	ND	211	1,420	ND	185	1,250
2,4-Dichlorophenol	120-83-2	ND	213	1,420	ND	186	1,250
2,4-Dimethylphenol	105-67-9	ND	711	1,420	ND	623	1,250
2.4-Dinitrophenol	51-28-5	ND	204	7,320	ND	179	6,420
2,4-Dinitrotoluene	121-14-2	ND	199	1,420	ND	174	1,250
2.6-Dinitrotoluene	606-20-2	ND	199	1,420	ND	174	1,250
2-Chloronaphthalene	91-58-7	ND	171	1,420	ND	150	1,250
2-Chlorophenol	95-57-8	ND	312	1,420	ND	274	1,250
2-Methylnaphthalene	91-57-6	ND	210	1,420	ND	184	1,250
2-Methylphenol(o-Cresol)	95-48-7	ND	218	1,420	ND	191	1,250
2-Nitroaniline	88-74-4	ND	197	7,320	ND	173	6,420
2-Nitrophenol	88-75-5	ND	236	1,420	ND	206	1,250
3&4-Methylphenol	108-39-4 [3] and 106-44-5 [4]	ND	191	2,840	ND	167	2,490
3,3'-Dichlorobenzidine	91-94-1	ND	1,440	2,890	ND	1,260	2,530
3-Nitroaniline	99-09-2	ND	280	7,320	ND	245	6,420
4,6-Dinitro-2-methylphenol	534-52-1	ND	1,200	7,320	ND	1,050	6,420
4-Bromophenylphenyl ether	101-55-3	ND	217	1,420	ND	190	1,250
4-Chloro-3-methylphenol	59-50-7	ND	167	1,420	ND	146	1,250
4-Chloroaniline	106-47-8	ND	711	1,420	ND	623	1,250
4-Chlorophenylphenyl ether	7005-72-3	ND	191	1,420	ND	168	1,250
4-Nitroaniline	100-01-6	ND	1,040	7,320	ND	910	6,420
4-Nitrophenol	100-02-7	ND	3,660	7,320	ND	3,210	6,420
Acenaphthene	[1]83-32-9	ND	168	1,420	ND	148	1,250
Acenaphthylene	[1]208-96-8	ND	165	1,420	ND	144	1,250
Anthracene	[1]120-12-7	ND	183	1,420	ND	160	1,250
Benzo(a)anthracene	[1]56-55-3	ND	201	1,420	ND	176	1,250
Benzo(a)pyrene	[1]50-32-8	ND	203	1,420	ND	178	1,250
	[1]205-99-2	ND	203	1,420	ND	178	1,250
Benzo(g,h,i)perylene	[1]191-24-2	ND	216	1,420	ND	189	1,250
	[1]207-08-9	ND	198	1,420	ND	173	1,250
Butylbenzylphthalate	85-68-7	ND	193	1,420	ND	169	1,250
Carbazole	86-74-8	ND	186	1,420	ND	163	1,250
Chrysene	[1]218-01-9	ND	203	1,420	ND	178	1,250
Di-n-butylphthalate	84-74-2	ND	146	1,420	ND	128	1,250
Di-n-octylphthalate	117-84-0	ND	208	1,420	ND	182	1,250
Dibenz(a,h)anthracene	[1]53-70-3	ND	221	1,420	ND	194	1,250
Dibenzofuran	132-64-9	ND	173	1,420	ND	152	1,250

Table 11. Organic compound concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

NWIS site No.		**443416117084000**					
NWIS site name		**Site 8a**			**Site 8b**		
Sample date and time		**05-08-12 0900**			**05-08-12 0915**		
Compound	**CASRN**	**Detection (µg/kg)**	**MDL (µg/kg)**	**RL (µg/kg)**	**Detection (µg/kg)**	**MDL (µg/kg)**	**RL (µg/kg)**
Semivolatile organics (SVOC)—EPA 8270							
Diethylphthalate	84-66-2	ND	186	1,420	ND	163	1,250
Dimethylphthalate	131-11-3	ND	198	1,420	ND	174	1,250
Fluoranthene	[1]206-44-0	ND	174	1,420	ND	152	1,250
Fluorene	[1]86-73-7	ND	183	1,420	ND	160	1,250
Hexachloro-1,3-butadiene	87-68-3	ND	353	1,420	ND	309	1,250
Hexachlorobenzene	118-74-1	ND	200	1,420	ND	175	1,250
Hexachloroethane	67-72-1	ND	336	1,420	ND	294	1,250
Indeno(1,2,3-cd)pyrene	[1]193-39-5	ND	208	1,420	ND	182	1,250
Isophorone	78-59-1	ND	171	1,420	ND	150	1,250
N-Nitroso-di-n-propylamine	621-64-7	ND	221	1,420	ND	194	1,250
N-Nitrosodimethylamine	62-75-9	ND	228	1,420	ND	200	1,250
N-Nitrosodiphenylamine	86-30-6	ND	206	1,420	ND	180	1,250
Naphthalene	[1]91-20-3	ND	277	1,420	ND	242	1,250
Nitrobenzene	98-95-3	ND	286	1,420	ND	250	1,250
Pentachlorophenol	[1]87-86-5	ND	1,440	2,890	ND	1,260	2,530
Phenanthrene	[1]85-01-8	ND	190	1,420	ND	166	1,250
Phenol	108-95-2	ND	258	1,420	ND	226	1,250
Pyrene	[1]129-00-0	ND	198	1,420	ND	173	1,250
bis(2-Chloroethoxy)methane	111-91-1	ND	241	1,420	ND	211	1,250
bis(2-Chloroethyl) ether	111-44-4	ND	291	1,420	ND	255	1,250
bis(2-Chloroisopropyl)ether	108-60-1	ND	339	1,420	ND	297	1,250
bis(2-Ethylhexyl)phthalate	117-81-7	ND	333	1,420	ND	292	1,250
Polyaromatic hydrocarbons PAH (low level)—EPA 8270(SIM)							
Acenaphthene	[2]83-32-9	ND	21.5	43.1	ND	18.9	37.7
Acenaphthylene	[2]208-96-8	ND	21.5	43.1	ND	18.9	37.7
Anthracene	[2]120-12-7	ND	21.5	43.1	ND	18.9	37.7
Benzo(a)anthracene	[2]56-55-3	ND	1.5	43.1	ND	1.3	37.7
Benzo(a)pyrene	[2]50-32-8	ND	1.3	43.1	ND	1.1	37.7
	[2]205-99-2	ND	6.6	43.1	ND	5.8	37.7
Benzo(g,h,i)perylene	[2]191-24-2	ND	1.4	43.1	ND	1.2	37.7
	[2]207-08-9	ND	5	43.1	ND	4.4	37.7
Chrysene	[2]218-01-9	ND	1.4	43.1	ND	1.2	37.7
Dibenz(a,h)anthracene	[2]53-70-3	ND	1.5	43.1	ND	1.3	37.7
Fluoranthene	[2]206-44-0	ND	21.5	43.1	ND	18.9	37.7
Fluorene	[2]86-73-7	ND	1.6	43.1	ND	1.4	37.7
Indeno(1,2,3-cd)pyrene	[2]193-39-5	ND	1.2	43.1	ND	1.1	37.7
Naphthalene	[2]91-20-3	ND	0.8	43.1	ND	0.7	37.7
Phenanthrene	[2]85-01-8	ND	1.2	43.1	ND	1.1	37.7
Pyrene	[2]129-00-0	ND	1.6	43.1	ND	1.4	37.7
Organochlorine pesticides—EPA 8081							
4,4'-DDD	72-54-8	ND	3.6	46.4	ND	3	39.2
4,4'-DDE	72-55-9	2.4	1.7	46.4	5.1	1.4	39.2
4,4'-DDT	50-29-3	ND	2.6	46.4	ND	2.2	39.2
Aldrin	309-00-2	ND	1.6	46.4	ND	1.3	39.2
Chlordane (technical)	57-74-9	ND	433	464	ND	366	392
Dieldrin	60-57-1	ND	1.1	46.4	ND	0.92	39.2
Endosulfan I	959-98-8	ND	0.68	46.4	ND	0.58	39.2

Table 11. Organic compound concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

NWIS site No.		443416117084000					
NWIS site name		**Site 8a**			**Site 8b**		
Sample date and time		**05-08-12 0900**			**05-08-12 0915**		
Compound	**CASRN**	**Detection (µg/kg)**	**MDL (µg/kg)**	**RL (µg/kg)**	**Detection (µg/kg)**	**MDL (µg/kg)**	**RL (µg/kg)**
Organochlorine pesticides—EPA 8081							
Endosulfan II	33213-65-9	ND	1.6	46.4	ND	1.3	39.2
Endosulfan sulfate	1031-07-8	ND	1.2	46.4	ND	0.99	39.2
Endrin	72-20-8	ND	1.4	46.4	ND	1.2	39.2
Endrin aldehyde	7421-93-4	ND	1.8	46.4	ND	1.5	39.2
Endrin ketone	53494-70-5	ND	2.2	46.4	ND	1.8	39.2
Heptachlor	76-44-8	ND	1.1	46.4	ND	0.9	39.2
Heptachlor epoxide	1024-57-3	ND	3	46.4	ND	2.6	39.2
Methoxychlor	72-43-5	ND	28.6	46.4	ND	24.2	39.2
Toxaphene	8001-35-2	ND	200	464	ND	170	392
alpha-BHC	319-84-6	ND	1.9	46.4	ND	1.6	39.2
beta-BHC	319-85-7	ND	2.1	46.4	ND	1.8	39.2
delta-BHC	319-86-8	ND	2.4	46.4	ND	2	39.2
gamma-BHC (lidane)	58-89-9	ND	4	46.4	ND	3.4	39.2
PCBs—EPA 8082							
PCB-1016 (Aroclor 1016)	12674-11-2	–	–	–	–	–	–
PCB-1221 (Aroclor 1221)	11104-28-2	–	–	–	–	–	–
PCB-1232 (Aroclor 1232)	11141-16-5	–	–	–	–	–	–
PCB-1242 (Aroclor 1242)	53469-21-9	–	–	–	–	–	–
PCB-1248 (Aroclor 1248)	12672-29-6	–	–	–	–	–	–
PCB-1254 (Aroclor 1254)	11097-69-1	–	–	–	–	–	–
PCB-1260 (Aroclor 1260)	11096-82-5	–	–	–	–	–	–
PCB-1262 (Aroclor 1262)	37324-23-5	–	–	–	–	–	–
PCB-1268 (Aroclor 1268)	11100-14-4	–	–	–	–	–	–
Chlorinated herbicides—EPA 8151							
2,4,5-T	93-76-5	–	–	–	–	–	–
2,4,5-TP (Silvex)	93-72-1	–	–	–	–	–	–
2,4-D	94-75-7	–	–	–	–	–	–
2,4-DB	94-82-6	–	–	–	–	–	–
Bentazon	25057-89-0	–	–	–	–	–	–
Dalapon	75-99-0	–	–	–	–	–	–
Dicamba	1918-00-9	–	–	–	–	–	–
Dichlorprop	120-36-5	–	–	–	–	–	–
Dinoseb	88-85-7	–	–	–	–	–	–
Pentachlorophenol	[3]87-86-5	–	–	–	–	–	–
Picloram	1918-02-1	–	–	–	–	–	–
Dioxin (2,3,7,8-TCDD)—EPA 1613							
2,3,7,8-TCDD	1746-01-6	ND	–	1	ND	–	1

[1] Analytical Method: EPA 8270 Preparation Method: EPA 3550.

[2] Analytical Method: EPA 8270 by SIM Preparation Method: EPA 3550.

[3] Analytical Method: EPA 8151.

Table 12. Pesticide and herbicide concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.

[Samples analyzed at Agriculture Laboratory according to laboratory methodologies listed in table 2. **NWIS site name**: Top subsample designated “a” (0–30 cm), and a bottom subsample designated “b” (30–75 cm). **CASRN**: Chemical Abstracts Service (CAS) Registry Number®, a registered trademark of the American Chemical Society
CAS Client Services℠. **Abbreviations:** NWIS, National Water Information System; HPLC-FLD, High Performance Liquid Chromatography with Postcolumn Fluorescence Derivatization, GC-ECD, Gas Chromatograph-Electron Capture Detector; GC-FPD, Gas Chromatography with Flame Photometric Detection; GC-MS, Gas Chromatograph(y)-Mass Spectrometry; SIM, Selected Ion Monitoring; EPA, U.S. Environmental Protection Agency; HPLC-MS, High-Performance Liquid Chromatography with Mass Spectrometry; cm, centimeter; µg/kg, microgram per kilogram; ND, not detected]

NWIS site No.			444954116542400		444455117021200		443416117084000	
NWIS site name			Site 1a	Site 1b	Site 5a	Site 5b	Site 8a	Site 8b
Sample date / time			05-07-12 14:00	05-07-12 14:15	05-09-12 0900	05-09-12 0915	05-08-12 0900	05-08-12 0915
Parameter	CASRN	Reporting level (µg/kg)	Pesticide and herbicide concentration (µg/kg)					
Halogenated pesticides—EPA 8081B (GC-ECD)								
Acetochlor	34256-82-1	0.2	ND	ND	ND	ND	ND	ND
Alachlor	15972-60-8	0.2	ND	ND	ND	ND	ND	ND
Aldrin	309-00-2	0.08	ND	ND	ND	ND	ND	ND
	1861-40-1	0.08	ND	ND	ND	ND	ND	ND
Bifenthrin	82657-04-3	0.08	ND	ND	ND	ND	ND	ND
α-BHC	319-84-6	0.08	ND	ND	ND	ND	ND	ND
β-BHC	319-85-7	0.08	ND	ND	ND	ND	ND	ND
δ-BHC	319-86-8	0.08	ND	ND	ND	ND	ND	ND
γ-BHC (Lindane)	58-89-9	0.08	ND	ND	ND	ND	ND	ND
Captafol	2425-06-1	0.08	ND	ND	ND	ND	ND	ND
Captan	133-06-2	0.2	ND	ND	ND	ND	ND	ND
Chlordane	57-74-9	0.39	ND	ND	ND	ND	ND	ND
Chlorobenzilate	510-15-6	0.2	ND	ND	ND	ND	ND	ND
Chloroneb	2675-77-6	0.2	ND	ND	ND	ND	ND	ND
Chlorothalonil	1897-45-6	0.08	ND	ND	ND	ND	ND	ND
	68359-37-5	0.39	ND	ND	ND	ND	ND	ND
Cyhalothrin	68085-85-8	0.39	ND	ND	ND	ND	ND	ND
Cypermethrin	52315-07-8	0.39	ND	ND	ND	ND	ND	ND
p,p’-DDD	72-54-8	0.08	ND	ND	ND	ND	ND	ND
p,p’-DDE	72-55-9	0.027	ND	ND	ND	0.03	ND	ND
p,p’-DDT	50-29-3	0.08	ND	ND	ND	ND	ND	ND
Dacthal (DCPA)	1861-32-1	0.08	ND	ND	ND	ND	ND	ND
Deltamethrin	52918-63-5	0.39	ND	ND	ND	ND	ND	ND
Dichlobenil	1194-65-6	0.08	ND	ND	ND	ND	ND	ND
Dicloran	99-30-9	0.08	ND	ND	ND	ND	ND	ND
Dicofol	115-32-2	0.2	ND	ND	ND	ND	ND	ND
Dieldrin	60-57-1	0.08	ND	ND	ND	ND	ND	ND
Dithiopyr	97886-45-8	0.08	ND	ND	ND	ND	ND	ND
Endosulfan I	959-98-8	0.08	ND	ND	ND	ND	ND	ND
Endosulfan II	33213-65-9	0.08	ND	ND	ND	ND	ND	ND
Endosulfan sulfate	1031-07-8	0.08	ND	ND	ND	ND	ND	ND
Endrin	72-20-8	0.08	ND	ND	ND	ND	ND	ND
Endrin aldehyde	7421-93-4	0.08	ND	ND	ND	ND	ND	ND

Table 12. Pesticide and herbicide concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

NWIS site No.			444954116542400		444455117021200		443416117084000	
NWIS site name			Site 1a	Site 1b	Site 5a	Site 5b	Site 8a	Site 8b
Sample date / time			05-07-12 14:00	05-07-12 14:15	05-09-12 0900	05-09-12 0915	05-08-12 0900	05-08-12 0915
Parameter	CASRN	Reporting level (µg/kg)	Pesticide and herbicide concentration (µg/kg)					
Halogenated pesticides—EPA 8081B (GC-ECD)—Continued								
Endrin ketone	53494-70-5	0.08	ND	ND	ND	ND	ND	ND
Esfenvalerate	66230-04-4	0.08	ND	ND	ND	ND	ND	ND
	55283-68-6	0.08	ND	ND	ND	ND	ND	ND
Etridiazole	2593-15-9	0.08	ND	ND	ND	ND	ND	ND
Fenarimol	60168-88-9	0.08	ND	ND	ND	ND	ND	ND
Fenvalerate	51630-58-1	0.08	ND	ND	ND	ND	ND	ND
Flutolanil	66332-96-5	0.8	ND	ND	ND	ND	ND	ND
Folpet	133-07-3	0.2	ND	ND	ND	ND	ND	ND
Heptachlor	76-44-8	0.08	ND	ND	ND	ND	ND	ND
Heptachlor epoxide	1024-57-3	0.08	ND	ND	ND	ND	ND	ND
Hexachlorobenzene	118-74-1	0.08	ND	ND	ND	ND	ND	ND
Iprodione	36734-19-7	0.08	ND	ND	ND	ND	ND	ND
Methoxychlor	72-43-5	0.08	ND	ND	ND	ND	ND	ND
Metolachlor	51218-45-2	0.2	ND	ND	ND	ND	ND	ND
Mirex	2385-85-5	0.08	ND	ND	ND	ND	ND	ND
	27314-13-2	0.08	ND	ND	ND	ND	ND	ND
Ovex	80-33-1	0.08	ND	ND	ND	ND	ND	ND
Oxadiazon	19666-30-9	0.08	ND	ND	ND	ND	ND	ND
	42874-03-3	0.08	ND	ND	ND	ND	ND	ND
Pentachloronitrobenzene (PCNB)	82-68-8	0.08	ND	ND	ND	ND	ND	ND
Permethrin	52645-53-1	0.39	ND	ND	ND	ND	ND	ND
Prodiamine	29091-21-2	0.08	ND	ND	ND	ND	ND	ND
Pronamide	23950-58-5	0.08	ND	ND	ND	ND	ND	ND
Propachlor	1918-16-7	0.20	ND	ND	ND	ND	ND	ND
Propanil	709-98-8	0.08	ND	ND	ND	ND	ND	ND
Propiconazole	60207-90-1	0.2	ND	ND	ND	ND	ND	ND
Terbacil	5902-51-2	0.08	ND	ND	ND	ND	ND	ND
T	141517-21-7	0.08	ND	ND	ND	ND	ND	ND
T	68694-11-1	0.08	ND	ND	ND	ND	ND	ND
T	1582-09-8	0.08	ND	ND	ND	ND	ND	ND
Vinclozalin	50471-44-8	0.08	ND	ND	ND	ND	ND	ND
Organophosphorous and organosulfur pesticides—EPA 8141B (GC-FPD)								
Aspon	3244-90-4	0.01	ND	ND	ND	ND	ND	ND
Azinphos-methyl	86-50-0	0.01	ND	ND	ND	ND	ND	ND
Carbofenothion	786-19-6	0.01	ND	ND	ND	ND	ND	ND
Chlorfenvinphos	470-90-6	0.01	ND	ND	ND	ND	ND	ND

Table 12. Pesticide and herbicide concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

NWIS site No.			444954116542400		444455117021200		443416117084000	
NWIS site name			Site 1a	Site 1b	Site 5a	Site 5b	Site 8a	Site 8b
Sample date / time			05-07-12 14:00	05-07-12 14:15	05-09-12 0900	05-09-12 0915	05-08-12 0900	05-08-12 0915
Parameter	CASRN	Reporting level (µg/kg)	Pesticide and herbicide concentration (µg/kg)					
Organophosphorous and organosulfur pesticides—EPA 8141B (GC-FPD)—Continued								
Chlorpyrifos	2921-88-2	0.08	ND	ND	ND	ND	ND	ND
Chlorpyrifos-methyl	5598-13-0	0.01	ND	ND	ND	ND	ND	ND
Coumaphos	56-72-4	0.01	ND	ND	ND	ND	ND	ND
Demeton	8065-48-3	0.01	ND	ND	ND	ND	ND	ND
Diazinon	333-41-5	0.01	ND	ND	ND	ND	ND	ND
Dichlorofenthion	97-17-6	0.01	ND	ND	ND	ND	ND	ND
Dichlorvos	62-73-7	0.01	ND	ND	ND	ND	ND	ND
Dicrotophos	141-66-2	0.01	ND	ND	ND	ND	ND	ND
Dimethoate	60-51-5	0.01	ND	ND	ND	ND	ND	ND
Disulfoton	298-04-4	0.01	ND	ND	ND	ND	ND	ND
EPN	2104-64-5	0.01	ND	ND	ND	ND	ND	ND
Ethion	563-12-2	0.01	ND	ND	ND	ND	ND	ND
Ethoprop	13194-48-4	0.01	ND	ND	ND	ND	ND	ND
Famphur	52-85-7	0.01	ND	ND	ND	ND	ND	ND
Fenamiphos	22224-92-6	0.01	ND	ND	ND	ND	ND	ND
Fenitrothion	122-14-5	0.01	ND	ND	ND	ND	ND	ND
Fensulfothion	115-90-2	0.01	ND	ND	ND	ND	ND	ND
Fenthion	55-38-9	0.01	ND	ND	ND	ND	ND	ND
Malathion	121-75-5	0.01	ND	ND	ND	ND	ND	ND
Methidathion	950-37-8	0.01	ND	ND	ND	ND	ND	ND
Merphos	150-50-5	0.01	ND	ND	ND	ND	ND	ND
Mevinphos	7786-34-7	0.01	ND	ND	ND	ND	ND	ND
Monocrotophos	6923-22-4	0.01	ND	ND	ND	ND	ND	ND
Parathion	56-38-2	0.01	ND	ND	ND	ND	ND	ND
Parathion-methyl	298-00-0	0.01	ND	ND	ND	ND	ND	ND
Phorate	298-02-2	0.01	ND	ND	ND	ND	ND	ND
Phosmet	732-11-6	0.01	ND	ND	ND	ND	ND	ND
Phosphamidon	13171-21-6	0.01	ND	ND	ND	ND	ND	ND
Pirimiphos-methyl	29232-93-7	0.01	ND	ND	ND	ND	ND	ND
Propargite	2312-35-8	0.098	ND	ND	ND	ND	ND	ND
Ronnel	299-84-3	0.01	ND	ND	ND	ND	ND	ND
Sulprofos	35400-43-2	0.01	ND	ND	ND	ND	ND	ND
Terbufos	13071-79-9	0.01	ND	ND	ND	ND	ND	ND
Tetrachlorvinphos	22248-79-9	0.01	ND	ND	ND	ND	ND	ND
Tokuthion	34643-46-4	0.01	ND	ND	ND	ND	ND	ND
Tricloronate	327-98-0	0.01	ND	ND	ND	ND	ND	ND

Table 12. Pesticide and herbicide concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

NWIS site No.			444954116542400		444455117021200		443416117084000	
NWIS site name			Site 1a	Site 1b	Site 5a	Site 5b	Site 8a	Site 8b
Sample date / time			05-07-12 14:00	05-07-12 14:15	05-09-12 0900	05-09-12 0915	05-08-12 0900	05-08-12 0915
Parameter	CASRN	Reporting level (µg/kg)	Pesticide and herbicide concentration (µg/kg)					
Organonitrogen pesticides—EPA 8270D (GC-MS, SIM mode)								
Amitraz	33089-61-1	0.098	ND	ND	ND	ND	ND	ND
Ametryn	834-12-8	0.051	ND	ND	ND	ND	ND	ND
Atrazine	1912-24-9	0.051	ND	ND	ND	ND	ND	ND
Azoxystrobin	131860-33-8	0.02	ND	ND	ND	ND	ND	ND
Bensulide	741-58-2	0.02	ND	ND	ND	ND	ND	ND
Boscalid	188425-85-6	0.02	ND	ND	ND	ND	ND	ND
Bromacil	314-40-9	0.02	ND	ND	ND	ND	ND	ND
Bromopropylate	18181-80-1	0.098	ND	ND	ND	ND	ND	ND
Carfentrazone-ethyl	128639-02-1	0.02	ND	ND	ND	ND	ND	ND
Clothianidin	210880-92-5	0.02	ND	ND	ND	ND	ND	ND
Cyanazine	11096-88-1	0.098	ND	ND	ND	ND	ND	ND
Diclofop-methyl	51338-27-3	0.098	ND	ND	ND	ND	ND	ND
Dimethenamid	87674-68-8	0.051	ND	ND	ND	ND	ND	ND
Diphenylamine	122-39-4	0.02	ND	ND	ND	ND	ND	ND
Ethofumesate	26225-79-6	0.051	ND	ND	ND	ND	ND	ND
Fenbuconazole	114369-43-6	0.098	ND	ND	ND	ND	ND	ND
Fenoxaprop-ethyl	82110-72-3	0.098	ND	ND	ND	ND	ND	ND
Fipronil	120068-37-3	0.098	ND	ND	ND	ND	ND	ND
Fluazifop-P-butyl	69806-50-4	0.098	ND	ND	ND	ND	ND	ND
Fludioxonil	131341-86-1	0.098	ND	ND	ND	ND	ND	ND
Flumioxazin	103361-09-7	0.02	ND	ND	ND	ND	ND	ND
Fluometuron	2164-17-2	0.02	ND	ND	ND	ND	ND	ND
Fluroxypyr-meptyl	81406-37-3	0.051	ND	ND	ND	ND	ND	ND
Hexazinone	51235-04-2	0.051	ND	ND	ND	ND	ND	ND
Imidacloprid	138261-41-3	0.02	ND	ND	ND	ND	ND	ND
Isoxaben	82558-50-7	0.02	ND	ND	ND	ND	ND	ND
Mefenoxam	70630-17-0	0.051	ND	ND	ND	ND	ND	ND
Metalaxyl	57837-19-1	0.051	ND	ND	ND	ND	ND	ND
Metribuzin	21087-64-9	0.098	ND	ND	ND	ND	ND	ND
Myclobutanil	88671-89-0	0.098	ND	ND	ND	ND	ND	ND
Napropamide	15299-99-7	0.098	ND	ND	ND	ND	ND	ND
Pendimethalin	40487-42-1	0.08	ND	ND	ND	ND	ND	ND
Pirimicarb	23103-98-2	0.051	ND	ND	ND	ND	ND	ND
Prometon	1610-18-0	0.098	ND	ND	ND	ND	ND	ND
Prometryn	7287-19-6	0.051	ND	ND	ND	ND	ND	ND
Propazine	139-40-2	0.051	ND	ND	ND	ND	ND	ND
Pyraclostrobin	175013-18-0	0.02	ND	ND	ND	ND	ND	ND

Table 12. Pesticide and herbicide concentrations in bed-sediment core samples collected from selected sites at Brownlee Reservoir near Oxbow, Oregon, May 7–9, 2012.—Continued

NWIS site No.			**444954116542400**		**444455117021200**		**443416117084000**	
NWIS site name			**Site 1a**	**Site 1b**	**Site 5a**	**Site 5b**	**Site 8a**	**Site 8b**
Sample date / time			**05-07-12 14:00**	**05-07-12 14:15**	**05-09-12 0900**	**05-09-12 0915**	**05-08-12 0900**	**05-08-12 0915**
Parameter	**CASRN**	**Reporting level (µg/kg)**	**Pesticide and herbicide concentration (µg/kg)**					
Organonitrogen pesticides—EPA 8270D (GC-MS, SIM mode)—Continued								
Pyridaben	96489-71-3	0.098	ND	ND	ND	ND	ND	ND
Pyrimethanil	53112-28-0	0.02	ND	ND	ND	ND	ND	ND
Sethoxydim	74051-80-2	0.51	ND	ND	ND	ND	ND	ND
Simazine	122-34-9	0.098	ND	ND	ND	ND	ND	ND
Simetryn	1014-70-6	0.051	ND	ND	ND	ND	ND	ND
Sulfentrazone	122836-35-5	0.02	ND	ND	ND	ND	ND	ND
Tebuconazole	107534-96-3	0.098	ND	ND	ND	ND	ND	ND
Tebuthiuron	34014-18-1	0.098	ND	ND	ND	ND	ND	ND
Thiabendazole	148-79-8	0.02	ND	ND	ND	ND	ND	ND
Triadimefon	43121-43-3	0.098	ND	ND	ND	ND	ND	ND
Phenylurea herbicides—EPA 8321B (HPLC-MS)								
Diuron	330-54-1	0.02	ND	ND	ND	ND	ND	ND
DCPMU	3567-62-2	0.02	ND	ND	ND	ND	ND	ND
Fenuron	101-42-8	0.02	ND	ND	ND	ND	ND	ND
Linuron	330-55-2	0.02	ND	ND	ND	ND	ND	ND
Monuron	150-68-5	0.02	ND	ND	ND	ND	ND	ND
Neburon	555-37-3	0.02	ND	ND	ND	ND	ND	ND
Siduron	1982-49-6	0.02	ND	ND	ND	ND	ND	ND
Carbamate pesticides—EPA 8321B (HPLC-MS)								
3-Hydroxycarbofuran	16655-82-6	0.02	ND	ND	ND	ND	ND	ND
Aldicarb	116-06-3	0.02	ND	ND	ND	ND	ND	ND
Aldicarb sulfone	1646-88-4	0.02	ND	ND	ND	ND	ND	ND
Aldicarb sulfoxide	1646-87-3	0.02	ND	ND	ND	ND	ND	ND
Bendiocarb	22781-23-3	0.02	ND	ND	ND	ND	ND	ND
Carbaryl	63-25-2	0.02	ND	ND	ND	ND	ND	ND
Carbofuran	1563-66-2	0.02	ND	ND	ND	ND	ND	ND
	35367-38-5	0.02	ND	ND	ND	ND	ND	ND
Fenobucarb	3766-81-2	0.02	ND	ND	ND	ND	ND	ND
Methiocarb	2032-65-7	0.02	ND	ND	ND	ND	ND	ND
Methomyl	16752-77-5	0.02	ND	ND	ND	ND	ND	ND
Oxamyl	23135-22-0	0.02	ND	ND	ND	ND	ND	ND
Propoxur	114-26-1	0.02	ND	ND	ND	ND	ND	ND
Thiobencarb	28249-77-6	0.02	ND	ND	ND	ND	ND	ND

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Exhibit 6.6-3

June 2013 Hells Canyon Complex (HCC) mercury data assessment, draft technical memorandum

HELLS CANYON COMPLEX MERCURY DATA ASSESSMENT

DRAFT TECHNICAL MEMORANDUM

Prepared for Idaho Power

Prepared by:

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Reed Harris Environmental Ltd.

June 2013

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1. Introduction

Idaho Power Company (IPC) owns three hydroelectric facilities collectively known as the Hells Canyon Complex (HCC) on the Snake River along the Idaho–Oregon border (Figure 1-1, Figure 1-2). These facilities resulted in the creation of Brownlee, Oxbow, and Hells Canyon Reservoirs, together spanning approximately 90 miles of the Snake River. IPC primarily uses reservoir storage in the HCC for hydropower generation and downstream flood control (Myers *et al.*, 2003), but also acknowledges other uses including recreation, flow attenuation, and flow augmentation for anadromous fish in the Snake and Columbia Rivers.

Mercury (Hg) contamination in HCC needs to be evaluated in connection with two regulatory frameworks: (1) protecting federally listed species under the Endangered Species Act (ESA) and (2) complying with water quality standards and antidegradation under the Clean Water Act. In 2003, IPC filed an application with the Federal Energy Regulatory Commission (FERC) for a new license for the Hells Canyon Complex. The existing license expired in 2005, and the project has since operated under an annual license (FERC, 2007; Idaho Power, 2012; Randolph, 2013). One of the issues being examined as part of FERC relicensing is modifying temperature regimes downstream of HCC in order to comply with the water quality standards of Oregon and Idaho for salmonid spawning. Cold-water pumping from deep waters in Brownlee Reservoir at selected times is being evaluated as a potential measure to modify downstream temperature regimes. These deep waters have recently been identified as having elevated methylmercury (MeHg) concentrations at some times of the year (Harrison *et al.*, 2012; Krabbenhoft, 2012). As a result, the potential exists for increased downstream exposure to MeHg if deep-water pumping is carried out. It may also be possible to release cold water from Hells Canyon Reservoir on some occasions. It is therefore important to understand whether pumping additional cold water from either Brownlee or Hells Canyon Reservoirs would increase fish MeHg concentrations downstream. In addition, the identification of elevated levels of MeHg in the deeper waters of Brownlee Reservoir has raised concerns from both the US Fish and Wildlife Service and the National Marine Fisheries Service regarding any actions that may affect MeHg dynamics related to critical habitat designations for ESA-listed species such as bull trout and fall Chinook salmon.

Brownlee and Hells Canyon Reservoirs are both on the Clean Water Act 303(d) list as impaired for Hg and have fish consumption advisories. Any activity that increases Hg levels in fish in these reservoirs would likely violate water quality standards of both Oregon and Idaho. Antidegradation is also a requirement of the Clean Water Act that mandates the protection of the existing uses of surface waters and the additional protection of high quality waters from degradation that is not found to be necessary and important. Antidegradation is concerned with an increase in discharge of a pollutant, and it is triggered by the 401 certification of the FERC license. Because an increase of pollutants in discharge from either Brownlee or Hells Canyon Reservoirs could violate the Clean Water Act, it is necessary to evaluate the discharge of each alternative for potential increased pollutants.

In connection with the above issues, this technical memorandum describes existing data identified for Hg concentrations in water, sediments and fish in the following areas:

- Hells Canyon Complex (Brownlee, Oxbow and Hells Canyon Reservoirs);
- Downstream of HCC to the confluence of the Snake and Clearwater Rivers (River Mile 108);
- Upstream of HCC in the Snake River as far as Palisades Reservoir (River Mile 917); and
- Regional or national background values.

Mercury wet deposition data are also presented for three sites operated in Idaho from 2007-2010 as part of the Mercury Deposition Network (MDN) (NADP, 2013).

Finally, comments are provided on the adequacy of existing Hg data to:

- Define baseline concentrations, spatial or temporal trends in fish in Hells Canyon Complex and upstream/downstream in the Snake River; and
- Determine whether fish Hg concentrations in Hells Canyon Complex are elevated compared to upstream in the Snake River or regional background levels.

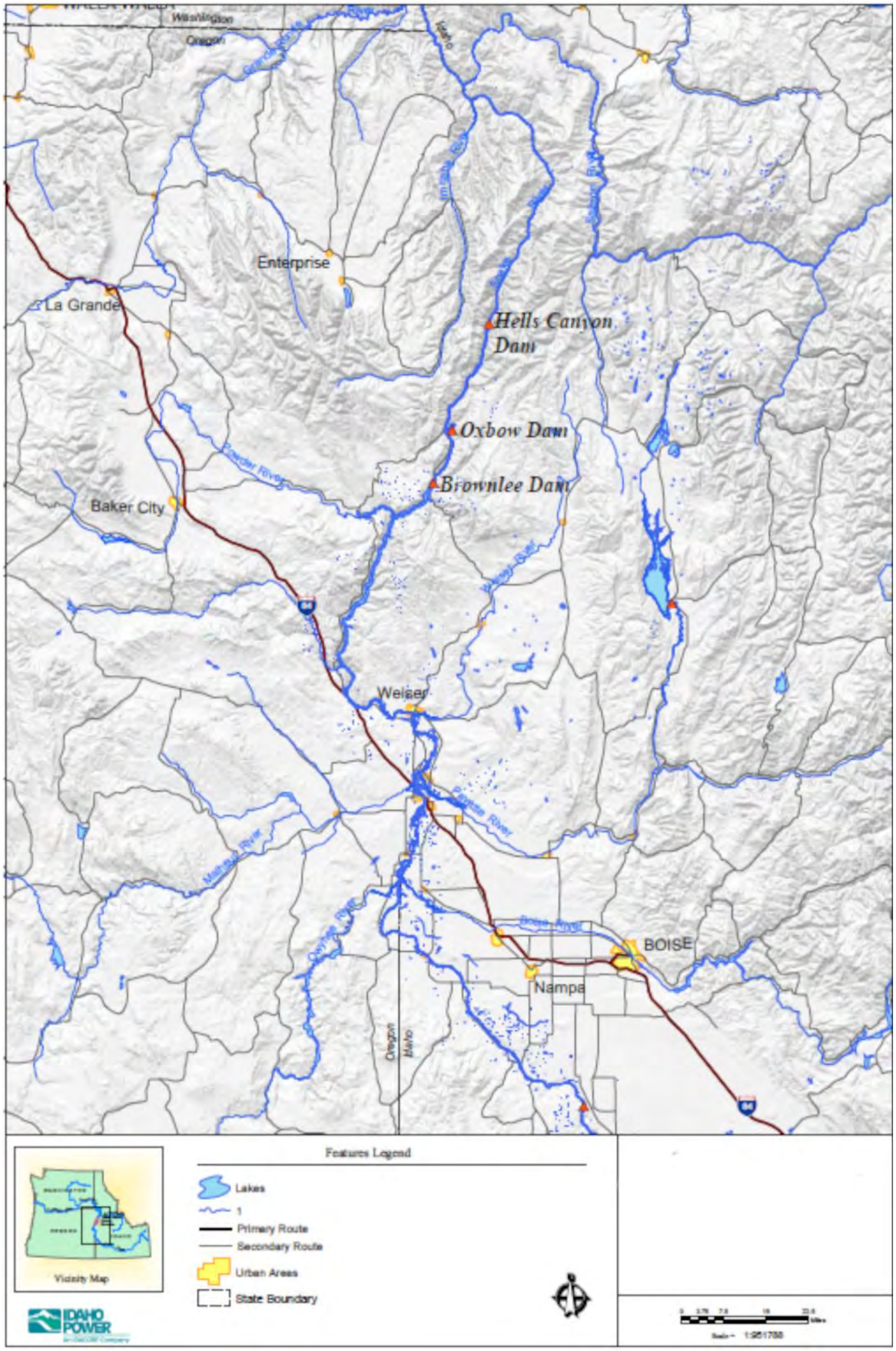


Figure 1-1. Map of Hells Canyon Complex on the Snake River. Adapted from Myers *et al.* (2003).

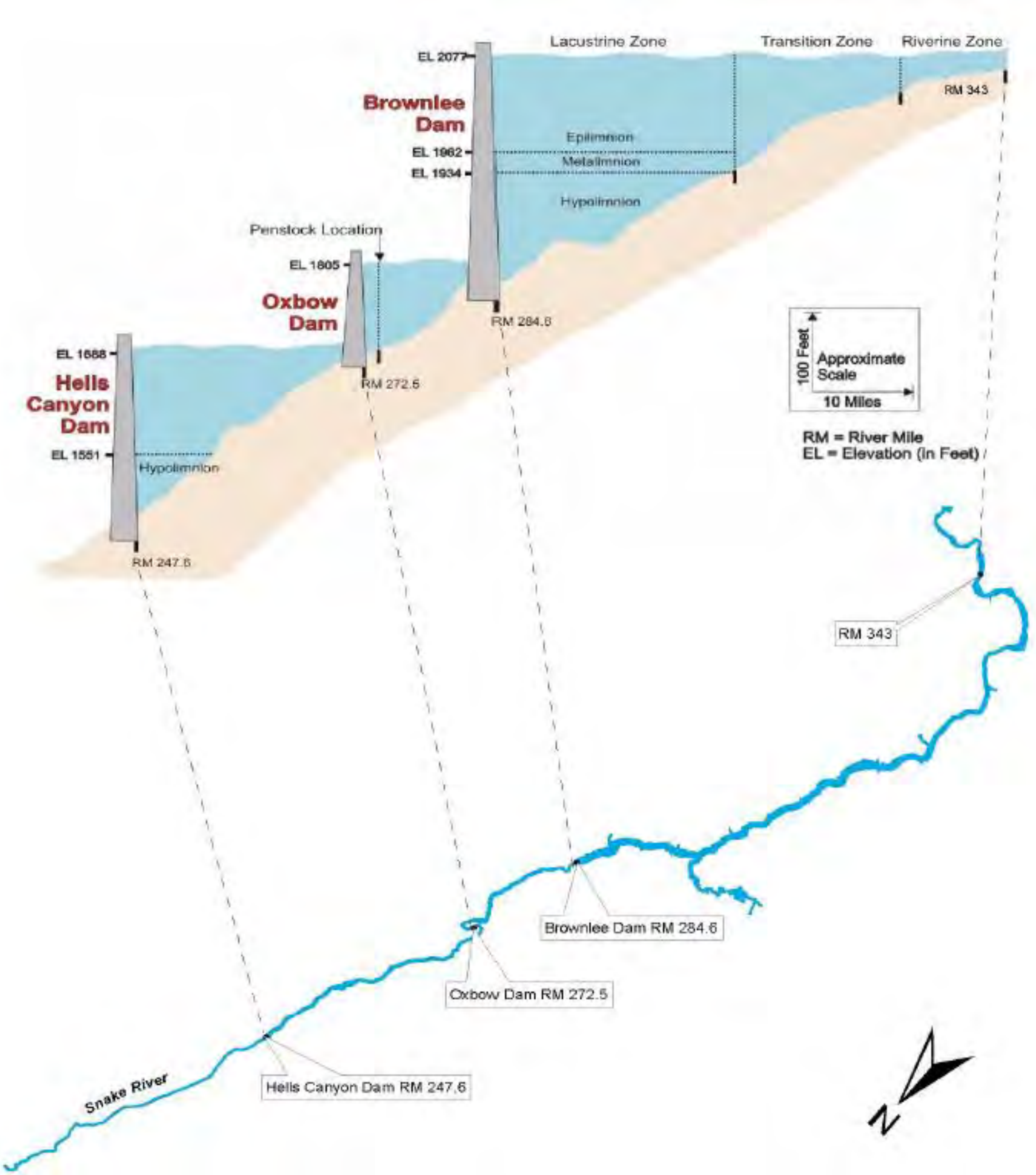


Figure 1-2. Cross sectional view of Hells Canyon Complex. From Myers *et al.* (2003). RM = River Mile, where RM 0 is the river mouth at the junction with the Columbia River.

2. Fish Mercury Concentrations

Fish Hg concentrations were obtained for the Snake River as far upstream as Palisades Reservoir (River Mile 917) and downstream to the confluence of the Snake and Clearwater Rivers (River Mile 108) near Lewiston, Idaho and Clarkston, Washington. For reference, the River Mile (RM) is zero at the junction with the Columbia River, and increases upstream. Brownlee Dam is located at RM 285 and the upstream end of Brownlee Reservoir is in the vicinity of RM 343 (Myers *et al.*, 2003). The Clearwater River confluence was chosen as the downstream limit because it is a major tributary which may influence Hg in biota downstream in the Snake River. The Salmon River is another tributary to the Snake River downstream of Hells Canyon Complex, at RM 188. The effect of the Salmon River on fish Hg concentrations in the Snake River was assumed to be small, given that the mean annual flow in the Salmon River is approximately 20% of the Snake River flow. This estimate was derived using a Snake River flow of 55,500 cfs (40 year average, 1910-16, 1963-90, 1996-2000; USGS, 2000) and a Salmon River flow of 11,060 cfs for water year 2005 (USGS, 2005).

The primary sources of information for fish Hg concentrations were datasets originally provided to Idaho Power Company from the USEPA (Rueda, 2013). These data were supplemented with measurements from an EPA Region 10 Assessment of fish Hg levels in Northeastern Oregon (Herget and Edmond, 2012), Idaha Department of Environmental Quality (IDEQ) assessments of fish Hg levels in Idaho lakes and reservoirs (Essig and Kosterman, 2008), and IDEQ sampling carried out in connection with the Brownlee Reservoir Hg TMDL (Stone, 2008).

Fish Hg data were identified for 24 fish species sampled between 1969 and 2011 (Table 2-1). In most cases, the number of fish collected for a specific location and date was less than 5 individuals. Since the year 2000, no fish sampling in HCC or downstream was identified with 5 or more analyses. Upstream, only two species (rainbow trout and smallmouth bass) were sampled at a given location and time with more than 5 individuals (in 2001). Because fish Hg concentrations depend partly on species and length, it is important to have sufficient individuals for each species to establish a fish Hg concentration for a standard size or age (Wiener *et al.*, 2007). Otherwise, meaningful comparisons cannot be made among locations or years. Typically, it is advisable to obtain 24-36 individuals over a range of sizes to establish a reliable estimate for Hg in a standard size adult fish. Fewer individuals may be needed if targeting a specific age class (e.g. young of the year). Composite samples are not suited to this approach because they do not provide a specific combination of Hg concentration and fish size. Based on these requirements, existing fish Hg data for HCC and downstream to the Clearwater River are insufficient to establish current baseline conditions using data available in the past decade. Several fish Hg datasets in HCC included 10 or more fish in the 1990s, but the use of data more than a decade old introduces uncertainty whether the information represents current conditions.

Table 2-1. Summary of fish Hg data in Hells Canyon Complex and the Snake River. Datasets are listed according to the year that fish were sampled. Datasets consisting of five or more discrete samples including lengths are shown in blue, and ten or more are shown in green. The downstream reach extends from Hells Canyon Dam to the confluence of the Snake and Clearwater Rivers near Lewiston, ID and Clarkston, WA. The upstream reach consists of the Snake River above Brownlee Reservoir. Data from Rueda (2013), Essig and Kosterman (2008), Herger and Edmond (2012) and Stone (2006).

Species	**Upstream**	**Hells Canyon**	**Oxbow**	**Brownlee**	**Downstream**
Black bullhead	1970[1], 1974				
Black crappie				1994, 1995, 2007, 2011	1973
Bluegill				1970, 2011	
Brown trout	1971				
Channel catfish	1969, 1970, 1971, 1975, 1989, 1990, 1997, 2004, 2006	2007		1969, 1970, 1975, 1990, 1994, 1995, 1997, 2007	1970
Chiselmouth chub					1970
Coho salmon	1971	1971			
Common carp	1971[2], 1978[2], 1990, 1997, 2008	2007		1970, 1990, 1994[2], 1997	1970[2], 1971, 1972, 1973, 1997
Cutthroat trout	1971, 2000, 2004				
Largemouth bass				1970	
Largemouth bass	1997			1970	
Largescale sucker	1969, 1970, 1970[3], 1971, 1971[3], 1972, 1973, 1978, 1980, 1984, 1986, 1996, 1997, 2006[3], 2008	1978		1970[3], 2000, 1997	1969, 1970[3], 1970, 1972, 1973, 1976, 1978, 1980, 1984, 1986, 1997
Mirron carp	2004				
Mountain whitefish	1970[4], 1971[4], 1986, 1988, 1990, 2004, 2005, 2006				
Northern pikeminnow	1969, 1970, 1971, 1972, 1973			1970	1969, 1970, 1971, 1972, 1976, 1984, 1986
Peachmouth chub	1971, 1972				
Rainbow trout	1969, 1970, 1971, 1973, 1974, 1978, 1980, 1984, 1986, 2001, 2004, 2007	1978, 1981		1994	
Shiner					1970

Species	Upstream	Hells Canyon	Oxbow	Brownlee	Downstream
Smallmouth bass	1989, 1990, 1997, 2001, 2004, 2007, 2008	2007		1970, 1975 1989, 1994, 1995, 1997, 2000, 2006, 2011	1969, 1970, 1971, 1975, 1978, 1997
Steelhead salmon		1997			
Utah chub	1970, 1971, 1974, 1986, 2004				
Utah sucker	1986, 1988, 1992, 1993, 1996, 2000, 2004,	1981			
White crappie	1970[5], 1971[5]			1990[5], 1994, 1995[5], 1997, 2011	1980
Yellow perch	1970[6], 1971[6], 1972[6], 1974, 1986, 1997, 2007			1994, 1995	

[1] Dataset labelled “bullhead”, assumed to be black bullhead
[2] Dataset labelled “carp”, assumed to be common carp
[3] Dataset labelled “sucker”, assumed to be largescale sucker
[4] Dataset labelled “whitefish”, assumed to be mountain whitefish
[5] Dataset labelled “crappie”, assumed to be white crappie
[6] Dataset labelled “perch”, assumed to be yellow perch

Additional descriptions of the fish Hg data upstream, within HCC and downstream are provided in the remainder of this section of the memorandum.

2.1. Fish Hg Data Upstream of Hells Canyon Complex

Fish Hg concentration data were obtained upstream of HCC as far as River Mile 917. A total of 411 Hg analyses were identified for approximately 20 fish species (some samples did not indicate specific species) sampled between 1969 and 2008 (Figure 2-1). Most samples were individual fish (71%) but some were composites. There was also a mixture of whole body and muscle tissue analyses. Because muscle Hg concentrations tend to be higher than whole body concentrations in fish (Wiener *et al.* 2007), the two types of data were not directly comparable. All fish Hg observations upstream of HCC were less than 1 µg g^{-1} wet weight. Also shown in Figure 2-1 are the US EPA methylmercury (MeHg) criterion for fish tissue (0.3 µg g^{-1} wet weight; USEPA, 2001) and the Oregon human health MeHg criterion of 0.04 µg g^{-1} wet weight (USEPA, 2011). Plots of upstream fish Hg concentrations for selected fish species (all years with data) are shown in Figure 2-2. Far fewer measurements of fish Hg concentrations upstream of HCC were available after 2000 (n=82 analyses for 11 species, Figure 2-3). Upstream fish Hg datasets with 10 or more individuals included perch (sampled in 1971 and 1972), rainbow trout (2001) and smallmouth bass (2001).

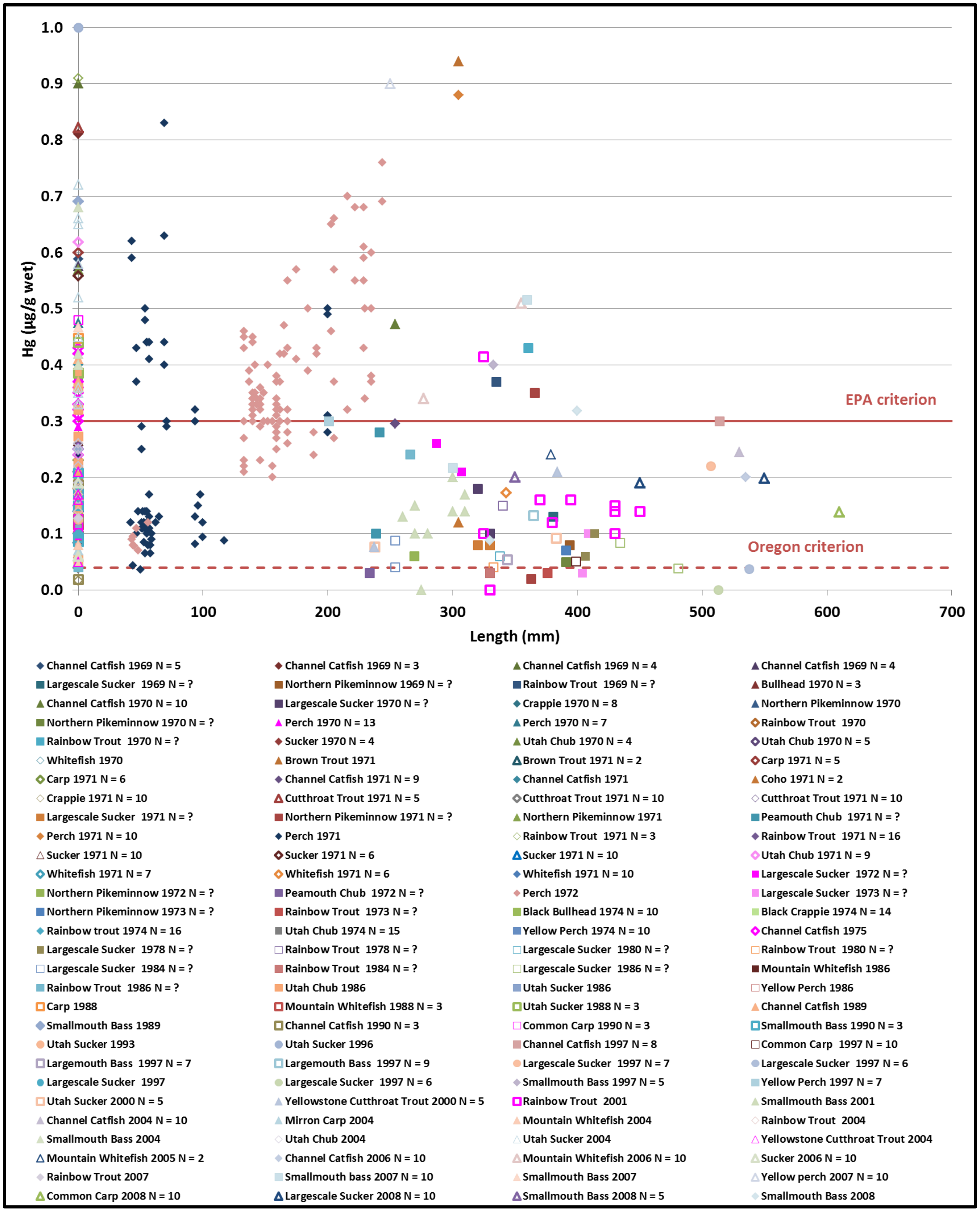


Figure 2-1. Fish Hg concentrations upstream of Hells Canyon Complex in the Snake River (all species and years (1969–2008)). The sample size (N) is given for composite samples. Composites with unknown sample size are indicated by a question mark. A length of zero indicates age-based data or samples with unknown length. ◊ and Δ = muscle concentrations, □ = whole body concentrations, ○ = liver concentrations.

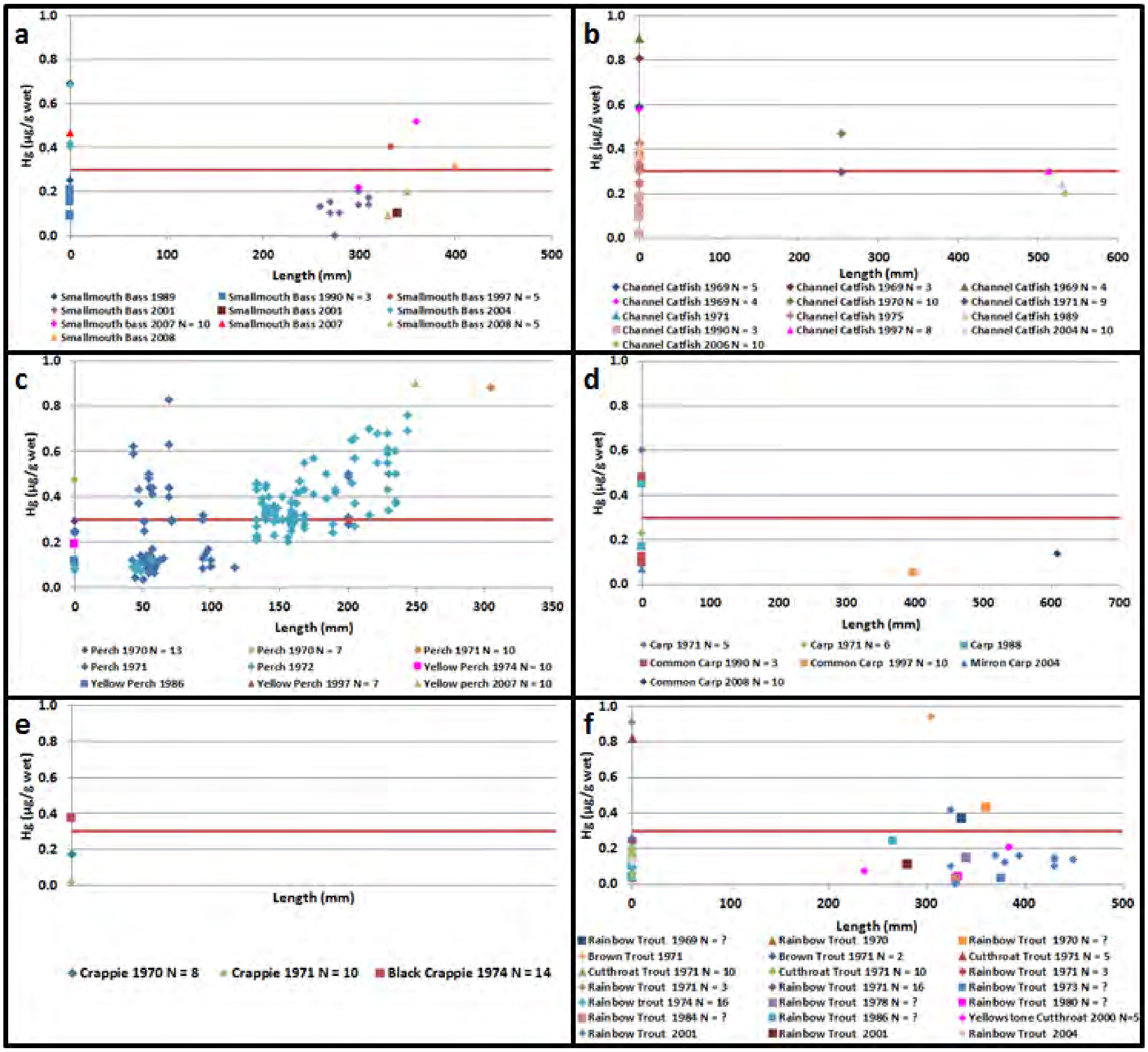


Figure 2-2. Fish Hg concentrations for selected species in the Snake River upstream of Hells Canyon Complex (all years). Species: a) smallmouth bass, b) channel catfish, c) perch, d) carp, e) crappie, f) trout. The sample size (N) is given for composite samples. Composites with unknown sample size are indicated by a question mark. A length of zero indicates age-based data or samples with unknown length. Red lines show the USEPA MeHg criterion for muscle (0.3 µg g^{-1}). ◊ and Δ = muscle concentrations, and □ = whole body concentrations.

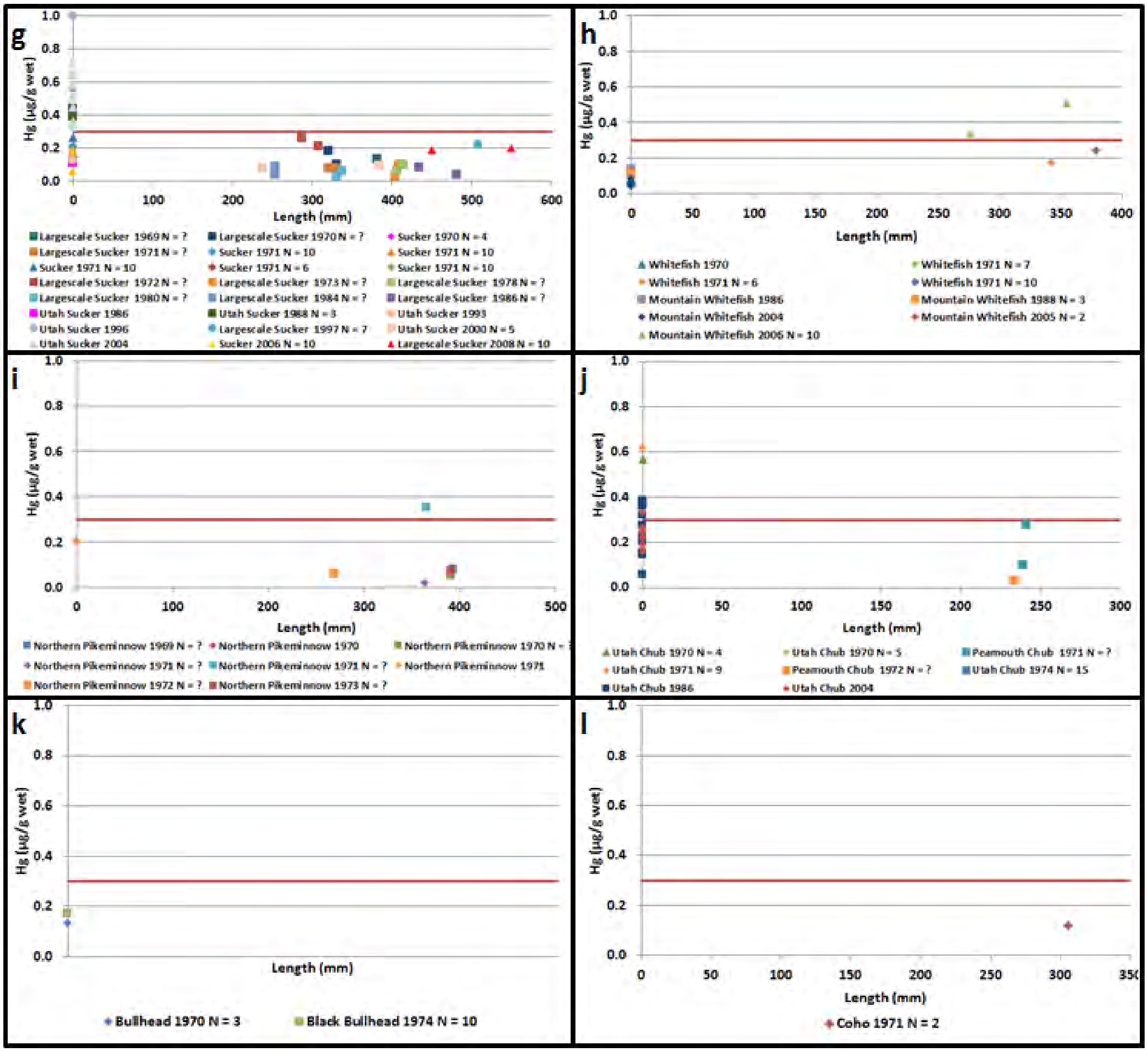


Figure 2-2 (continued). Fish Hg for selected species in the Snake River upstream of Hells Canyon Complex (all years). Species: g) sucker, h) whitefish, i) northern pikeminnow, j) chub, k) bullhead, l) coho salmon. The sample size (N) is given for composite samples. Composites with unknown sample size are indicated by a question mark. A length of zero indicates age-based data or samples with unknown length. Red lines show the USEPA MeHg criterion for muscle (0.3 µg g^{-1}). ◊ and Δ = muscle concentrations, □ = whole body concentrations, and ○ = liver concentrations.

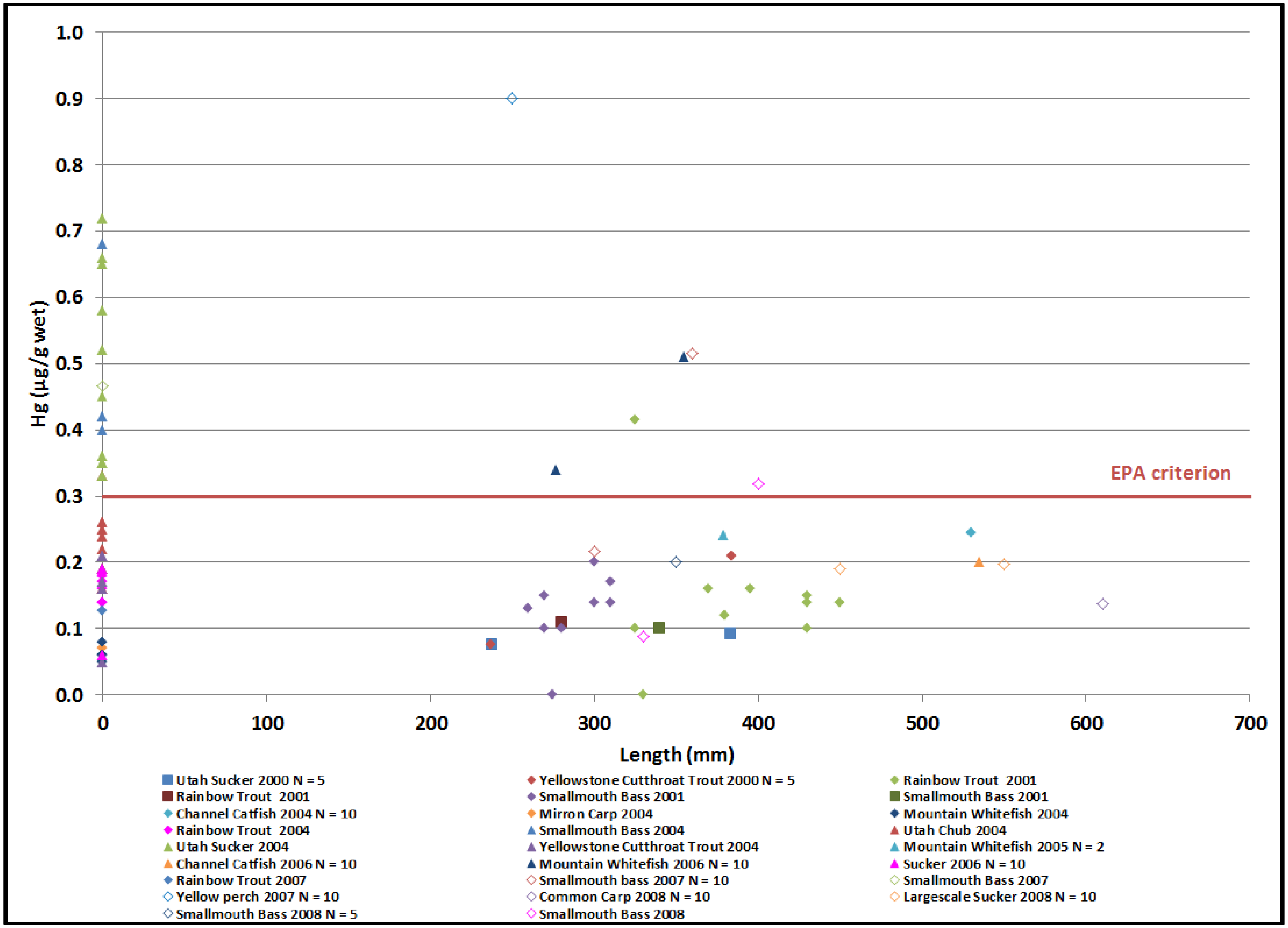


Figure 2-3. Fish Hg concentrations upstream of Hells Canyon Complex in the Snake River since 2000 (all species). The sample size (N) is given for composite samples. Composites with unknown sample size are indicated by a question mark. A length of zero indicates age-based data or samples with unknown length. ◊ and Δ = muscle concentrations, □ = whole body concentrations.

2.2. Fish Hg Data from Brownlee Reservoir

Within Brownlee Reservoir, 248 Hg analyses were identified for ~12 fish species between 1969 and 2011 (Figure 2-4). The analyses included individual fish samples (87% of total) and composites (13%). There was also a mixture of whole body and muscle tissue analyses. Fish Hg observations within Brownlee Reservoir ranged from less than 0.1 $\mu g\ g^{-1}$ to approximately 1.3 $\mu g\ g^{-1}$ wet weight in smallmouth bass and channel catfish (a concentration of 1.4 $\mu g\ g^{-1}$ was also reported in 2006 for a composite sample of "bottom feeders" consisting of unknown species). Plots of fish Hg concentrations for specific species in Brownlee Reservoir are shown in Figure 2-5. Measurements of fish Hg concentrations for Brownlee Reservoir since 2000 are very limited (n= 23 analyses for 7 species, Figure 2-6). While sufficient fish were sampled to establish Hg versus length relationships for some species (crappie, catfish, carp, perch), none of those datasets were collected after 2000.

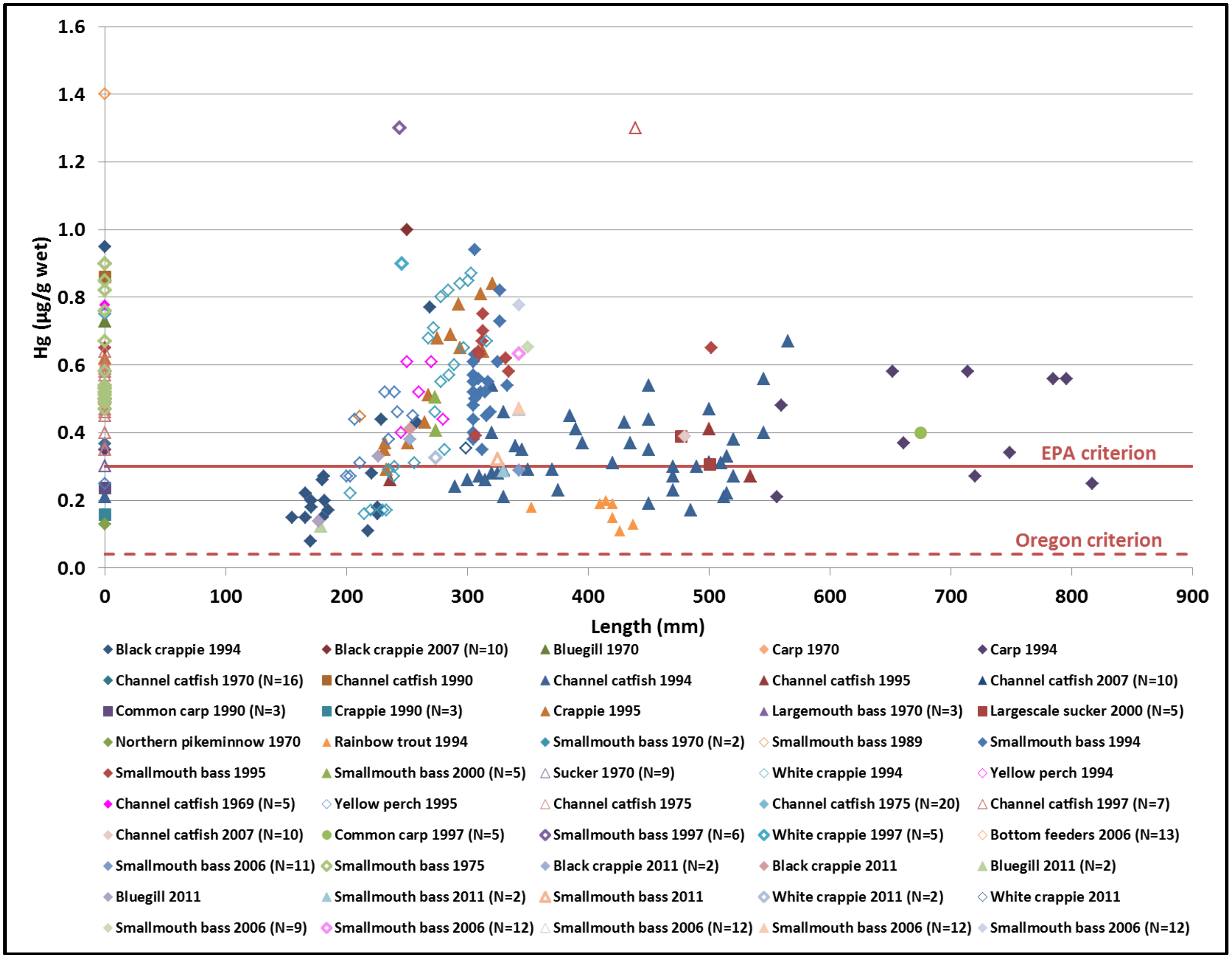


Figure 2-4. Fish Hg Concentrations in Brownlee Reservoir (all species and years). The sample size (N) is given for composite samples. Composites with unknown sample size are indicated by a question mark. A length of zero indicates age-based data or samples with unknown length. ◊ and Δ = muscle concentrations, □ = whole body concentrations, ○ = liver concentrations.

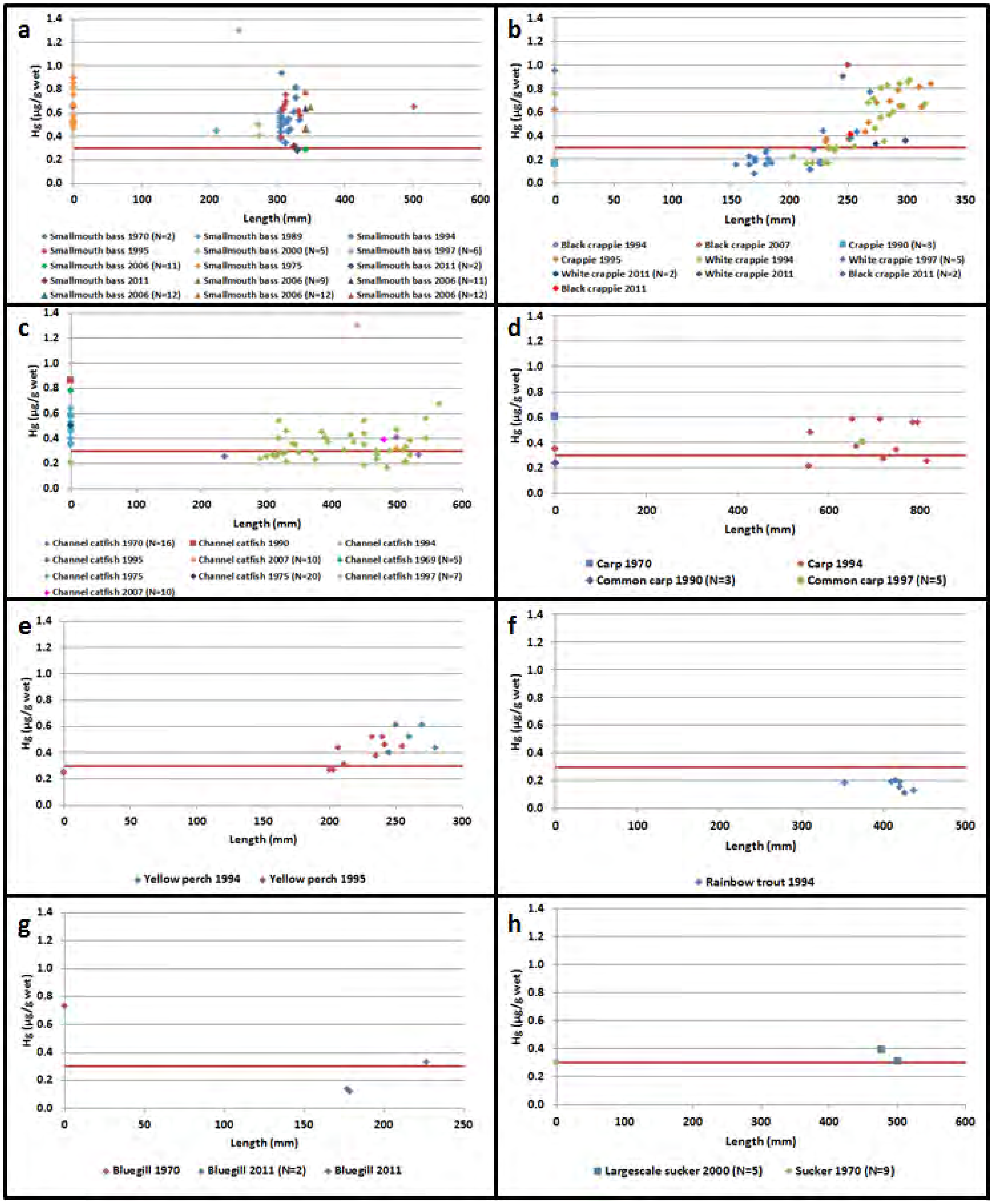


Figure 2-5. Fish Hg concentrations for selected fish species in Brownlee Reservoir (all years). Species: a) smallmouth bass, b) crappie, c) channel catfish, d) carp, e) yellow perch, f) rainbow trout, g) bluegill, h) sucker. The sample size (N) is given for composite samples. Composites with unknown sample size are indicated by a question mark. A length of zero indicates age-based data or samples with unknown length. Red lines show the USEPA MeHg criterion for muscle (0.3 µg g^{-1}). ◊ and Δ = muscle concentrations, □ = whole body concentrations,○ = liver concentrations.

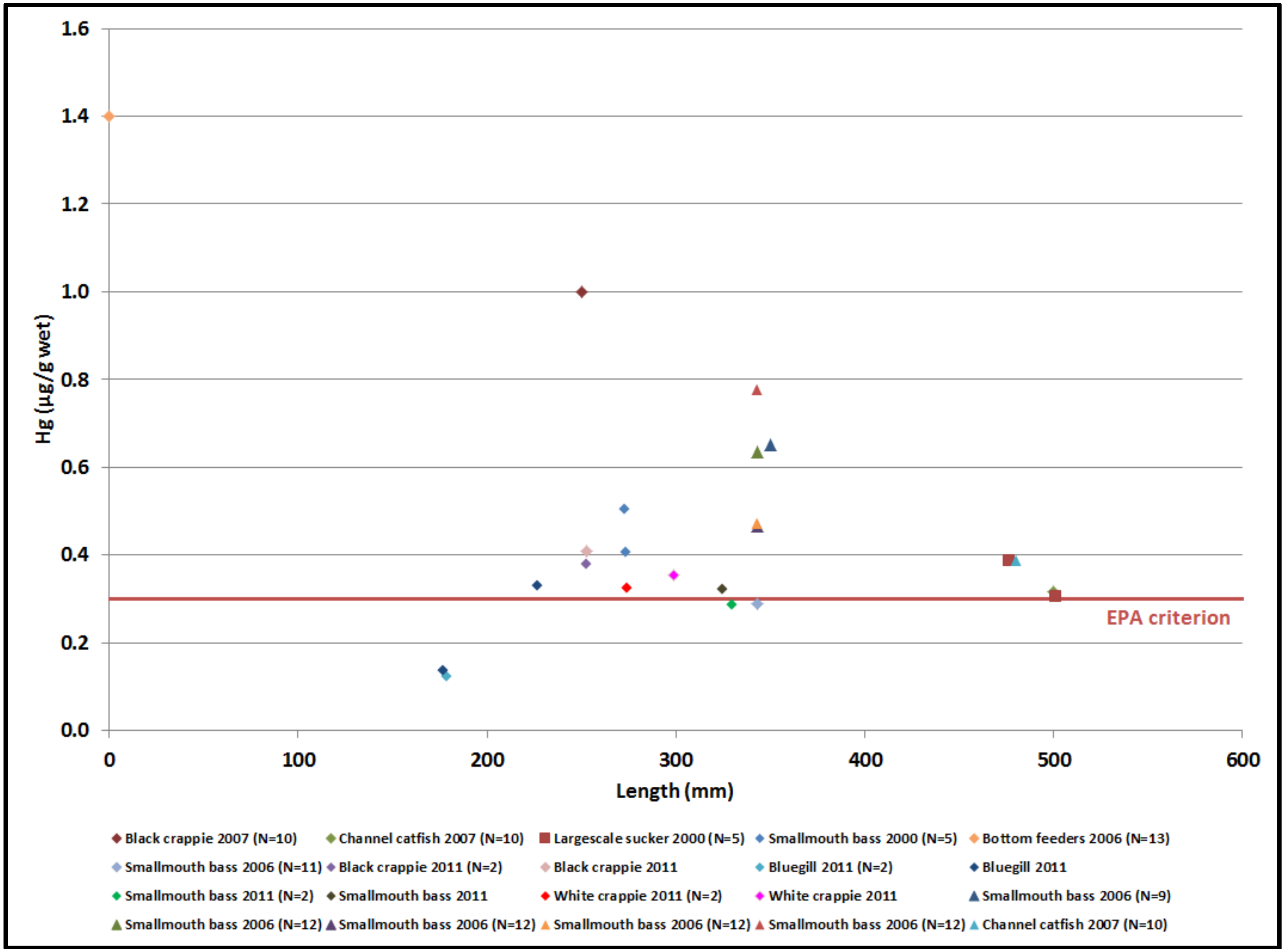


Figure 2-6. Fish Hg concentrations in Brownlee Reservoir since 2000 (all species). The sample size (N) is given for composite samples. Composites with unknown sample size are indicated by a question mark. A length of zero indicates age-based data or samples with unknown length. ◊ and Δ = muscle concentrations, □ = whole body concentrations

2.3. Fish Hg Data from Oxbow Reservoir

No fish Hg data were identified for Oxbow Reservoir.

2.4. Fish Hg Data from Hells Canyon Reservoir

Fish Hg datasets within Hells Canyon Reservoir were very limited (n=12 analyses, 6 species), insufficient to establish Hg concentrations for a standard size or age of a given species in any years (Figure 2-7).

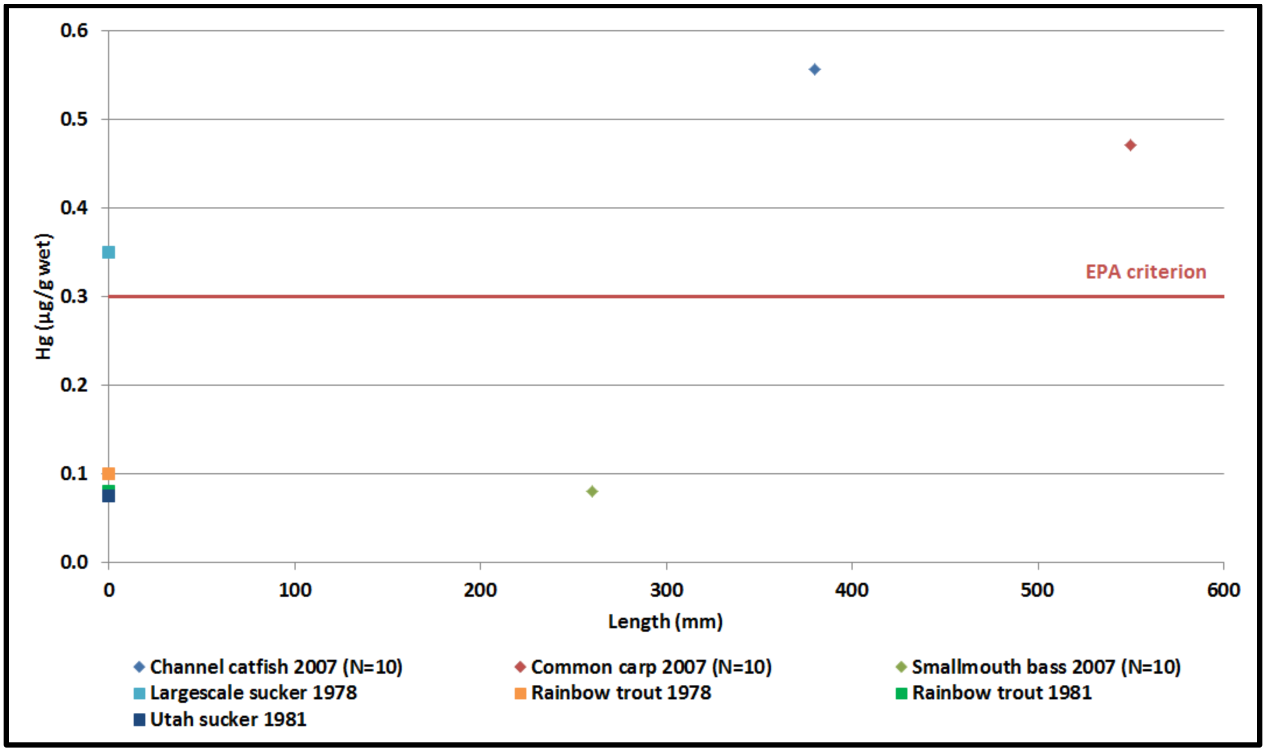


Figure 2-7. Fish Hg concentrations in Hells Canyon Reservoir (all species and years). The sample size (N) is given for composite samples. Composites with unknown sample size are indicated by a question mark. A length of zero indicates age-based data or samples with unknown length. ◊ = muscle concentrations and □ = whole body concentrations

2.5. Fish Hg Downstream of Hells Canyon Dam

Fish Hg data downstream of Hells Canyon Dam to the confluence of the Snake and Clearwater Rivers (RM 108) were limited (Figure 2-8, Figure 2-9). All datasets had less than 5 individual analyses. In many cases, composite samples with unknown numbers of individual fish were analyzed for Hg concentrations. No downstream fish Hg data were identified after 1997.

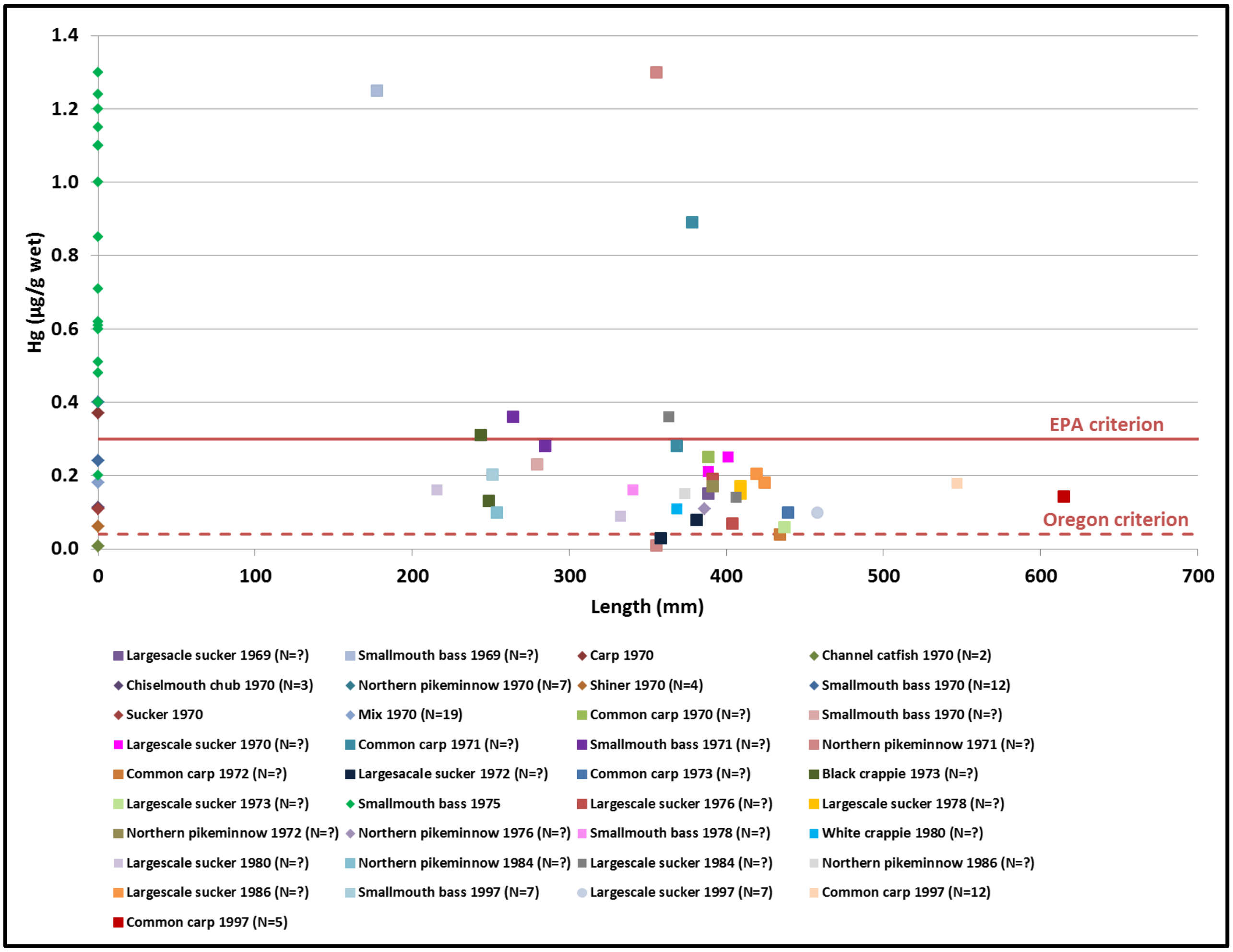


Figure 2-8. Fish Hg concentrations in the Snake River downstream of Hells Canyon Complex (all species and years). All available data are shown for the river reach between Hells Canyon Dam and the Clearwater River at Lewiston-Clarkston. The sample size (N) is given for composite samples. Composites with unknown sample size are indicated by a question mark. A length of zero indicates age-based data or samples with unknown length. ◊ = muscle concentrations, □ = whole body concentrations, ○ = liver concentrations.

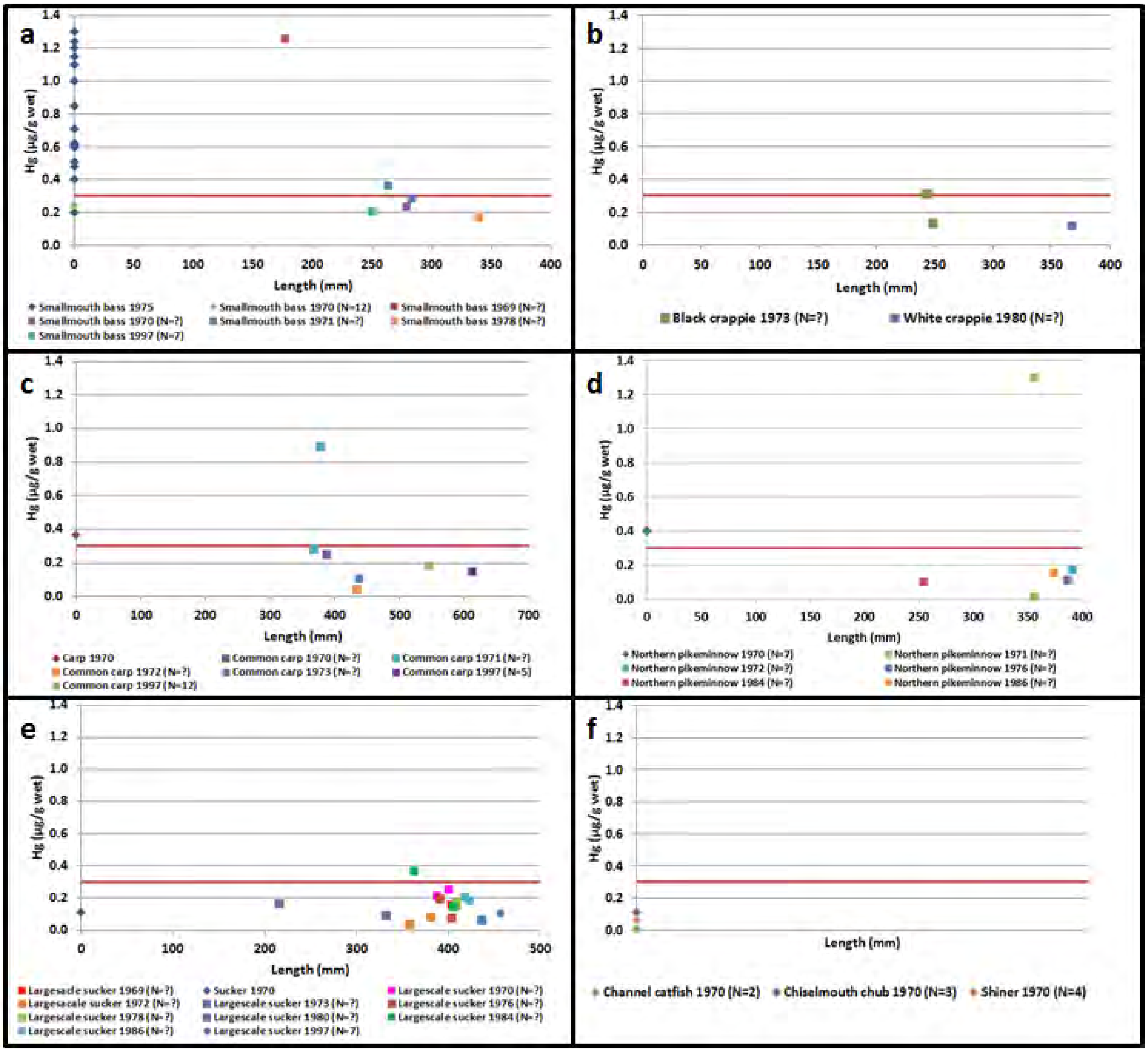


Figure 2-9. Fish Hg concentrations for selected fish species in the Snake River downstream of Hells Canyon Complex (all years). Species: a) smallmouth bass, b) crappie, c) carp, d) northern pikeminnow, e) sucker, f) other species. The sample size (N) is given for composite samples. Composites with unknown sample size are indicated by a question mark. A length of zero indicates age-based data or samples with unknown length. Red lines show the USEPA MeHg criterion for muscle (0.3 µg g^{-1}). ◊ = muscle concentrations, □ = whole body concentrations, and ○ = liver concentrations.

2.6. Spatial Comparison of Fish Hg Data

While available fish Hg data were insufficient to carry out robust analyses of spatial or temporal trends, data from Brownlee Reservoir were qualitatively compared to upstream and downstream sites. An examination of Figure 2-10 suggested but did not confirm that smallmouth bass Hg concentrations were higher in Brownlee Reservoir than upstream or downstream. Carp Hg concentrations also appeared higher in Brownlee Reservoir than downstream. In contrast, perch Hg concentrations did not appear to be higher in Brownlee Reservoir than upstream or downstream, but most of the upstream perch data are from the 1970s (Figure 2-11). Mercury concentration data for other species were limited, and qualitative comparisons could not be made (Figure 2-12, Figure 2-13).

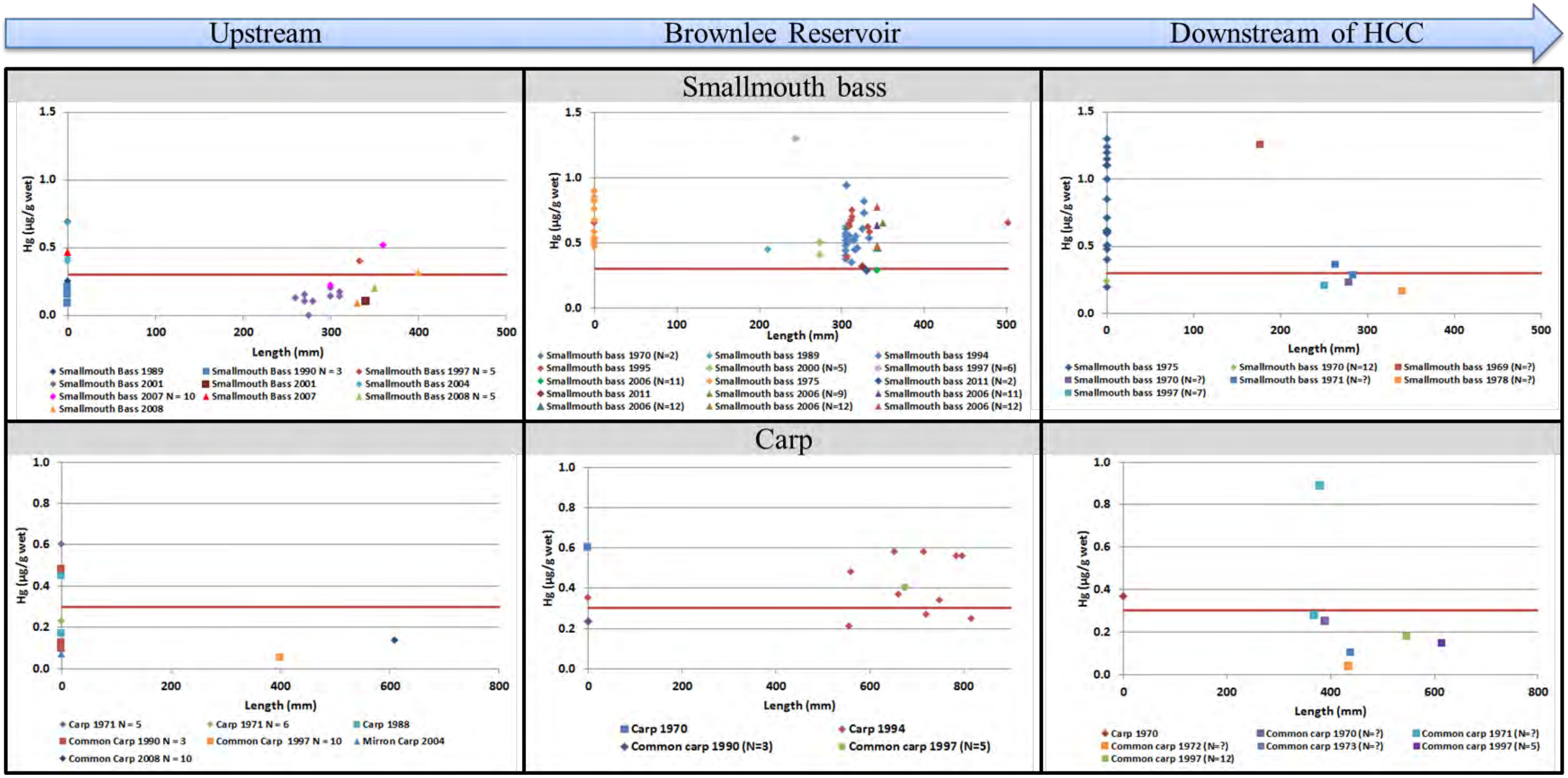


Figure 2-10. Mercury concentrations in smallmouth bass and carp upstream, within HCC (Brownlee Reservoir), and downstream of HCC in the Snake River (all years). The sample size (N) is given for composite samples. Composites with unknown sample size are indicated by a question mark. A length of zero indicates age-based data or samples with unknown length. Red lines show the USEPA MeHg criterion for muscle (0.3 µg g^{-1}). ◊ and Δ = muscle concentrations, □ = whole body concentrations.

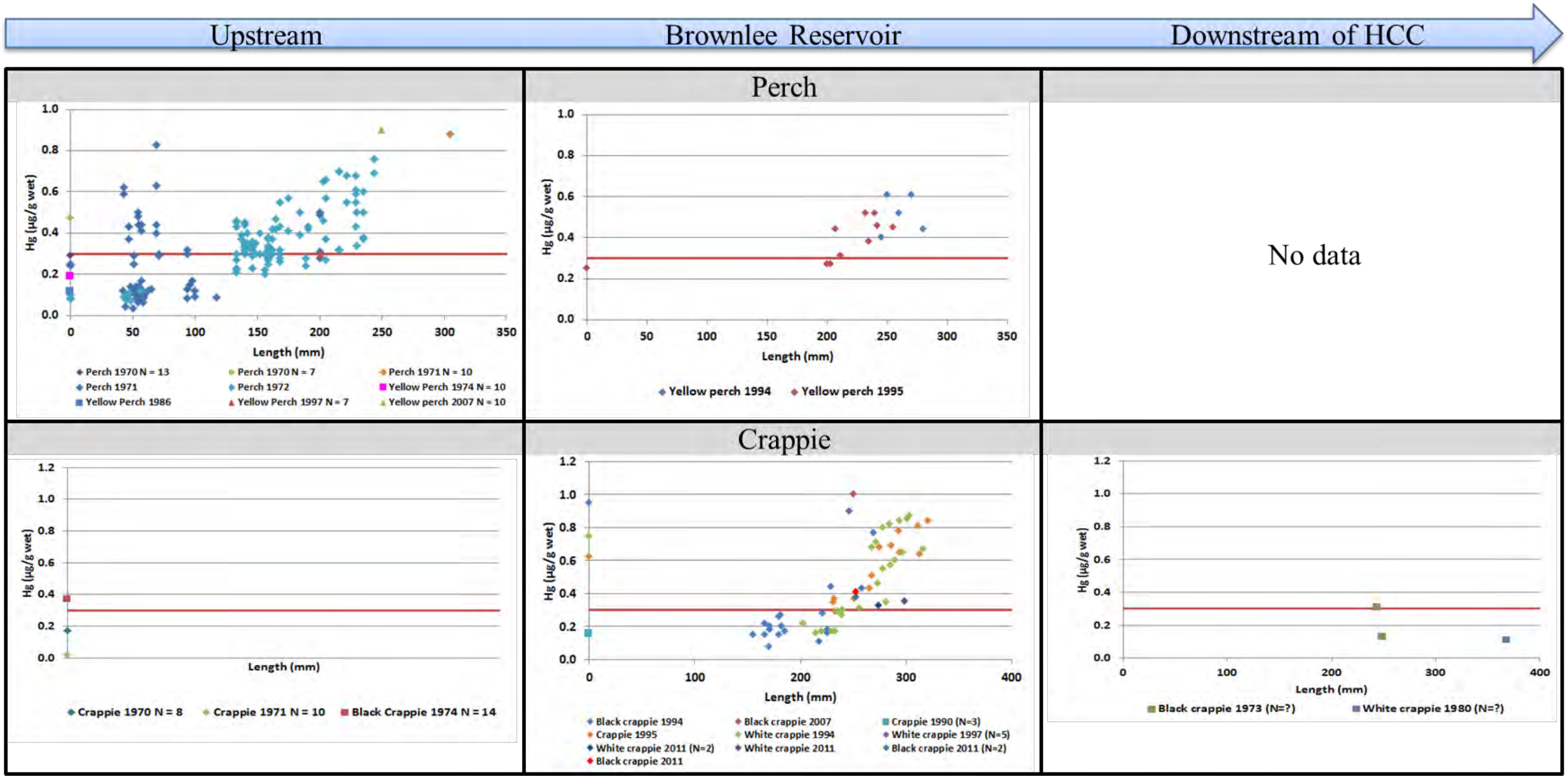


Figure 2-11. Mercury concentrations in perch and crappie upstream, within HCC (Brownlee Reservoir), and downstream of HCC in the Snake River (all years). The sample size (N) is given for composite samples. Composites with unknown sample size are indicated by a question mark. A length of zero indicates age-based data or samples with unknown length. Red lines show the USEPA MeHg criterion for muscle (0.3 µg g^{-1}). ◊ and Δ = muscle concentrations, □ = whole body concentrations.

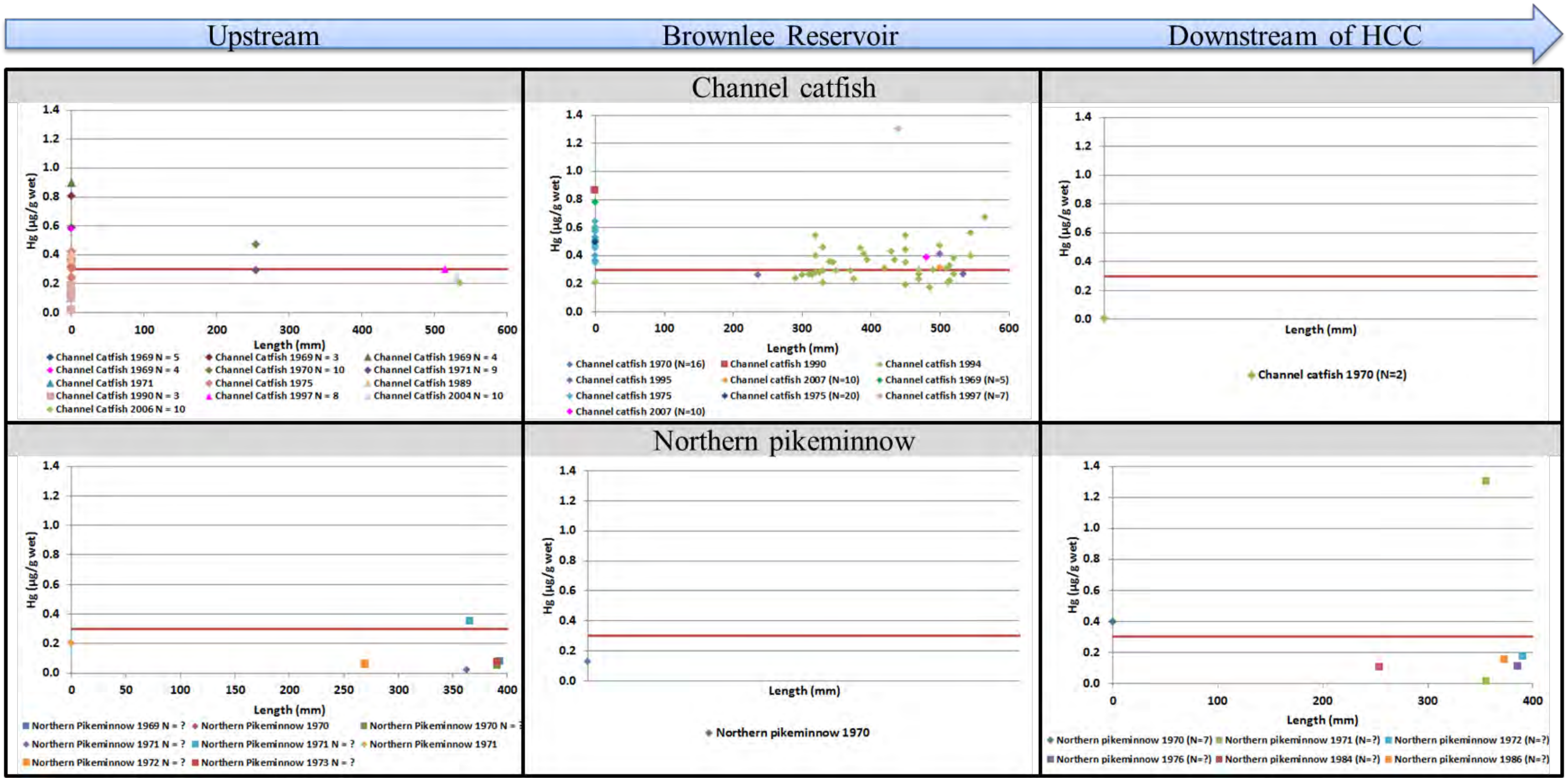


Figure 2-12. Mercury concentrations in channel catfish and northern pikeminnow upstream, within HCC (Brownlee Reservoir), and downstream of HCC in the Snake River (all years). The sample size (N) is given for composite samples. Composites with unknown sample size are indicated by a question mark. A length of zero indicates age-based data or samples with unknown length. Red lines show the USEPA MeHg criterion for muscle (0.3 µg g^{-1}). ◊ and Δ = muscle concentrations, □ = whole body concentrations, ○ = liver concentrations.

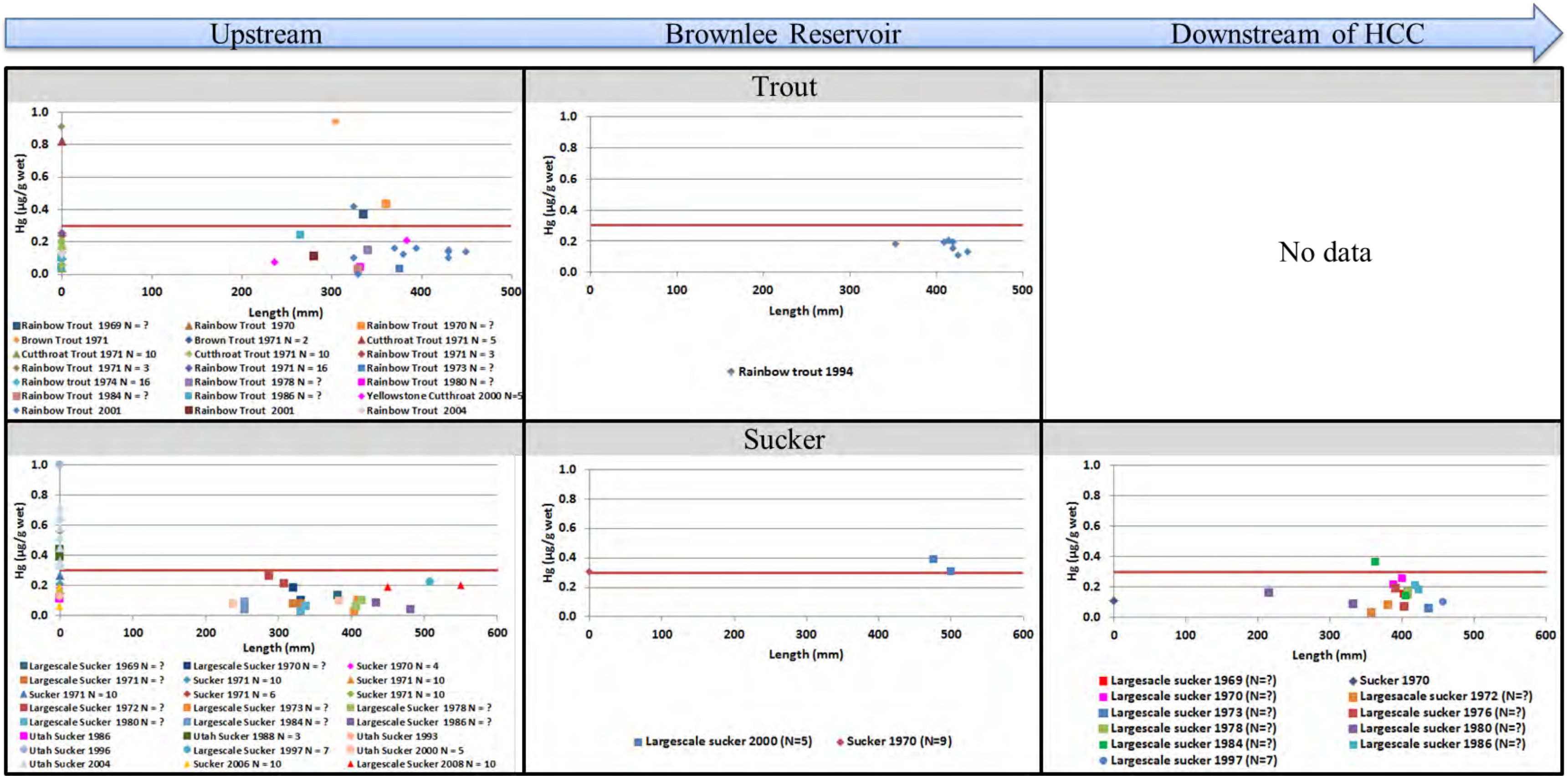


Figure 2-13. Mercury concentrations in trout and sucker upstream, within HCC (Brownlee Reservoir), and downstream of HCC in the Snake River (all years). The sample size (N) is given for composite samples. Composites with unknown sample size are indicated by a question mark. A length of zero indicates age-based data or samples with unknown length. Red lines show the USEPA MeHg criterion for muscle (0.3 µg g^{-1}). ◊ and Δ = muscle concentrations, □ = whole body concentrations, ○ = liver concentrations.

3. Hg Concentrations in the Water Column and Sediments

Water column and sediment Hg datasets upstream, within and downstream of HCC were identified for the years listed in Table 3-1. In the water column the majority of data were from 2011 and 2012, and included samples at multiple depths. Similarly, the most comprehensive sediment data were also from 2012, collected by the USGS. Additional information is provided in Sections 3.1 to 3.3.

Table 3-1. Summary of years when Hg data were available on the Snake River for water column and sediments upstream. nd = no data

Compartment	Hg parameter	Site				
		Upstream	**Brownlee Reservoir**	**Oxbow Reservoir (at Brownlee discharge)**	**Hells Canyon Reservoir**	**Downstream**
Surface waters	THg	2006, 2008	2007, 2012 (May)	2006, 2011 (fall)	nd	nd
	MeHg	2006, 2008	2012 (May)	2011 (fall)	nd	nd
Hypolimnion	THg	not applicable	2012 (May) 2011 (Fall)	not applicable	nd	nd
	MeHg	not applicable	2012 (May) 2011 (Fall)	not applicable	nd	nd
Surface sediments	THg	1992, 1993, 1995, 1997	2012 (May) 1997 (August)	nd	nd	nd
	MeHg	nd	2012 (May)	nd	nd	nd

3.1. Water Column and Sediment Hg Data Upstream of Hells Canyon Complex

Water column samples were collected from the Snake River upstream of Hells Canyon Complex in July-August, 2008 (Essig, 2010) and analyzed for Hg concentrations. Total Hg (THg) and MeHg concentrations are given in Table 3-2 for different locations identified by river mile. Also indicated in Table 3-2, in brackets beside the river mile, are the approximate distances from the upstream end of Brownlee Reservoir. The data in the rightmost column of Table 3-2 (RM 900) are from the South Fork of the Snake River, downstream of Palisades Reservoir, ID.

Table 3-2. THg and MeHg concentrations in the Snake River upstream of Hells Canyon Complex. Sampling was conducted by Essig (2010) between July-August 2008. The number in brackets beside River Mile is the approximate distance from the upstream end of HCC, assumed to be RM 343.

Mercury parameter	River Mile			
	420 (77)	480 (137)	610 (267)	900 (557)
THg (ng L^{-1} unfiltered)	1.71	0.94	1.82	0.72
MeHg (ng L^{-1} unfiltered)	0.101	0.075	0.102	0.034
Percent MeHg	6%	8%	6%	5%

Water column sampling was also carried out upstream of HCC in 2006 near RM 409 (66 miles upstream of HCC) (Brandt and Bridges, 2007). Unfiltered THg concentrations ranged from 2.6 ng L^{-1} (average of three samples, range 2.1–3.6 ng L^{-1}) during periods of higher runoff in June, to 2.2 ng L^{-1} during base flow conditions in September. These concentrations are slightly higher than observed in 2008 by Essig (2010).

Limited sediment Hg data were available upstream of HCC. Sediment THg was measured at 7 sites in the Snake River between 1992-1997 (Table 3-3; Clarke and Maret, 1998). The locations of the sites are shown in Figure 3-1. While the detection limit was relatively coarse at 0.01 µg g^{-1}, these data suggest low to moderate Hg concentrations at the sampled locations, with no obvious source of point source contamination. Additional information on grain size and organic content would help interpret the Hg data, but were not available.

Table 3-3. Sediment mercury in the Snake River upstream of Hells Canyon Complex. Sampling was conducted by Clarke and Maret (1998) between 1992-1997. Locations of the sampling sites are shown in Figure 3-1.

Location on Snake River	Site ID	Date sampled	Sediment Hg Concentration (µg g^{-1} dry)
Flagg Ranch, WY	SNK-FR	September 1995	0.04
Near Blackfoot	SNK-BF	September 1993	<0.02
Near Minidoka	SNK-MD	July 1993	<0.02
Near Kimberley	SNK-KI	August 1992	0.04
Near Buhl	SNK-BU	July 1993	0.02
King Hill	SNK-KH	July 1997	0.06
C.J. Strike Reservoir at Hwy. 51	SNK-CJ	August 1997	0.04

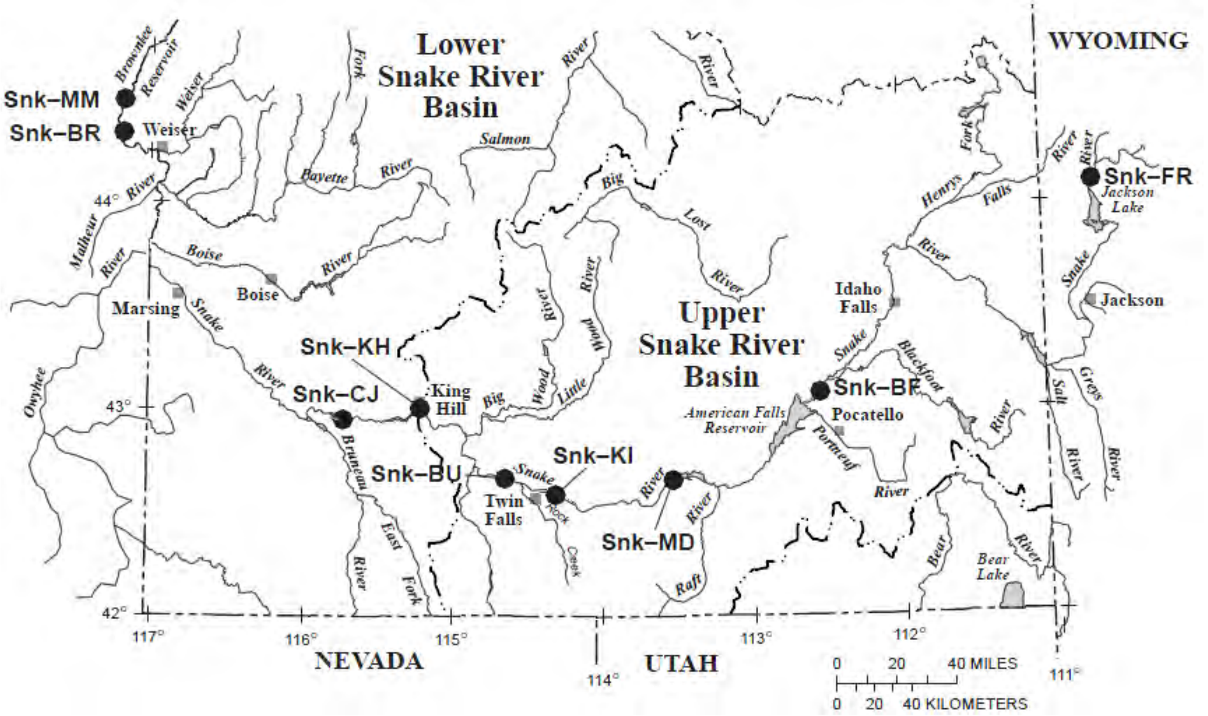


Figure 3-1. Locations of sediment sampling sites listed in Table 3-3. Adapted from Clarke and Maret (1998).

3.2. Water Column and Sediment Hg Data from Brownlee Reservoir

Water column samples were collected by the USGS in Brownlee Reservoir in May 2012 and analyzed for Hg concentrations (Krabbenhoft, 2012; USGS, 2013). The locations of the eight sampling sites are shown in Figure 3-2. Each location was sampled at three depths (surface, intermediate, near bottom). Results for THg and MeHg concentrations are shown in Figure 3-3 and Figure 3-4. THg concentrations ranged from 0.75–3.08 ng L^{-1}, and MeHg concentrations ranged from 0.07–0.72 ng L^{-1}. Higher concentrations tended to occur in deeper waters, particularly for MeHg.

Water column Hg sampling in Brownlee Reservoir was also conducted in fall 2011 by Harrison *et al.* (2012). Samples were collected from the hypolimnion (>60 m depth) at 3 sites within Brownlee Reservoir and in Oxbow Reservoir near the Brownlee dam discharge, at 3 sites across the channel. Results for THg and MeHg concentrations are given in Table 3-4. Brownlee hypolimnetic THg and MeHg concentrations were significantly elevated compared to values from Oxbow Reservoir near the Brownlee discharge, which were likely representative of surface or intermediate depth waters in Brownlee Reservoir. These hypolimnetic MeHg concentrations were also significantly higher than observed by Krabbenhoft *et al.* in May 2012, suggesting a possible buildup of MeHg in deep waters during summer stratification.

Water column Hg data were also available from Brownlee Reservoir in 2007, sampled by the Idaho Department of Environmental Quality (Stone, 2008). Concentrations in samples collected at multiple locations and composited ranged from 2.7 ng/L in June to 9.0 ng/L in September. These results are viewed as being of limited use however. The detection limit was 1.5 ng L^{-1} and the practical quantification limit was 5 ng L^{-1}.

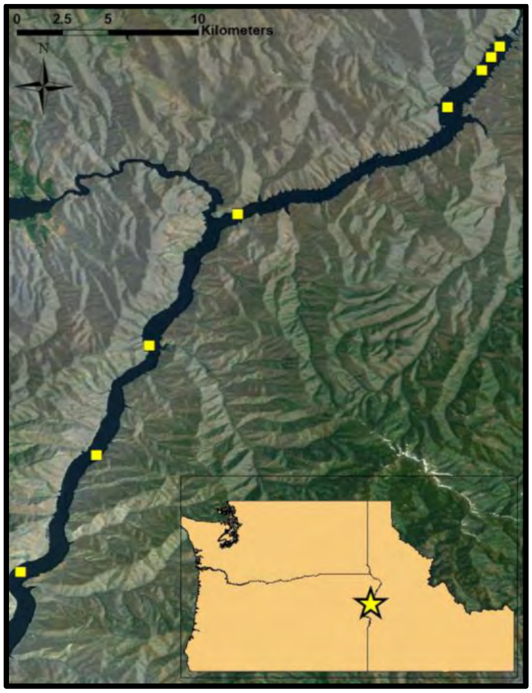


Figure 3-2. Locations of eight USGS sampling sites in Brownlee Reservoir, May 2012. Copied from Krabbenhoft (2012).

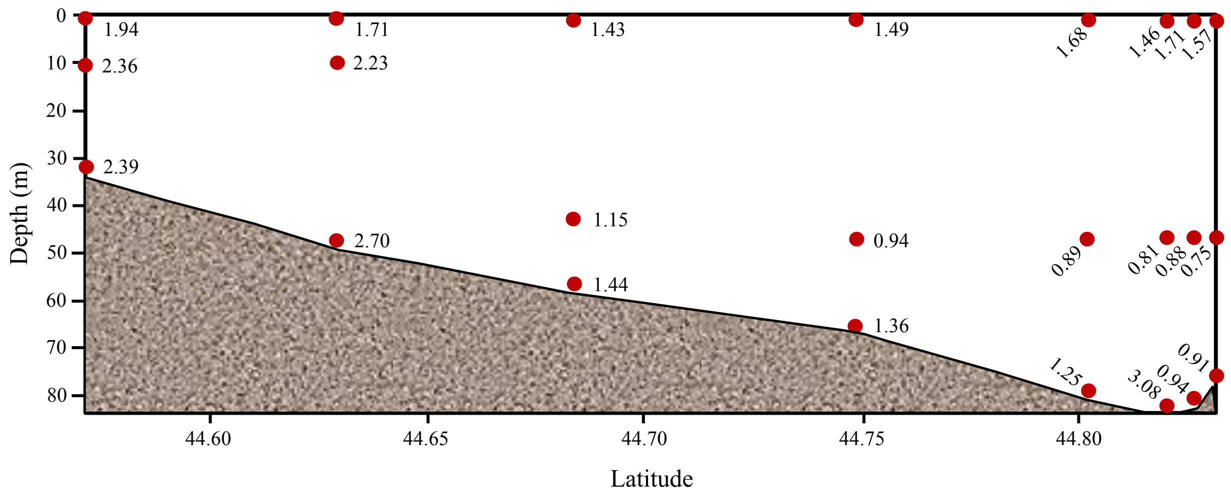


Figure 3-3. Water total Hg concentrations (ng L^{-1} unfiltered) in Brownlee Reservoir, May 2012. Derived from Krabbenhoft (2012) and USGS (2013).

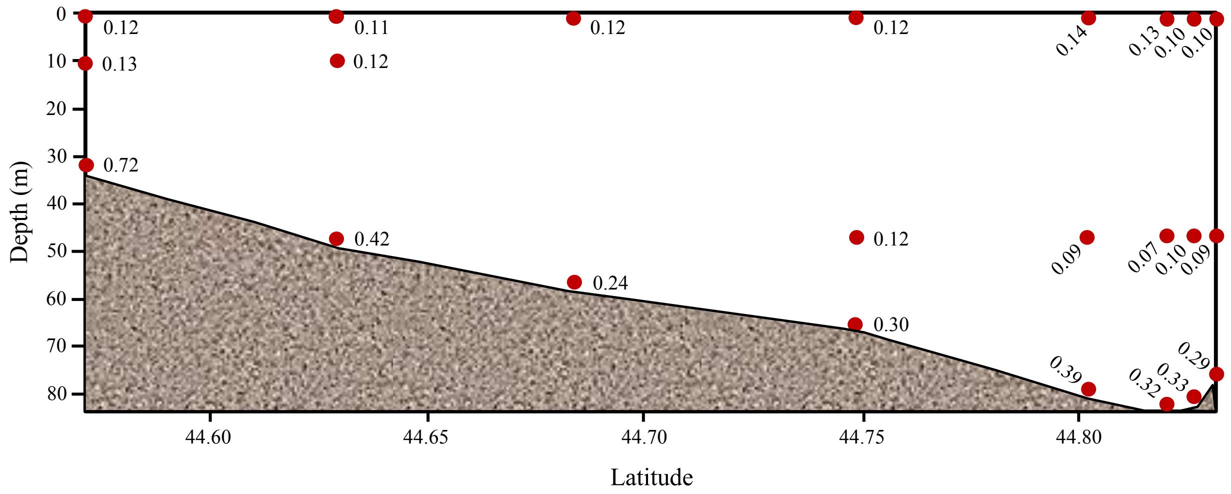


Figure 3-4. Water MeHg concentrations (ng L^{-1} unfiltered) in Brownlee Reservoir, May 2012. Derived from Krabbenhoft (2012) and USGS (2013).

Table 3-4. THg and MeHg concentrations in the hypolimnion of Brownlee Reservoir and in Oxbow Reservoir near the discharge from the Brownlee dam. Sampling was conducted by Harrison *et al.* (2012) in fall 2011. Data assumed to represent unfiltered samples.

	Brownlee Reservoir Hypolimnion			Oxbow Reservoir at Brownlee discharge		
Site	**1**	**2**	**3**	**4**	**5**	**6**
RM	286	286.5	287	283.8	283.8	283.8
Total mercury (ng L^{-1})	4.20	3.90	4.80	0.60	0.6	0.70
Methyl mercury (ng L^{-1})	2.70	2.50	2.90	0.10	<0.1	0.10
Percent methylmercury	64%	64%	60%	17%	–	14%

Total Hg concentration in surface sediments (0-2 cm) sampled by the USGS in May 2012 in Brownlee Reservoir ranged from 61–103 ng g^{-1} dry (Figure 3-5). Sediment Hg was also measured in August 1997 at two sites in Brownlee Reservoir (Clarke and Maret, 1998). THg was 60 ng g^{-1} at Burnt River, OR and 130 ng g^{-1} at Mountain Man Lodge, OR (shown in Figure 3-1: SNK-BR and SNK-MM).

MeHg concentration in surface sediments (0–2 cm) ranged from 5–18 ng g^{-1}. MeHg concentrations in the upper few cm were higher than in deeper samples. This is typical, reflecting MeHg production near the sediment water interface. While THg concentrations in sediments were not unusual, the absolute concentrations of MeHg (Figure 3-5) and the percent of THg as MeHg (Figure 3-6) were both high in surface sediments.

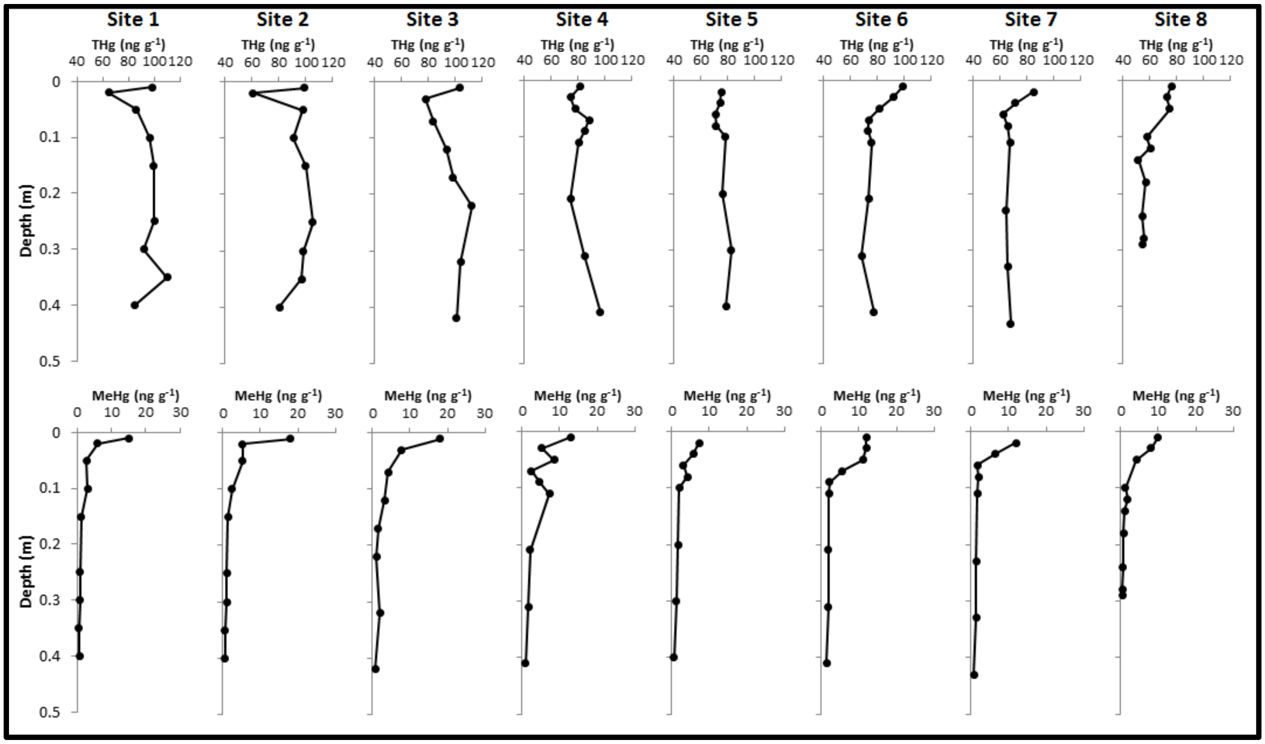


Figure 3-5. Sediment profiles of THg (top) and MeHg (bottom) concentrations in Brownlee Reservoir, May 2012. Data from USGS (2013).

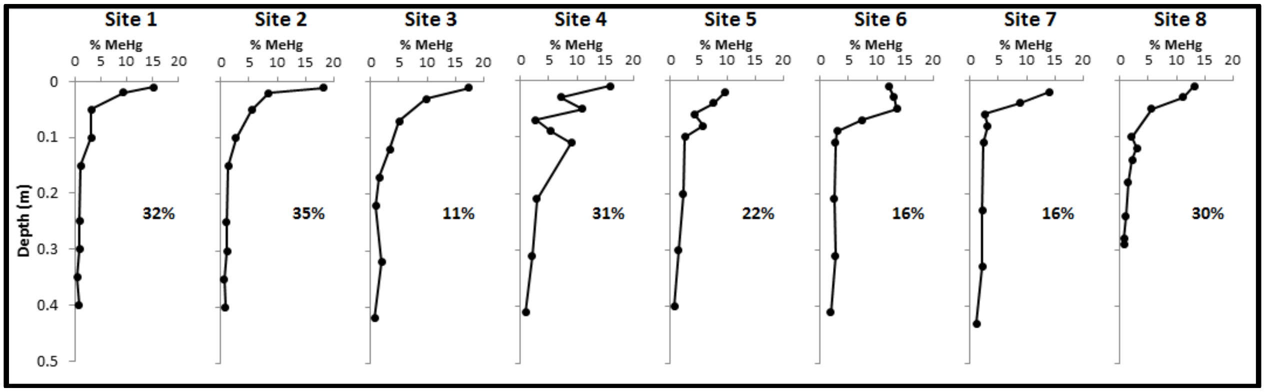


Figure 3-6. Percent of THg as MeHg in sediments (profiles) compared to %MeHg in overlying bottom waters (unfiltered). Data from USGS (2013).

MeHg concentrations in Brownlee Reservoir surface sediments (0–2 cm) showed a positive relationship with THg concentrations (Figure 3-7). This could indicate that MeHg production and concentrations depend on inorganic Hg(II)(the main component of total Hg in sediments) and/or a tendency of both THg and MeHg concentrations to increase as the organic content of particles increases. Further analysis of grain size, organic content, THg and MeHg concentrations would help assess this issue.

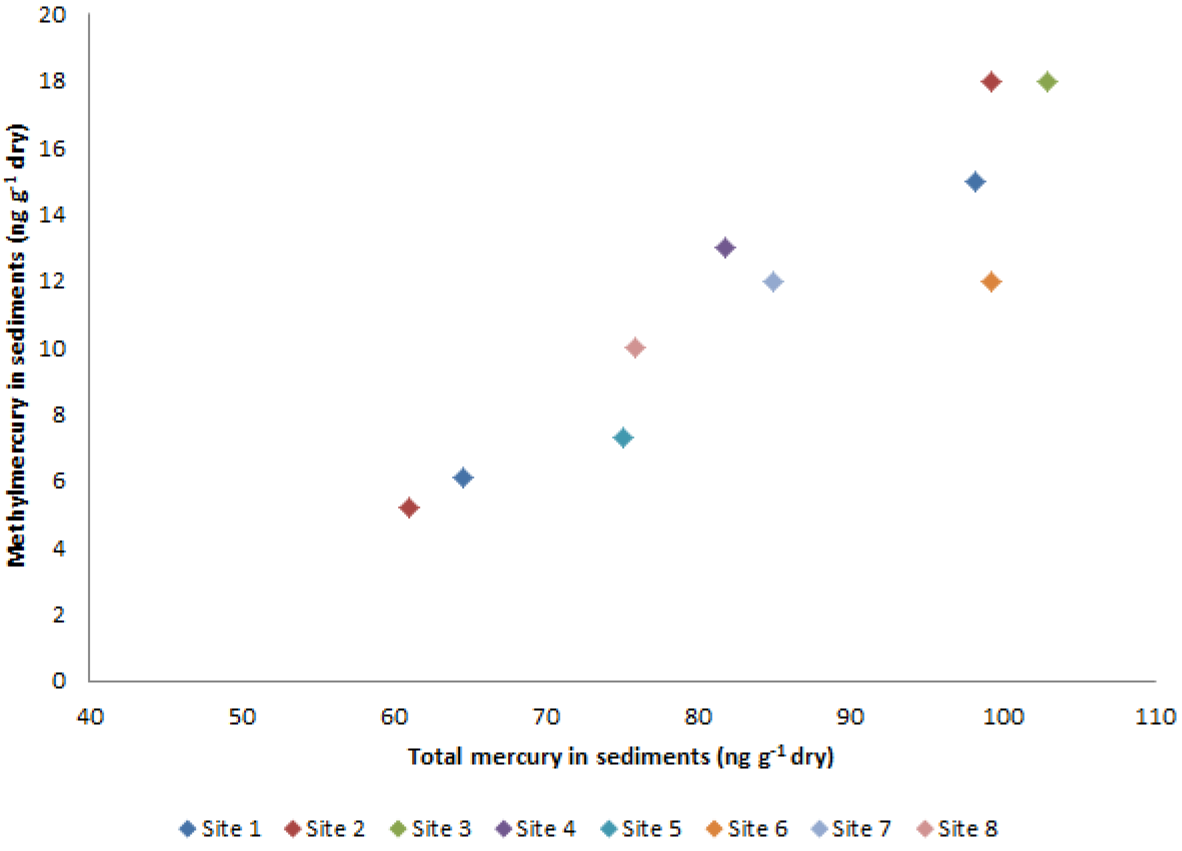


Figure 3-7. MeHg versus THg concentrations in the top 2 cm of sediments in Brownlee Reservoir, May 2012. Data from USGS (2013).

3.3. Water column and Sediment Hg Data Downstream of Brownlee Reservoir

Data for Hg concentrations in the water column or sediments downstream of Brownlee Reservoir were very limited. Water sampling was conducted at four intervals in 2006 in Oxbow Reservoir below Brownlee Dam. Unfiltered THg concentrations were 0.97–1.71 ng L^{-1} during periods of higher runoff in June (avg. 1.39 ng L^{-1}, N=3) and 1.15 ng L^{-1} during base flow conditions in September (Brandt and Bridges, 2007). No water column or sediment Hg data were identified for Hells Canyon Reservoir or downstream.

3.4. Comparison of Hells Canyon Complex Water and Sediment Hg Concentrations versus Regional Data

The USGS carried out a national survey of Hg concentrations in fish, sediments and the water column in streams (Table 3-5, derived from Scudder *et al.*, 2009). Observations from 79 to 337 sites sampled from 1998–2005 were used, depending on the parameter. The mean and median THg concentrations in surface waters in basins not mined for gold or Hg were 2.96 and 1.90 ng L^{-1}. Surface water concentrations were higher in mined basins, with mean and median concentrations of 23.5 and 3.79 ng L^{-1}. Mercury concentrations in the epilimnion of Brownlee Reservoir in May, 2012 (0–10 m) ranged from 1.46–2.36 ng L^{-1}, and did not suggest local point source Hg contamination.

The mean and median MeHg concentrations in surface waters in basins not mined for gold or Hg were 0.20 and 0.11 ng L^{-1} (Scudder *et al.* 2009). Surface water MeHg concentrations were not higher in mined basins, with mean and median concentrations of 0.18 and 0.10 ng L^{-1}. MeHg concentrations in the epilimnion of Brownlee Reservoir in May, 2012 (0–10 m) ranged from 0.10–0.14 ng L^{-1}.

Table 3-5. Summary statistics for Hg in the water column of U.S. streams, 1998–2005. From Scudder *et al.* (2009)

Parameter	Site Grouping	Mean	Median	Std. Dev.	Min	Max	n	Units
MeHg	All sites	0.19	0.11	0.35	<0.010	4.11	337	ng L^{-1}
	Sites in unmined basins	0.2	0.11	0.37	<0.010	4.11	257	
	Sites in mined basins	0.18	0.1	0.31	<0.010	2.02	80	
THg	All sites	8.22	2.09	32.8	0.27	446	336	ng L^{-1}
	Sites in unmined basins	2.96	1.90	5.29	0.27	75.1	250	
	Sites in mined basins	23.50	3.79	62.1	0.48	446	86	
MeHg/THg	All sites	7.08	4.6	8.18	0.02	81.5	328	Percent
	Sites in unmined basins	7.46	5.35	6.72	0.19	46.8	249	
	Sites in mined basins	5.87	2.37	11.6	0.02	81.5	79	

The USGS also compiled data available for THg and MeHg concentrations in sediments in natural (unimpounded) waters and reservoirs in Idaho, Oregon and Washington States. The median THg concentration observed by the USGS in May 2012 (82 ng g^{-1} median, 61–103 ng g^{-1} range) was within the observed range for natural waters and reservoirs (Figure 3-8). In contrast, sediment MeHg concentrations in Brownlee Reservoir sediments (12 ng g^{-1} median, 5–18 ng g^{-1} range) were significantly higher that the range reported for natural waters and reservoirs (< 2 ng g^{-1}).

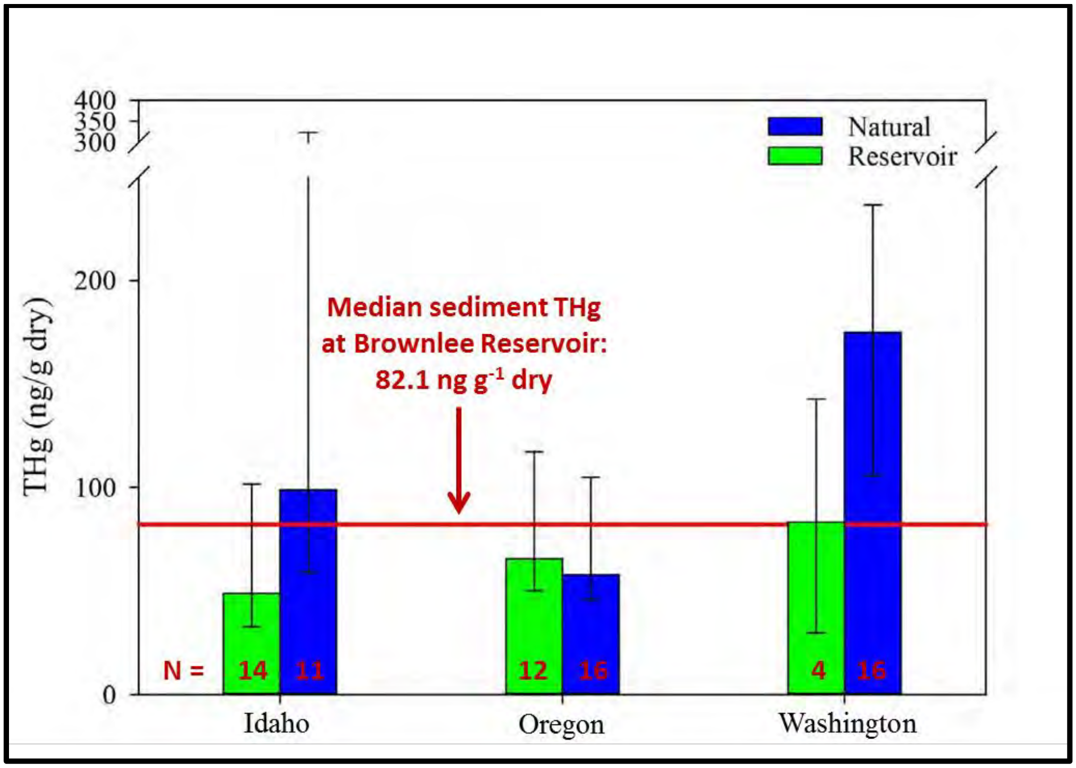


Figure 3-8. Total mercury in sediments in natural lakes and reservoirs. Data are from a 2007 regional USEPA National Lakes Assessment. Values in red are the number of samples. Modified from Krabbenhoft (2012).

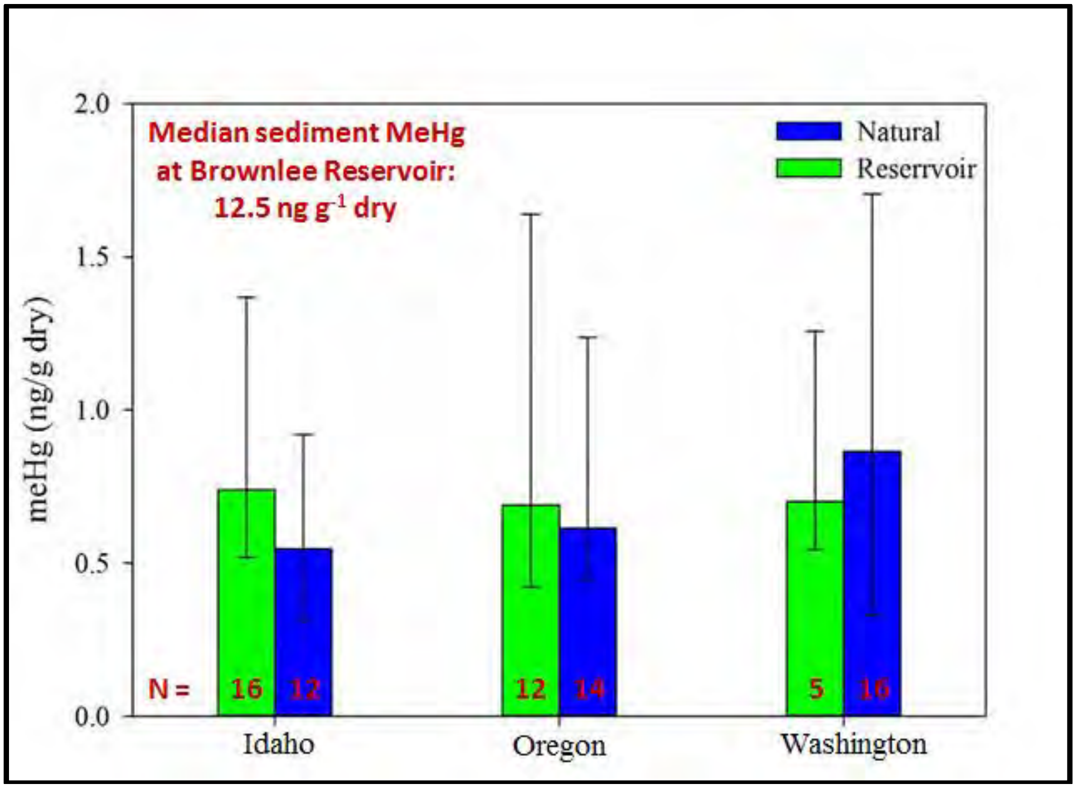


Figure 3-9. Methylmercury in the top 2 cm of sediments in natural lakes and reservoirs. Data are from a 2007 regional USEPA National Lakes Assessment. Values in red are the number of samples. Modified from Krabbenhoft (2012).

The USGS national survey also reported on fish Hg concentrations in streams (Table 3-6) but a review of the report did not identify sampling in Idaho. It is quite possible that national averages are not the same as regional averages. Fish Hg concentrations were either presented as means or medians without adjusting for length, or concentrations were divided by the fish length (e.g. $\mu g\ g^{-1}\ m^{-1}$) to account for the fact that fish Hg concentrations tend to increase with age and size for a given species. This approach does not yield the same values as, for example, developing a regression of fish Hg versus length and choosing a standard length of interest.

Table 3-6. Summary statistics for Hg concentrations in selected fish species from a survey of U.S. streams, 1998--2005. From Scudder *et al.* (2009). *Value in brackets is number of sites in basins mined for gold or Hg.

	Hg Concentration ($\mu g\ g^{-1}$ wet)					**Fish Length (cm)**		
Species	**Mean**	**Median**	**Std. Dev.**	**Min**	**Max**	**Mean**	**Range**	**n***
Largemouth bass	0.460	0.333	0.346	0.081	1.80	29.7	15.8 - 47.0	62 (10)
Smallmouth bass	0.245	0.204	0.257	0.02	1.95	26.2	12.6 - 41.5	60 (9)
Rock bass	0.175	0.139	0.118	0.039	0.506	16	8.96 - 20.8	17 (0)
Spotted bass	0.485	0.42	0.228	0.148	0.943	28.8	17.2 - 37.0	14 (5)
Pumpkinseed	0.139	0.111	0.095	0.042	0.379	10.6	6.66 - 13.7	18 (2)
Rainbow-cutthroat trout	0.11	0.07	0.137	0.014	0.588	20.7	13.2 - 28.1	26 (7)
Brown trout	0.113	0.091	0.098	0.014	0.457	28	19.4 - 51.3	22 (9)
Channel catfish	0.084	0.08	0.029	0.036	0.131	33.3	16.0 - 47.7	12 (2)

The US EPA reported on Hg concentrations in fish tissue in the Columbia River Basin (Figure 3-10), where 75 percent of fish consumption advisories are due to Hg contamination. The data in Figure 3-10 are not species-specific however, making comparisons to Snake River data in this report difficult. Nevertheless, the data suggest that fish Hg concentrations may be elevated in a regional context in the Owyhee River system, west of Boise. Mercury was used in gold mining in the Owyhee River basin in the 1800s, which may be a factor contributing to elevated Hg (US EPA, 2009).

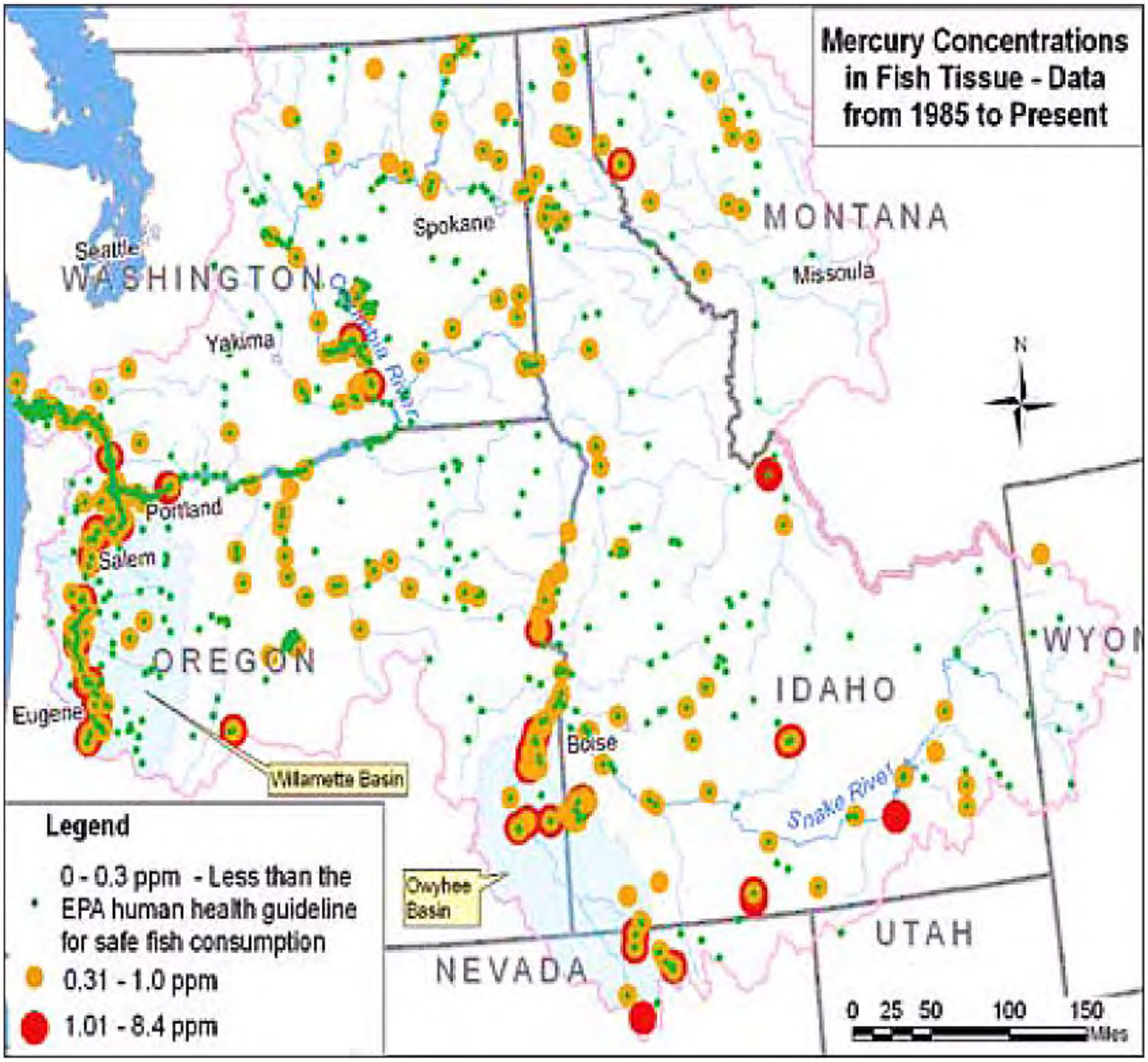


Figure 3-10. Fish Hg concentrations in Columbia River Basin. Copied from US EPA 2009

4. Hg Wet Deposition

The National Atmospheric Deposition Program (NAPD) maintained three Mercury Deposition Network (MDN) monitoring sites in Idaho. Mercury wet deposition records extend back to 2007 at one site; however, as of 2010, all three sites were no longer active. The locations of the sites are shown in Figure 4-1 and average annual wet deposition is given in Table 4-1.

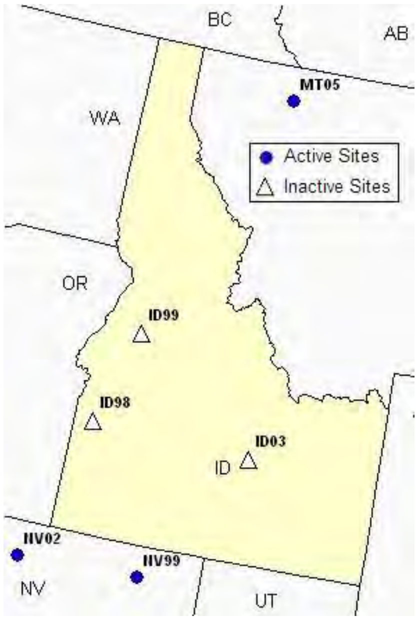
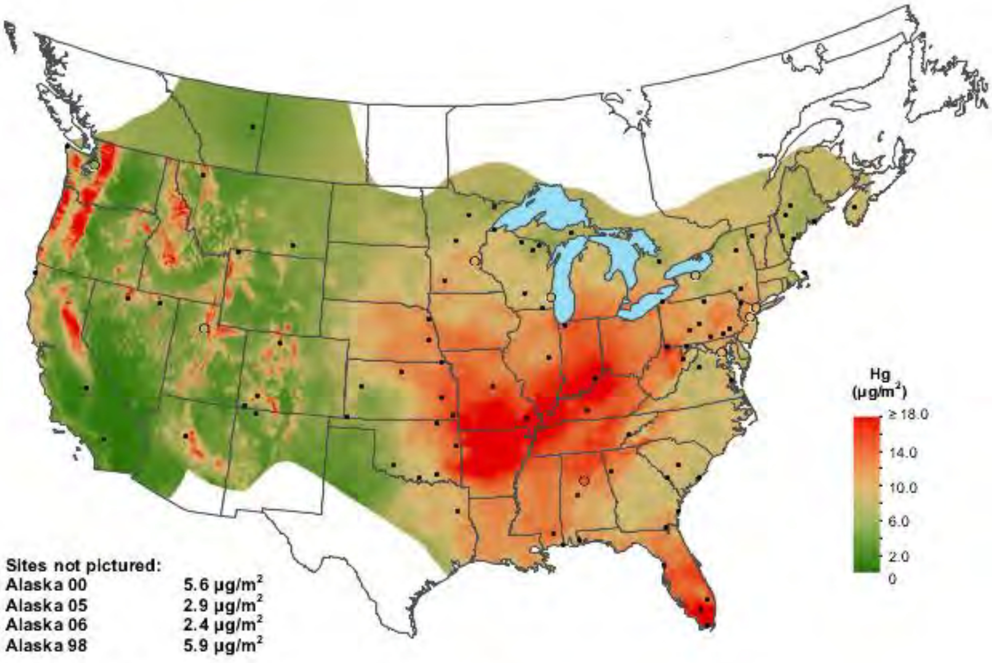


Figure 4-1. Locations of Mercury Deposition Network monitoring sites in the vicinity of Hells Canyon Complex. Adapted from NADP (2013).

Table 4-1. Average wet deposition at Mercury Deposition Network monitoring sites. Data source: NADP 2013.

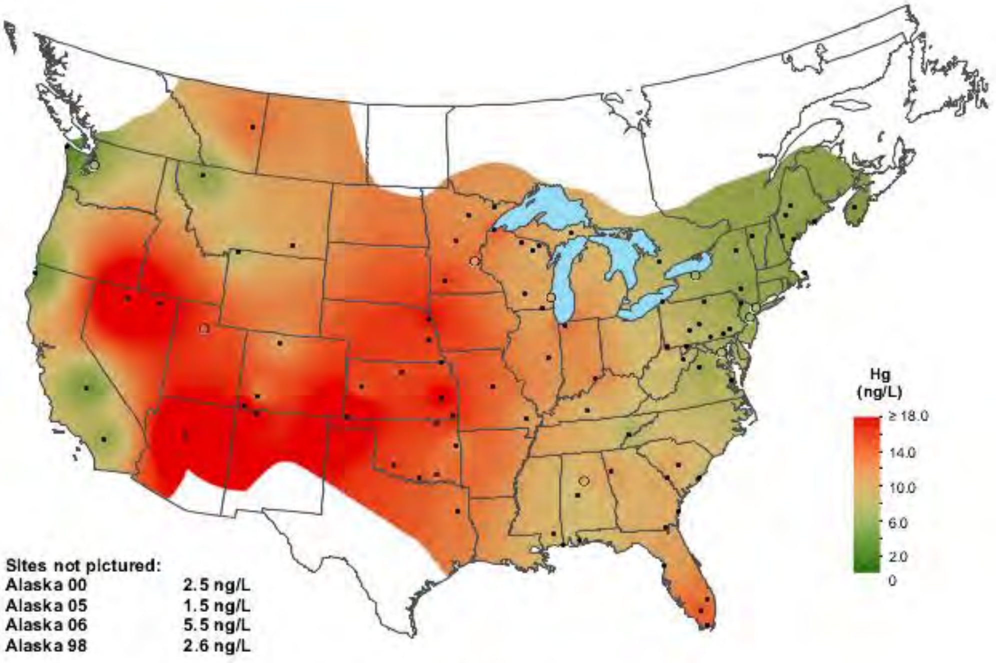
	Wet Hg deposition (µg m^{-2} yr^{-1})				
Site	**2007**	**2008**	**2009**	**2010**	**Average**
ID03	2.8	3.0	7.3	5.4	4.6
ID98	-	2.9	-	-	2.9
ID99	-	7.6	5.0	-	6.3

National scale maps of annual Hg wet deposition rates and Hg concentrations in precipitation are also produced by the MDN (Figure 4-2 and Figure 4-3). These maps are produced by a model that interpolates among observation points to develop contours of Hg deposition or concentration (NAPD, 2013). Given the limited number of observation sites in the western United States used to develop these maps and the high degree of spatial variability in estimated Hg deposition rates in mountainous areas, some caution is advised in interpreting local Hg deposition rates from these maps.



National Atmospheric Deposition Program/Mercury Deposition Network
http://nadp.isws.illinois.edu

Figure 4-2. MDN estimated THg wet deposition for 2011.



National Atmospheric Deposition Program/Mercury Deposition Network
http://nadp.isws.illinois.edu

Figure 4-3. MDN estimated THg concentrations in precipitation for 2011.

5. Discussion and Conclusions

This technical memorandum describes data obtained regarding Hg concentrations in fish, water and sediments in Hells Canyon Complex and upstream/downstream in the Snake River from RM 108 to RM 917. While many fish have been sampled and analyzed for fish Hg concentrations since the late 1960s (736 analyses identified), the data are split among 24 fish species, multiple years and multiple sampling locations (Table 2-1). It is concluded that the data included in this assessment are insufficient to estimate current baseline fish Hg concentrations, temporal trends or spatial variability for any species in Hells Canyon Complex or more broadly from RM 108 to RM 917 in the Snake River. The data are either limited by insufficient numbers of analyses of individual fish from sampling events and/or the data are too old (e.g. more than a decade) to be considered representative of current conditions. Fish Hg data collected since 2000 are very limited (see Figure 2-3 for upstream sites and Figure 2-6 for Brownlee Reservoir). No fish sampling was identified for Oxbow Reservoir at any time, and only 12 analyses were identified for fish in Hells Canyon Reservoir. No fish Hg data were identified downstream of HCC after 1997.

Hg concentrations in fish tend to increase with age and size. A commonly used approach to address the effects of fish size is to collect 2-3 dozen fish for a desired species at a given location and time, spanning a range of sizes. Statistical regressions can then be developed for fish Hg concentration versus length, and a standard length chosen for each fish species. This approach allows data from different locations or times to be assessed for temporal or spatial trends, and is the approach recommended for the Snake River. An example of this practice is the extensive sampling of perch in the early 1970s (Figure 2-2c), but those data cannot be assumed representative of current conditions. Fish samples were sometimes aggregated into composites that were subsequently analyzed for Hg concentrations. These results are of limited use to establish baseline concentrations or trends, because the composite Hg concentration cannot be associated with a specific size fish.

Measurements of Hg concentrations were available for the water column in Brownlee Reservoir in the fall of 2011 and May 2012, Oxbow Reservoir in 2006 and 2011, and upstream of HCC in 2006 and 2008 between RM 409 and RM 900 (about 66–557 miles upstream of HCC) (Table 3-1). Additional water column Hg data from Brownlee Reservoir in 2007 were considered of limited use due to analytical detection and quantification limits reported. Observed concentrations of THg and MeHg in surface waters were typical of systems without point source Hg loads. Sediment THg concentrations were also within the range reported for systems without point-source Hg loads. In contrast, MeHg concentrations and the percent of THg in the form of MeHg in deep waters and surface sediments of Brownlee were significantly elevated, particularly for hypolimnion samples collected in fall 2011 (Harrison *et al*., 2012). These data suggest highly efficient conversion of inorganic Hg into MeHg in deep waters and/or sediments in the late summer and fall when anoxic conditions are established that are favorable for microbes that methylate Hg (*e.g.* sulfate reducing bacteria). While the existing data identify the buildup of MeHg in deep waters, additional water column sampling in Brownlee Reservoir and downstream on a seasonal basis, possibly monthly in the fall, would better quantify the mass of MeHg produced in deep waters, mixed into surface waters, and exported downstream. Because of consideration also being given to releasing cold water from Hells Canyon Reservoir, water column sampling designed to identify the formation of MeHg in the hypolimnion of Hells Canyon Reservoir is recommended.

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Exhibit 7.1-1
Technical information for Hells Canyon Complex modeling used in development of the Brownlee Reservoir operational component.

Technical information for Hells Canyon Complex Modeling Used in Development of the Brownlee Reservoir Operational Component

Idaho Power Company

CE-QUAL-W2 and Multiple Regression Modeling

Technical Report

Hells Canyon Complex, FERC Project No. 1971

May 2018

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1. INTRODUCTION

This document provides technical supporting information for modeling used in development of the Brownlee operational component of IPC's proposed Temperature Management Plan (TMP) in the CWA Section 401 Water Quality Certification Application as updated in February 2018.

IPC's Brownlee operational component of the TMP is to draft Brownlee Reservoir, beginning after Labor Day, to a lower elevation than would otherwise be required for the Snake River Fall Chinook (SRFC) flow program. IPC's current fall drafts of Brownlee Reservoir are set primarily to accommodate stable SRFC spawning flows. Specifically, the fall minimum elevation is reached around the second Monday in October after which the Hells Canyon Complex (HCC) outflows are held stable for the SRFC flow program (i.e., until the 2nd Friday in December). The targeted minimum Brownlee elevation is identified in early September, based primarily on forecasted inflow volumes, the level of HCC outflows planned during the stable flow period and the ability to refill Brownlee for winter power production. Other factors considered include system reliability, power markets, and recreational impacts.

IPC's proposal for the TMP is to include forecasted HCC outflow 7-day average maximum (7-DAM) temperature conditions into the decision matrix, as a priority, and draft Brownlee to a lower elevation than otherwise planned in years when there is a high probability that temperature will exceed 16.5°C. The goal of this operation will be to cool HCC outflows and remain below 16.5°C as a 7-DAM temperature during the salmonid spawning period. For compliance purposes, IPC proposes that this component would be applied so that the 16.5°C target would not be exceeded in 3 consecutive years. The 3-consecutive year threshold is based on several factors. First, the 3-consecutive year threshold is intended to be consistent with the Nez Perce Tribe comments submitted on February 28, 2017 regarding Oregon and Idaho's draft 401 certifications. Second, potential future climate conditions and forecasting uncertainty precludes a realistic expectation that a 7-DAM of 16.5°C can be ensured every year. In addition, the 3-consecutive year target is based on SRFC life history and avoiding effects of high temperatures on the same cohort as eggs and on embryo production resulting from that cohorts potentially reduced adult return. If 16.5°C is exceeded in three consecutive years, the adaptive management and alternative measures provisions of the TMP would be implemented.

We used both CE-QUAL-W2 models and multiple regression modeling to develop the Brownlee operational component. CE-QUAL-W2 modeling was used to simulate the effectiveness of a deeper fall draft of Brownlee in cooling the outflow from Brownlee which carries through Oxbow and Hells Canyon reservoirs to cool the river downstream of the HCC. Since the Brownlee operational component of IPC's proposal will require forecasting HCC outflow temperature at the beginning of the salmonid spawning period we used multiple regression modeling as an example of one potential forecasting tool available, at this time, to explore the potential uncertainty and variability in forecasting these conditions.

2. CE-QUAL-W2 MODEL DEVELOPMENT AND CALIBRATION

Prior to this modeling effort, to support the FERC license application process, IPC developed CE-QUAL-W2 models for Brownlee, Oxbow, and Hells Canyon reservoirs (Harrison et al. 1999; Zimmerman et al. 2002). Models were initially developed for 1992, 1995, 1994, 1997, and 1999. These years were selected based on water-year conditions combined with data availability for set-up and calibration. The initial calibration effort was focused on 1992, 1995, and 1997 for low, medium, and high water years, respectively. The 1994 and 1999 models represent medium-low and medium-high water years, respectively. The 1994 and 1999 models were developed as verification years (e.g., the model settings developed through calibration of the other years were applied to these years). The general calibration process for the HCC models is described in Harrison et al. (1999) and Zimmerman et al. (2002). Most of the calibration effort was focused on conditions in Brownlee Reservoir where physical and biological processes are more complex. Also, field studies consistently show that conditions in Oxbow and Hells Canyon Reservoirs are driven by Brownlee outflow conditions.

In 2002, a large data collection effort by IPC and others provided additional information relative to inflowing Snake River organic matter, including algae (Harrison 2005). Also studied were Brownlee hydrodynamics, temperature stratification, DO dynamics, meteorological conditions, and intake channel configuration (Botelho et al. 2003, Botelho and Imberger 2007). A 2002 CE QUAL-W2 model was developed using this additional information, which reduced uncertainty relative to boundary conditions for the existing low-water year model (i.e., 1992). After the 2002 model was developed, many of the updates and improvements were then applied to the other model years, and calibration for all the years was re-evaluated. This collection of models was used to develop IPC’s responses to the FERC additional information requests on the New FERC License Application for the HCC and the initial 401 water quality certification applications (Figure 1).

A subset (1992, 1995, 1997 and 2002) of the HCC models have recently been upgraded to CE-QUAL-W2 Version 3.7 (Figure 1). As part of this upgrade process, the settings for all the models were reviewed. Two changes, specific to temperature settings and the Hells Canyon Reservoir model, included resetting evaporation coefficients to default values and updating the bathymetry to include the old coffer dam that remains in place upstream of HCD.

Of this subset of updated models, we used the 2002 model along with a newly developed 2015 model to develop the Brownlee operational component. The 2015 model was developed specifically for this effort to include the year with the warmest (of the 27-year dataset) HCC outflow temperature conditions at the start of the salmonid spawning period. The 2002 and 2015 models are both low-water year models which allowed us to evaluate conditions when the largest exceedances of the salmonid spawning criterion are typically seen in historical data.

To initially set up the 2015 CE-QUAL-W2 model, parameters that govern the hydrodynamics, chemical, and biological processes in the reservoir were set to match the latest previously developed and calibrated models. Generally, measured field data were used as boundary conditions. After the boundary conditions were developed, parameters governing the reservoir processes were refined, through the process of calibration. Attachment 1 provides electronic files for water quality, meteorological and streamflow boundary condition along with water quality data and comparisons used to calibrate and optimize the 2002 and 2015 models used in development of the Brownlee operational component.

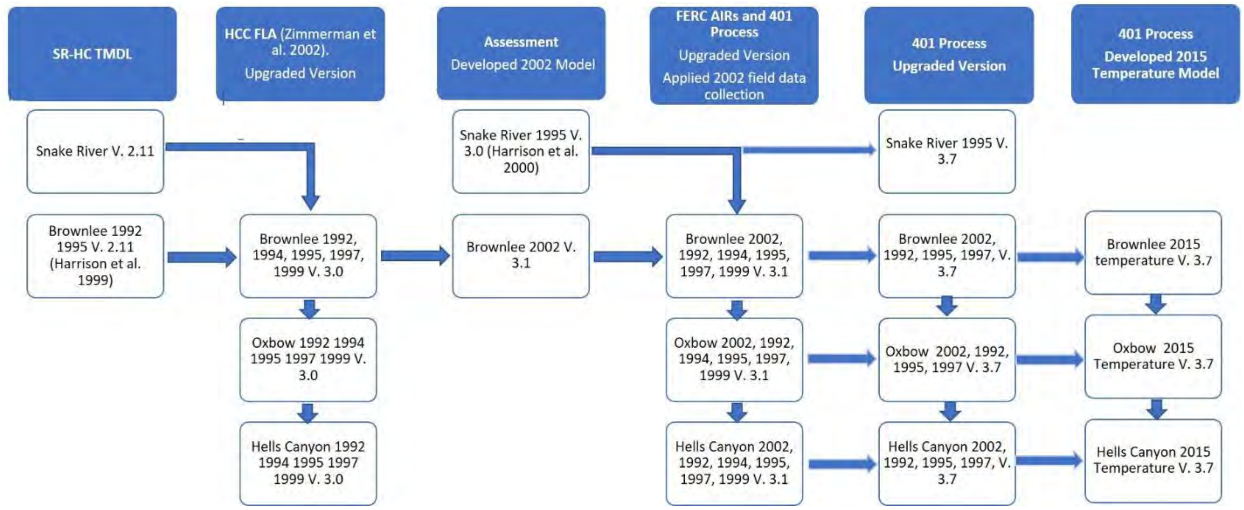


Figure 1
Evolution of IPC CE-QUAL-W2 modeling efforts beginning with the Snake River-Hells Canyon TMDL (SR-HC TMDL) development process in 1995, continuing to the development of the Final License Application (FLA) for the Hells Canyon Complex (HCC) in 2003, responding to the FERC Additional Information Requests (AIRS) in 2005 and continuing through the 401 application process.

2.1. Boundary Conditions and Model Configuration

The boundary conditions we used in the selected CE-QUAL-W2 models consist of time-series data spanning the entire calendar year for flows, water quality and meteorological conditions. Boundary conditions also include reservoir bathymetry, dam geometry, topographical shading and initial conditions which do not change over the year. Boundary conditions for the selected model years were based on measured data from various locations (Table 1). In most cases, the raw data could be used but in some instances the boundary conditions were developed through transformations or relationships with the measured data. The Brownlee Oxbow and Hells Canyon Reservoir models were run as linked models meaning the output temperature and water quality constituents from the upstream model was used for the input to the downstream model ending at the outflow from Hells Canyon Reservoir.

Table 1
Description of boundary conditions used in the 2002 and 2015 Brownlee, Oxbow and Hells Canyon Reservoir CE-QUAL-W2 models. For the 2015 model Na indicates not applicable because the 2015 models were only developed for temperature.

Boundary condition	Boundary Condition Description	
	2002	2015
Brownlee Reservoir		
Snake River inflow rate	Historical Snake River at Weiser gage 7-day “centered” average, balanced	IPC estimated daily total Brownlee inflow minus the Powder Powder River near Richland, Eagle Creek near New Bridge and Burnt River near Huntington, balanced.

Boundary condition	**Boundary Condition Description**	
	2002	**2015**
Snake River inflow temperature	Measured at Brownlee inflow (RM 345.6) every 10 minutes or RM 340 every two weeks to fill gaps	Measured at Brownlee inflow (RM 345.6 or 345.2) every 10 or 30 minutes.
Snake River dissolved oxygen	Measured at Brownlee inflow (RM 345.6) every 10 minutes or RM 340 every two weeks to fill gaps	Na
Snake River inflow water quality[1]	Algae (as chlorophyll a) measured at Brownlee inflow (RM 345.6) every 10 minutes. Dissolved nutrients measured at RM 340 or RM 345.6 approximately every two weeks. Organic matter partitioned using measurements of organic carbon, chlorophyll a, BOD and COD.	Na
Powder River inflow rate	Measured hourly average Powder River near Richland plus Eagle Creek near New Bridge	Measured Powder River near Richland plus Eagle Creek near New Bridge
Powder River inflow temperature	2002 measured hourly or biweekly near Powder River mouth	2015 measured every 15 minutes at Powder River near Richland gage
Powder River inflow DO	1999-2000 measured near Powder River mouth approximately monthly	Na
Powder River inflow Water Quality	1999-2000 measured near Powder River mouth approximately monthly and relationships with Snake River data	Na
Burnt River inflow rate	Measured hourly Burnt River near Huntington	Measured daily average Burnt River near Huntington
Burnt River inflow temperature	2002 measured hourly or biweekly near Powder River mouth	2015 measured every 15 minutes at Burnt River near Huntington
Burnt River inflow DO	1999-2000 measured near Burnt River mouth approximately monthly	Na
Burnt River inflow Water Quality	1999-2000 measured near Burnt River mouth approximately monthly	Na
Meterological conditions	Measured data from Lake Stations, Brownlee Dam, Boise, Idaho or transformed measured wind data from Parma, Idaho	Hourly average from Brownlee Dam met station (7/28 to 12/31) or Ontario, Or Agrimet. Cloud cover from Mountain Home, ID. Adjustments were applied.
Turbine outflow rate	IPC measured Brownlee turbine flows hourly	IPC measured Snake R. Below Brownlee gage hourly average, balanced
Spill outflow rate	IPC measured Brownlee spill flow hourly	IPC measured Brownlee spill flow hourly average
Oxbow Reservoir		
Snake River inflow rate	Combined measured Brownlee turbine plus spill outflow hourly	IPC measured Snake R. Below Brownlee gage hourly average, balanced
Snake River inflow temperature	Flow weighted turbine and spill outflow temperature from Brownlee model	Flow weighted turbine and spill outflow temperature from Brownlee model
Snake River inflow DO	Flow weighted turbine and spill outflow DO from Brownlee model	Na
Snake River inflow water quality	Flow weighted turbine and spill outflow constituents from Brownlee model	Na
Wildhorse River inflow rate	2002 measured near Wildhorse River mouth hourly	Daily average measured at Wildhorse at Brownlee gage.
Wildhorse River inflow temperature	2002 Measured near Wildhorse River mouth hourly	2015 measured every 15 minutes at Wildhorse at Huntington gage
Wildhorse River inflow DO	1999-2000 measured near Wildhorse River mouth approximately monthly	Na

Boundary condition	**Boundary Condition Description**	
	2002	**2015**
Wildhorse River inflow Water Quality	1999-2000 measured near Wildhorse River mouth approximately monthly	Na
Meterological conditions	Same as applied to Brownlee model waterbody 3 (closest to Dam)	Same as applied to Brownlee model waterbody 3 (closest to Dam) with adjustment to air temperature based on historic Hells Canyon Dam vs. Brownlee Dam Met station data
Turbine outflow rate	IPC measured Oxbow turbine outflows hourly	IPC measured Snake R. Below Oxbow gage hourly average, balanced
Spill outflow rate	IPC measured Oxbow spill flow hourly	IPC estimated Oxbow spill flow hourly
Hells Canyon Reservoir		
Snake River inflow rate	IPC measured Oxbow turbine flows hourly and measured Oxbow spill flow hourly (two separate inputs)	IPC measured Snake R. Below Oxbow gage hourly average, balanced
Snake River inflow temperature	Oxbow model output turbine outflow temperature and spill outflow temperature hourly (two separate inputs)	Oxbow model output turbine outflow temperature and spill outflow temperature hourly (two separate inputs)
Snake River inflow DO	Oxbow model output turbine outflow DO and spill outflow DO hourly (two separate inputs)	Na
Snake River inflow water quality	Oxbow model output turbine outflow DO and spill outflow DO hourly (two separate inputs)	Na
Pine Creek inflow rate	2002 measured Pine Creek near Oxbow hourly	2015 measured Pine Creek near Oxbow hourly average
Pine Creek inflow temperature	1999 measured near Pine Creek mouth hourly	2015 measured Pine Creek near Oxbow hourly average
Pine Creek inflow DO	1999-2000 measured near Pine Creek mouth approximately monthly	Na
Pine Creek inflow Water Quality	1999-2000 measured near Pine Creek mouth approximately monthly	Na
Meterological conditions	Same as applied to Brownlee model waterbody 3 (closest to Dam)	Same as applied to Brownlee model waterbody 3 (closest to Dam) with adjustment to air temperature based on historic Hells Canyon Dam vs. Brownlee Dam Met station data
Turbine outflow rate	IPC measured Hells Canyon turbine ouflow hourly	IPC measured Snake River below Hells Canyon turbine ouflow hourly average
Spill outflow rate	IPC measured Hells Canyon spill outflow rate	IPC measured Hells Canyon spill outflow rate

2.1.1. Reservoir Bathymetry and Dam Geometry

Topographic data from IPC’s geographical information system (GIS), along with detailed bathymetry surveys were used to generate the model grids for all three HCC reservoirs. Overall, the Brownlee Reservoir model grid includes the Snake River from the Brownlee Dam (RM 284.6) to the head of Brownlee Reservoir (RM 336), a separate grid for the Powder River arm (entering at RM 296) and a separate grid for the turbine intake channel (Table 2). The Brownlee Reservoir grid was divided into three waterbodies to allow for spatially variable meteorological conditions and other kinetic coefficients to be applied to each waterbody. The Oxbow and Hells Canyon Reservoir model grids are relatively simple with variable segment lengths based on orientation, width and depth of the reservoirs (Table 2).

Table 2
Description of Hells Canyon Complex CE-QUAL-W2 model grid for the 2002 and 2015 models.

Reservoir	Waterbody	Branches within waterbody	Description	Model segments	Segment length/layer height
Brownlee	1	Branch 1	Brownlee Reservoir Main Branch,	2-41	1004.84 m long. 1.52 m high
Brownlee	2	Branch 2	Brownlee Reservoir Main Branch,	44-70	1004.84 m long. 1.52 m high
Brownlee	3	Branch 3	Brownlee Reservoir Main Branch,	73-93	1004.84 m long. 1.52 m high
Brownlee	3	Branch 4	Powder River Branch connects to Brownlee Reservoir at River Mile 296	96-109	1071.14 m long. 1.52 m high
Brownlee	3	Branch 5	Brownlee Turbine Intake Channel	112-116	43.57 m long. 1.52 m high
Oxbow	1	Branch 1	Oxbow Reservoir Main Branch	2-33	Variable from 222.77-1039.45 m long. 2.0 m high
Hells Canyon	1	Branch 1	Hells Canyon Reservoir Main Branch	2-59	Variable from 121.7-1294.1 m long. 2.0 m high

2.1.2. Topographical Shading

Topographical shading is included for all 3 reservoir models. Input files were developed using IPC's geographical information system (GIS) based on Digital Elevation Model files.

2.1.3. Meteorological Data

Meteorological (Met) parameters included in the 2002 and 2015 models include high frequency (i.e., every 15 minutes to hourly) air temperature, wind speed and direction, dew point temperature, solar radiation and cloud cover.

For the 2002 Brownlee model, depending on availability, we used measured data from 3 Lake Stations deployed on Brownlee Reservoir (Botelho et al. 2003, Botelho and Imberger 2007), data from the Brownlee Dam station, or transformed (using relationships with Lake Station data) measured wind data from Parma, Idaho. A different wind condition was applied to each of the 3 waterbodies in the Brownlee model. For the 2002 Oxbow and Hells Canyon Models, we applied the same Met conditions as the most downstream waterbody in the Brownlee model. Additional information on development of Met conditions for 2002 is provided in Attachment 1.

There were no Lake Stations deployed on Brownlee in 2015, therefore, Met conditions were used from the Brownlee Dam Met station, the Ontario, Oregon Agrimet station and Mountain Home, ID. The same Met condition was applied to all 3 waterbodies in the Brownlee model (Figure 2). Air temperature, wind speed and wind direction were available from the Brownlee dam met station only for the second half of 2015 (July 28th to end of year) and were used preferentially.

Other datasets from Ontario, Oregon and Mountain Home, Idaho were used to fill in the gaps in the Brownlee Dam met data. Mountain Home was only used for cloud cover data because that parameter was not available at any of the other stations.

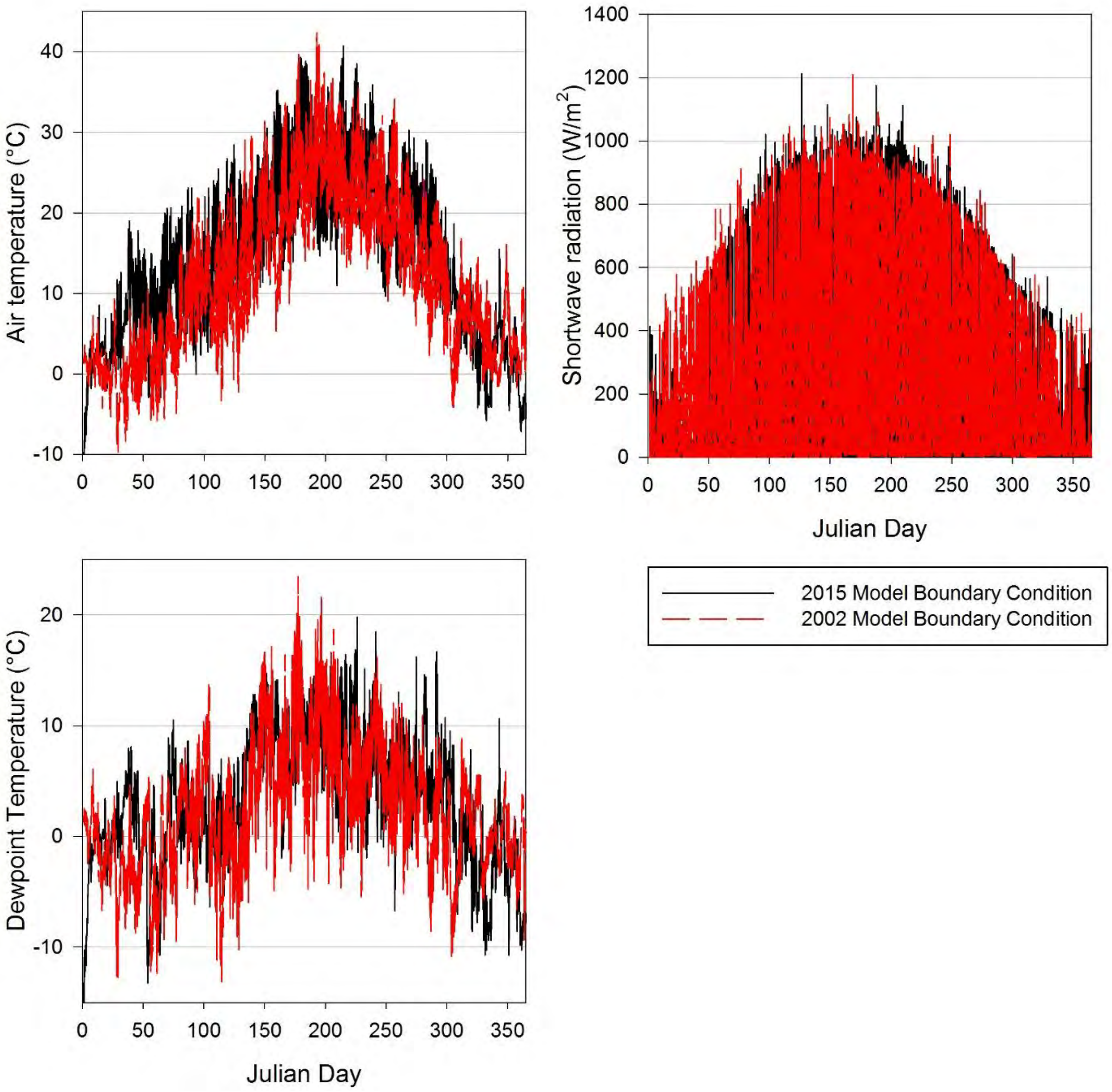


Figure 2
Selected meteorological boundary conditions for the Brownlee Reservoir CE-QUAL-W2 model, waterbody 3, compared between 2015 and 2002.

Before the datasets were combined, comparisons were made to look for large discrepancies that could cause issues when adjusting model coefficients during calibration (i.e. wind sheltering coefficients) and/or could be adjusted for by converting data before applying it to the model. These comparisons were made using a multi-year dataset from August 2012-December 2015 containing data from 3 locations of interest (Brownlee Dam, Parma, and Ontario). Linear regression of air temperature between Ontario and Brownlee Dam showed Brownlee air temperature overall was warmer (about 1.5°C) than Ontario so the regression equation (Figure 3) was used to adjust 2015 Ontario air temperature to represent Brownlee air temp when using Ontario data (first half of 2015). A similar relationship was seen with humidity and regression was used to adjust Ontario humidity also before calculating dew point temperature.

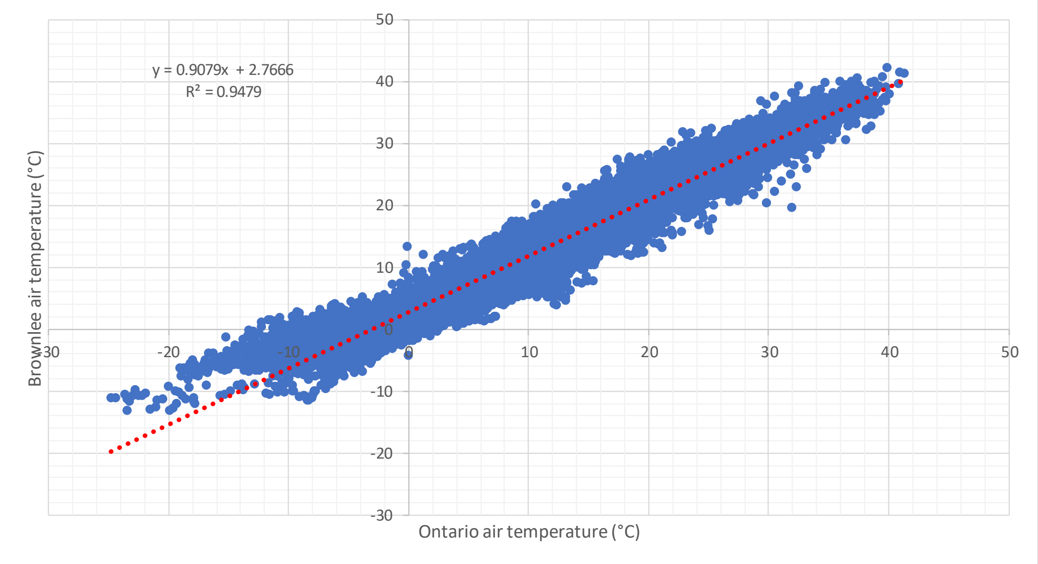


Figure 3
Hourly air temperature compared between the IPC Brownlee Dam Meteorological station and Ontario Agrimet station where available from August 2012 to December 2015. The regression equation was used to adjust Ontario air temperature when used for the Brownlee Reservoir CE-QUAL-W2 2015 model.

2.1.4. Hydrology

Measured data from gages maintained by USGS and IPC were used to develop the base hydrology boundary conditions for the models (Table 1). Because of inherent small error in any measured flow data, as well as the inability to measure all flow sources to a system the size of the HCC, completing the water balance for the model is an iterative process. After running the models initially with the measured flows the reservoirs were balanced to add or subtract flows as needed to match the water surface elevations observed in each year as closely as possible. Additional information on the flow boundary condition for the 2002 model is provided in Attachment 1.

For the 2015 model, we balanced the flows throughout the HCC using the water balance utility program (provided as part of the CE-QUAL-W2 package) to compute balance flows starting with the Hells Canyon model and working upstream. For each reservoir we added or subtracted flow from inflows and used the balanced flow files as the outflow for the next upstream model. The Hells Canyon model was balanced first, the balanced Hells Canyon Reservoir inflows were then used as Oxbow outflows when balancing the Oxbow model and then the balanced Brownlee Dam outflows were then used in balancing the Brownlee Reservoir model where adjustments were made to the Snake River inflow boundary condition. Following this process, the resulting daily average inflow boundary condition to Brownlee showed generally more flow compared to measured data from the Snake River at Weiser, ID gage location (Figure 4). This additional flow is explained partially by the many unmeasured inputs into Brownlee Reservoir.

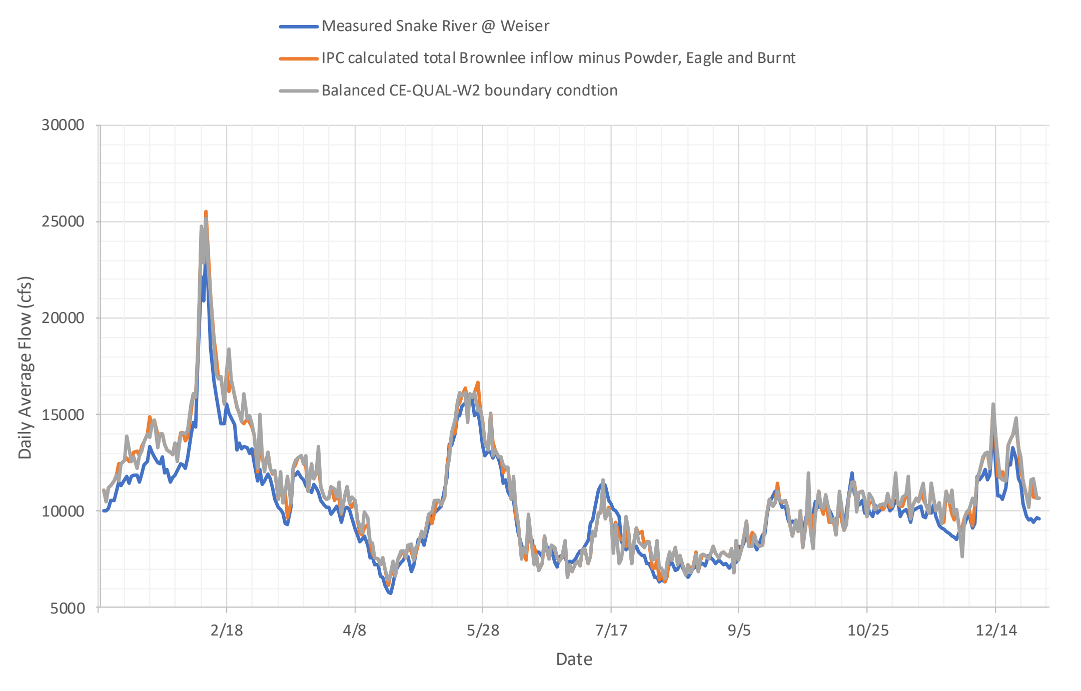


Figure 4
Comparison of measured daily average Snake River flow at Weiser, ID with the base boundary condition and the final balanced boundary condition for the 2015 model.

2.1.5. Water Quality Constituents

A full suite of water quality constituents including dissolved oxygen, algae, dissolved nitrogen and phosphorus, multiple organic matter fractions (e.g. labile and refractory dissolved and particulate organic matter) and inorganic suspended sediment was included in the 2002 model (Table 1, Attachment 1). Water quality constituents were not included in the 2015 model which was developed for temperature only.

2.1.6. Water Temperatures

High frequency water temperature measurements (every 10 minutes to hourly) were used for most of the temperature boundary conditions in both the 2002 and 2015 models (Table 1, Attachment 1). Snake River inflow to Brownlee was warmer in 2015 than 2002 during most of the year but most significantly in the fall (Figure 5).

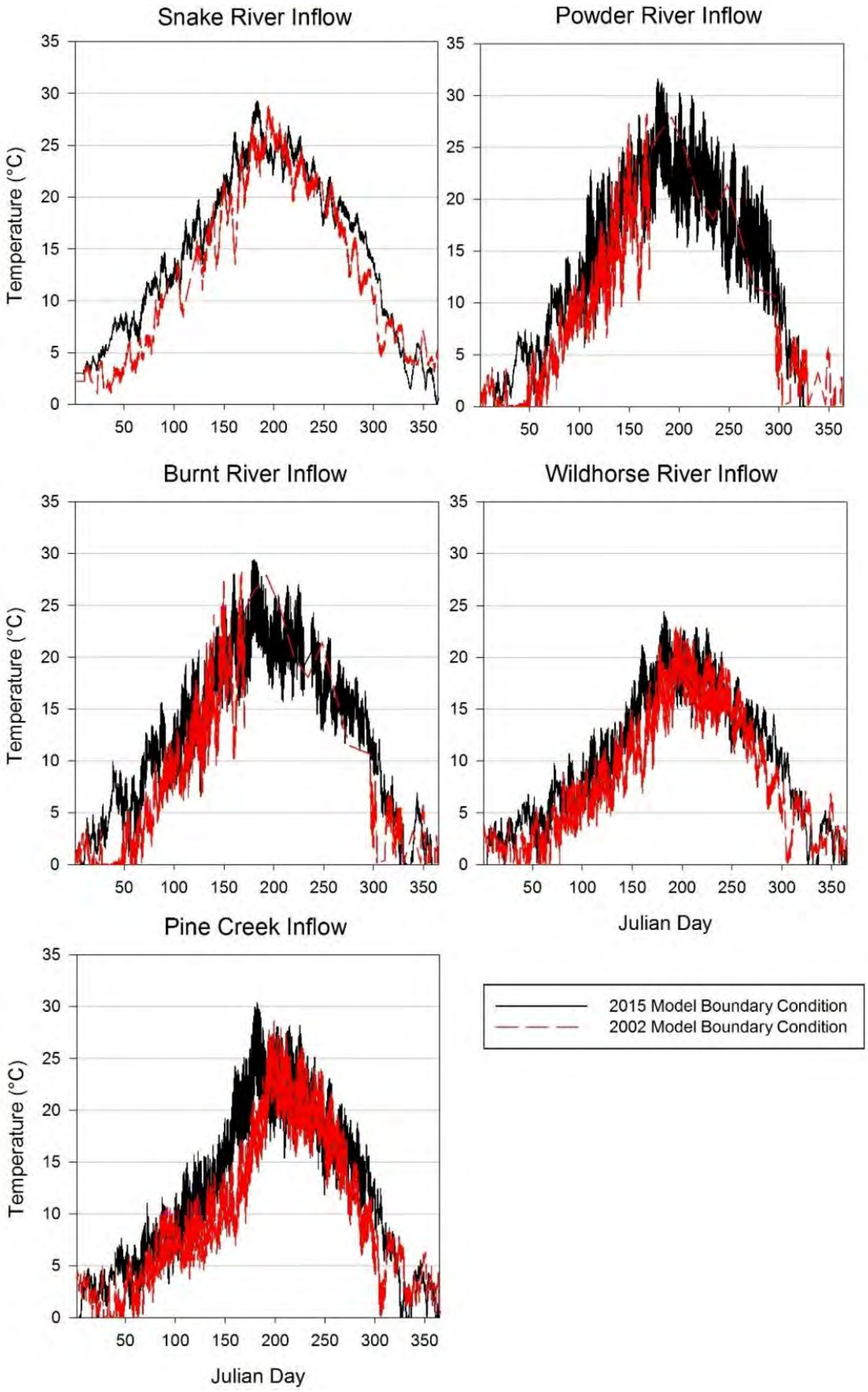


Figure 5.
CE-QUAL-W2 model temperature boundary conditions for 2002 and 2015.

2.2. CE-QUAL-W2 Calibration

The general calibration process for the 2015 and 2002 models was similar to the calibration process IPC used in previous CE-QUAL-W2 model development. That process is described and documented in Harrison et al. (1999) and Zimmerman et al. (2002). Most of the calibration effort was focused on conditions in Brownlee Reservoir where physical and biological processes are more complex. Also, field studies consistently show that conditions in Oxbow and Hells Canyon Reservoirs are driven by Brownlee outflow conditions.

Exactly matching historical data on a small time step with model-generated output is difficult because it is impossible to capture the entire range of complex climatological, hydrodynamic, and biological interactions. Instead, through the calibration process, we focused on fine-tuning the model so that it recreated the trends and range of processes of the historical field data to an acceptable degree of accuracy. The approach to model calibration addresses the following separate but related groups of processes:

- Physical processes that influence the hydrodynamics and bathymetry of the reservoir
- Biological processes that describe the nutrient, phytoplankton, or DO dynamics within the reservoir

Of these two groups of processes, physical processes drive the circulation patterns and determine the distribution of temperatures in the reservoir. Several parameters can affect these circulation patterns and temperature structure in the reservoir:

- Inflow rates and corresponding temperatures
- Discharge rates through the turbines and over the spillways
- The bathymetry or geometry of the reservoir
- Bottom friction and surface wind-shear stresses
- Heat transfer through the water surface or reservoir bottom
- Mixing and transport within the reservoir

Biological processes—or the nutrient, phytoplankton, or DO interactions within the reservoir—also depend on several factors:

- Advection of water quality constituents with currents in the reservoir
- Water depth and incident solar radiation
- Reaction kinetic parameters, such as rates of phytoplankton growth and decay, nutrient
- uptake, and so forth
- Water temperatures, which influence reaction rates
- Benthic interaction with the water column, such as sediment oxygen demand (SOD) and
- nutrient recycling

In general, biological processes have little influence on the hydrodynamics of the reservoir. However, the transport and reaction rates of the water quality constituents depend directly on the water circulation and temperature structure. In calibrating the model, it is important to first focus on recreating the hydrodynamic patterns within the reservoir. This was done during the calibration process by focusing on temperature calibration within the reservoirs first. During temperature calibration, only the wind-sheltering coefficient was adjusted significantly. As discussed in Section 2.1.3 the 2002 and 2015 wind boundary conditions were developed using different data sources (due to Lake Station data availability for 2002) and methods. This resulted in wind boundary conditions that were likely more representative of actual wind on the reservoir for the 2002 model. The wind-sheltering coefficients in CE-QUAL-W2 are designed to fine-tune the wind velocity for each model segment since the exact same wind condition on long narrow reservoirs such as the HCC reservoirs is not realistic. As a result, a different collection of wind sheltering coefficients resulted for the 2002 and the 2015 models.

Calibrating the 2002 model for water quality (e.g., DO) involved evaluating the following organic matter partitioning and various first-order kinetic, rate, and temperature coefficients. During calibration, we found that water quality components of the model were most sensitive to the following factors:

- Labile to refractory decay rate
- Phosphorus partitioning coefficient for suspended solids
- Sediment oxygen demand
- Algal growth rate
- Temperature coefficients

We used several methods to analyze model output for comparing model runs and improving its calibration. These methods included animations of temperature and other constituents over time, time-series plots of the outflow constituents, and isopleths and profile plots at various locations and times in the reservoir. We also used absolute mean error (AME) analysis as a quantitative means of assessing in-reservoir calibration. Measured temperature collected at multiple depths and locations in the reservoir were compared with modeled values and summarized to show the overall error over the year. The equation for AME can be described as:

$$AME = \frac{\sum |\mathrm{X_m} - \mathrm{X_d}|}{N}$$

Where:

- X_m = Modeled value
- X_d = Measured value
- N = number of data pairs

Overall, both the 2002 and 2015 models simulated Brownlee in-reservoir temperature with an AME of less than 1°C (Table 3, Attachment 1) with 2015 performing slightly better than 2002. The 2002 model simulated Brownlee in-reservoir DO with an AME 1.1 mg/L. For Brownlee, in 2002, we compared 62 separate profiles at 11 locations in the reservoir from June through November, while in 2015 we summarized approximately 264 individual profiles at 22 locations in the reservoir from April through October. Example profile comparison plots show that Brownlee temperature stratification was simulated very well by the models for both years (Figure 6). In-reservoir Hells Canyon temperature was not measured in 2002, however, 8 in-reservoir Hells Canyon profiles were available from 2 locations from April through October for comparison in the 2015 model. Hells Canyon in reservoir temperature was also simulated well in 2015 with an average AME of 0.9°C.

Table 3
CE-QUAL-W2 calibration absolute mean error (AME) statistics for in Brownlee Reservoir, Hells Canyon Reservoir and Hells Canyon Outflow for the 2002 and 2015 models. AME for Hells Canyon outflow is averaged for both year round and for the fall to show more resolution on the period preceding and during the beginning of the salmonid spawning period.

Model Year	Brownlee in-reservoir AME (°C)	Hells Canyon in-Reservoir AME (°C)	Hells Canyon outflow 7-DAM AME (°C)	
			Average year round	Average Sept 1 – Dec 31
2002	0.70	Na	0.59	0.52
2015	0.55	0.90	0.40	0.32

Note: Na indicates not available

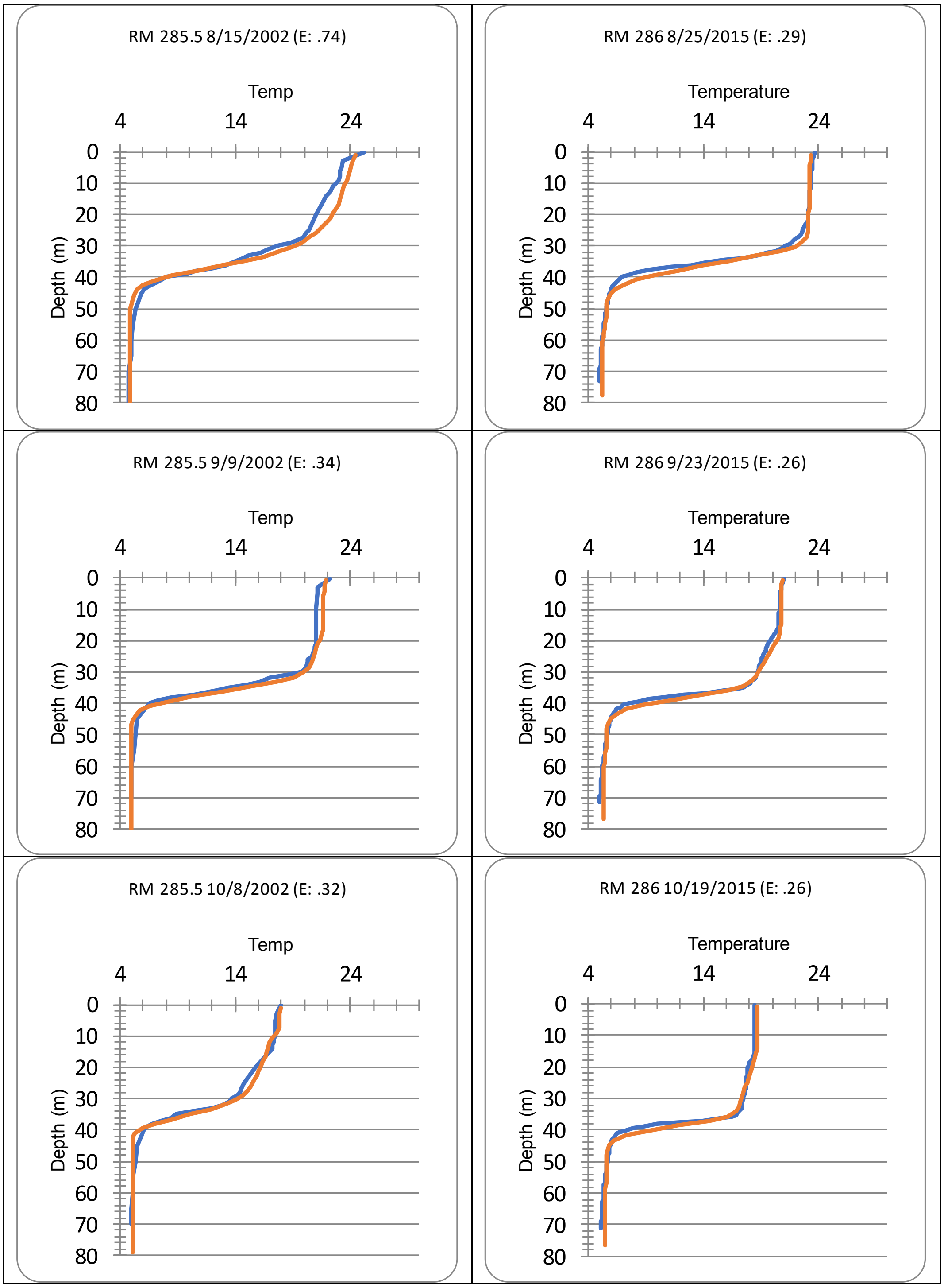


Figure 6
Example profile comparison plots for 2002 and 2015 modeled (orange line) and measured (blue line) temperature near Brownlee Dam.

Modeled Brownlee and Hells Canyon outflow temperature resulting from linking (i.e., outflow conditions from the upstream reservoir used as input conditions for the next downstream reservoir) was also compared with measured temperature as part of calibration. Since the salmonid spawning period temperature criterion is based on a 7-DAM temperature statistic we used the hourly model output and measured data to calculate this statistic and made error comparisons using a 7-DAM temperature. At Hells Canyon outflow the AME for 7-DAM temperature was also slightly better for 2015 than for 2002 (Table 3). During the time frame when the Brownlee Operational Component would be implemented (i.e., beginning after Labor Day) both models were consistently slightly cooler than measured data with 2015 showing a closer calibration than 2002 (Figures 7 and 8).

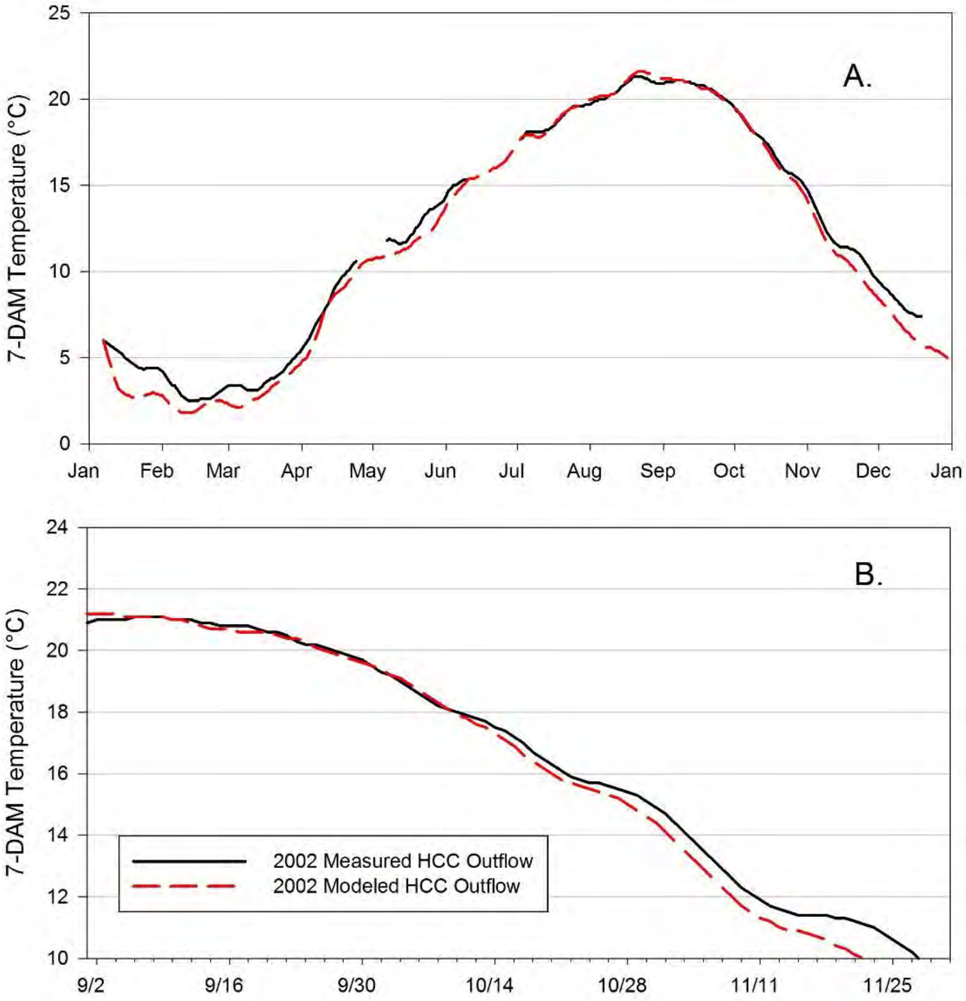


Figure 7
Modeled Hells Canyon outflow 7-DAM temperature compared with measured 7-DAM temperature for the 2002 CE-QUAL-W2 model. Panel A. shows the comparison for the year while Panel B. is rescaled to show more resolution on the period preceding and during the beginning of the salmonid spawning period.

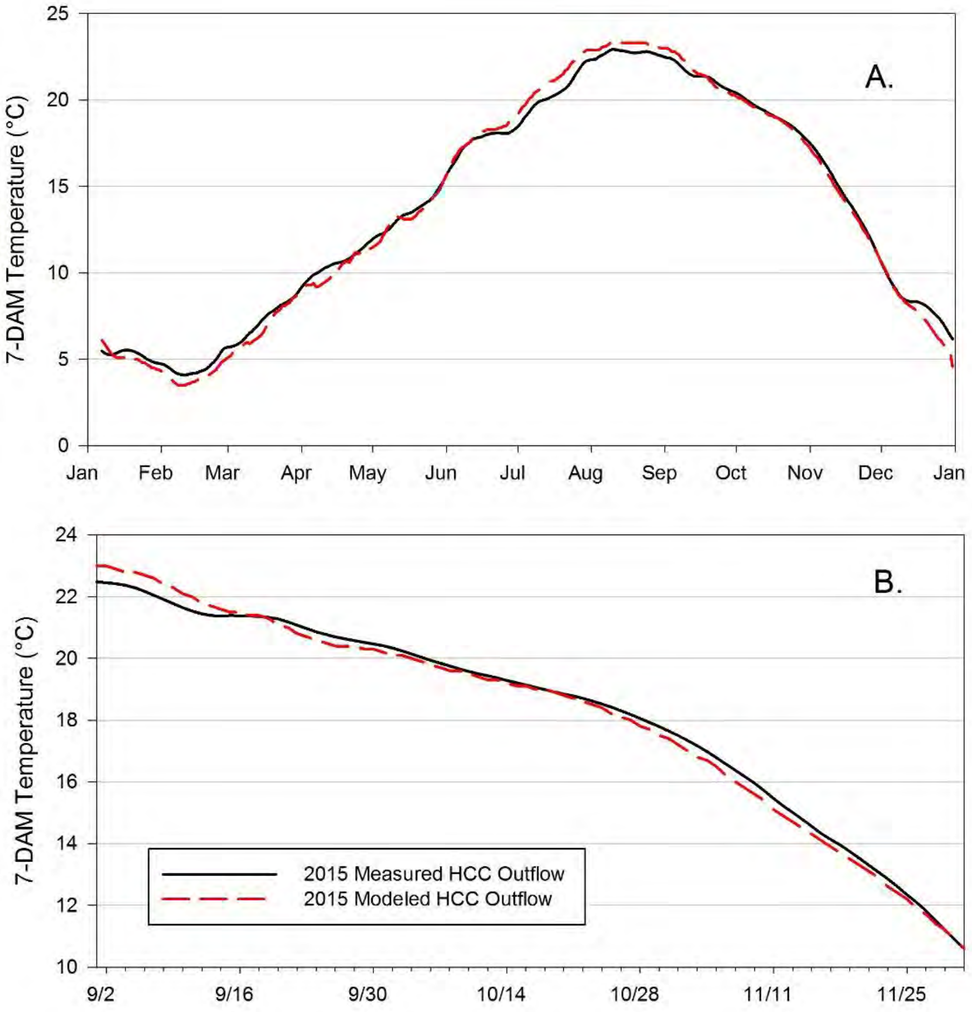


Figure 8
Modeled Hells Canyon outflow 7DAM temperature compared with measured 7DAM temperature for the 2015 CE-QUAL-W2 model. Panel A. shows the comparison for the year while Panel B. is rescaled to show more resolution on the period preceding and during the beginning of the salmonid spawning period.

2.3. Brownlee Operational Component CE-QUAL-W2 Scenarios

2.3.1. Scenario Development

To identify flows that would be associated with target Brownlee water surface elevation in early October, we used IPC's operational planning model. The model is a proprietary model developed and used by IPC for planning purposes. The model has been used since 1991 to plan and implement the annual fall drafting of Brownlee to accommodate the SRFC flow program. The planning model incorporates the components of IPC's proposed operations as described in Section 4.5 of IPC's CWA Section 401 Water Quality Certification Application as updated in February 2018. The HCC reservoir operational scenarios were then used in the CE-QUAL-W2 models by replacing the reservoir inflows/outflows used in CE-QUAL-W2 calibration with the flows from the planning model. Brownlee inflows were not replaced. The planning model was originally developed with a monthly time-step meaning output (e.g., Hells Canyon outflow flow) is constant for a month. Since the SRFC flow program includes a fall minimum Brownlee elevation around the second Monday in October and stable HCC outflows until the 2nd Friday in December these points were also added to the planning model which increased the planning model resolution slightly. For each year (i.e., 2015 and 2002) the scenarios included a planning model baseline and various deeper fall drafts of Brownlee (Table 4).

Table 4
Brownlee Reservoir operational scenarios developed to assess the effects of deeper fall drafts of Brownlee Reservoir.

Year	Drafting scenario/	Minimum Brownlee water surface on the second Monday in October (ft. elevation)
2002	Baseline	2051
2002	2010	2010
2015	Baseline	2052
2015	2024	2024
2015	2010	2010
2015	1990	1990

The baseline scenario for the 2015 planning model was developed to represent actual operations and Brownlee water surface elevations at the resolution of the planning model. For 2002, the baseline differed somewhat from the actual operations in that it was not developed to represent actual operations but rather for an optimized operation for power production (Figure 9). Since Oxbow and Hells Canyon water surface elevations are relatively constant (i.e., fluctuate by approximately 3 ft.) compared to Brownlee, the increased Brownlee outflow needed for the deeper Brownlee draft moves through the lower reservoirs and results in increases in Hells Canyon outflows while drafting and decreases when filling (Figure 10).

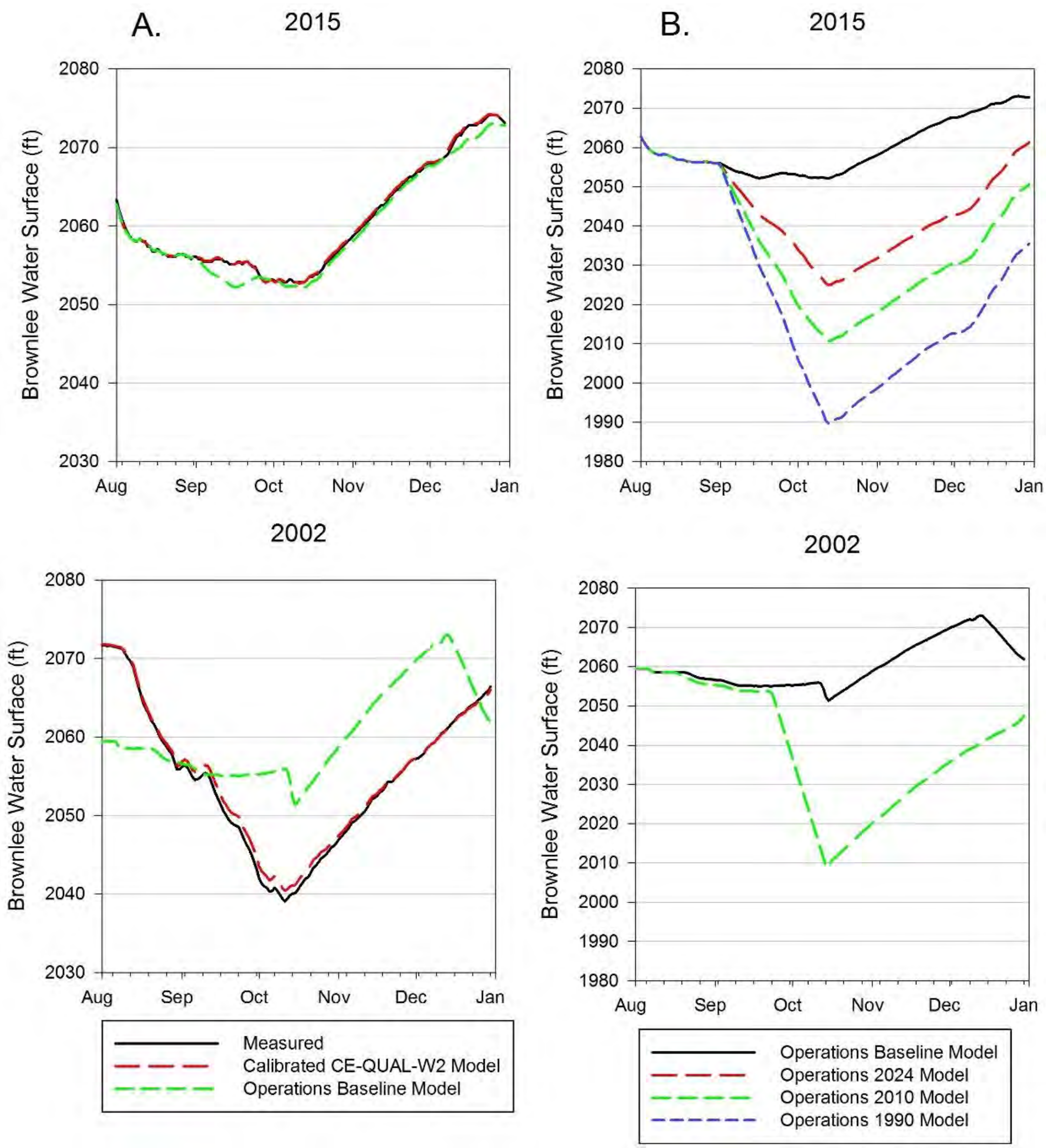


Figure 9
CE-QUAL-W2 modeled Brownlee water surface elevation from August 1 to December 31 compared between calibrated and the baseline planning model (Panel A.) and between the various deeper draft scenarios (Panel B.) for 2002 and 2015.

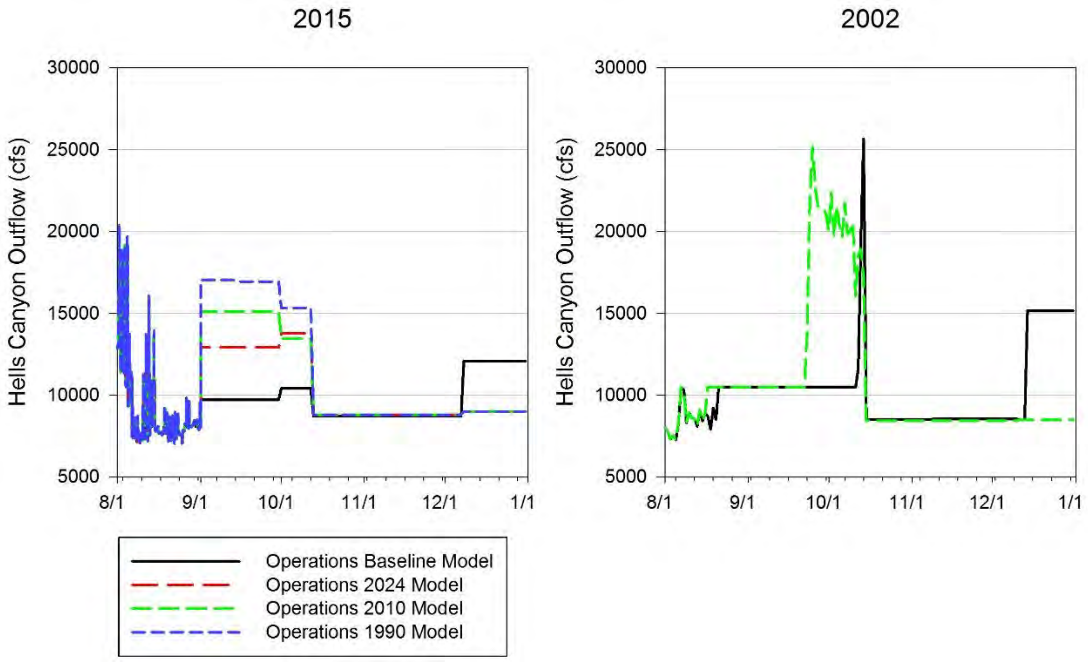


Figure 10
Hells Canyon outflow flow compared between baseline and the various deeper draft scenarios from the planning model.

2.3.2. Temperature Effects

Drafting Brownlee to a lower elevation, as described above, is effective in cooling Brownlee outflow temperature, which moves through the lower reservoirs resulting in a cooler HCC outflow temperature. The deeper drafts of Brownlee resulted in modeled cooling at Hells Canyon outflow averaging 0.4 to 1.2°C during the period when baseline was above the salmonid spawning criterion (Table 5, Figure 11). Brownlee outflow temperature is reduced due to decreasing the volume of the epilimnion in Brownlee. By decreasing the volume of the epilimnion, the deeper draft reduces the residence time of the inflowing water, which is cooler during the fall, while at the same time reducing the volume of warm water within Brownlee Reservoir that needs to be cooled either from meteorological conditions or mixing with the inflow water (Figures 12 and 13). During the period when Brownlee is being drafted there is more water being moved downstream, however, neither the 2015 or 2002 model showed an increase in outflow temperature compared to baseline.

IPC's Section 401 Application as updated February 2018 includes a discussion of attenuation of upstream thermal benefits that occurs in the HCC reservoirs. Attenuation is defined as a decrease in upstream thermal benefits that occurs as water moves through the reservoirs due to reservoir processes such as mixing, storage timing, and warming. The effect of the deeper drafting of Brownlee in the fall would be to reduce the attenuation of upstream thermal benefits due to the same thermal processes discussed above.

Table 5
CE-QUAL-W2 average modeled cooling effect, based on Hells Canyon outflow 7DAM, of an additional deeper draft of Brownlee Reservoir in the fall.

Model year	Brownlee October minimum water surface elevation (ft.)		Modeled average cooling during exceedance period(°C)	Modeled cooling effect (°C/ft. additional draft)
	Baseline	**Additional Draft**		
2002	2,052	2,010	1.0	0.024
2015	2,052	2,025	0.4	0.015
2015	2,052	2,010	0.7	0.017
2015	2,052	1,990	1.2	0.019
Average			0.83	0.019

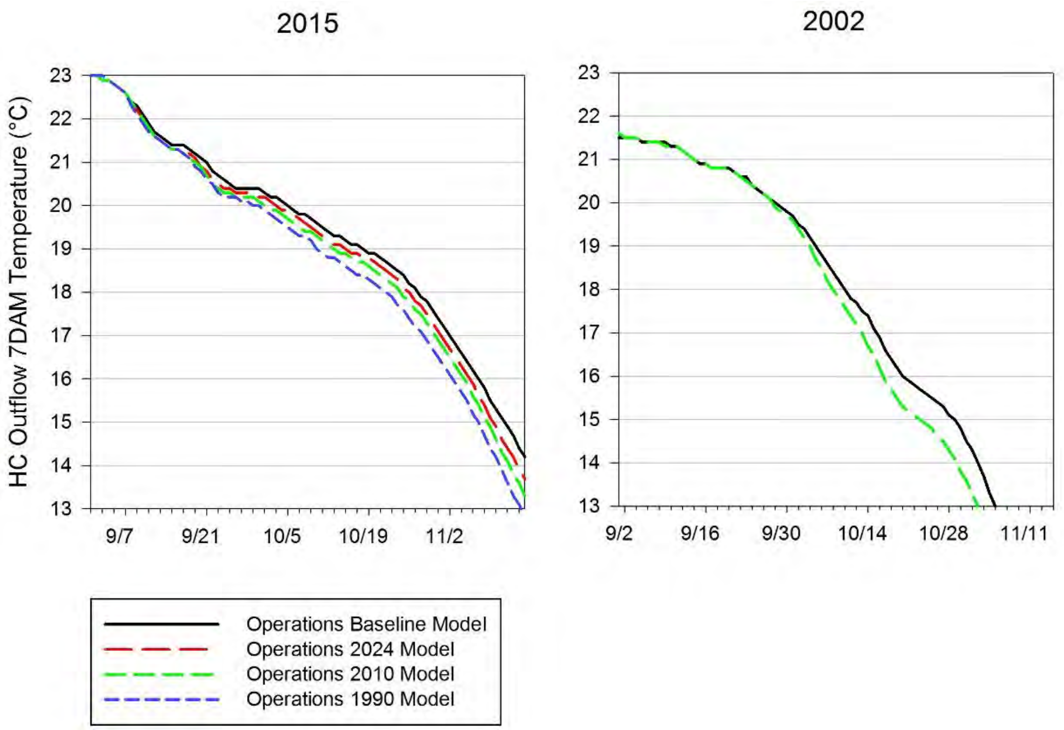


Figure 11
CE-QUAL-W2 modeled Hells Canyon outflow 7-day average maximum (7DAM) compared between operations baseline and the various deeper draft scenarios for 2015 and 2002.

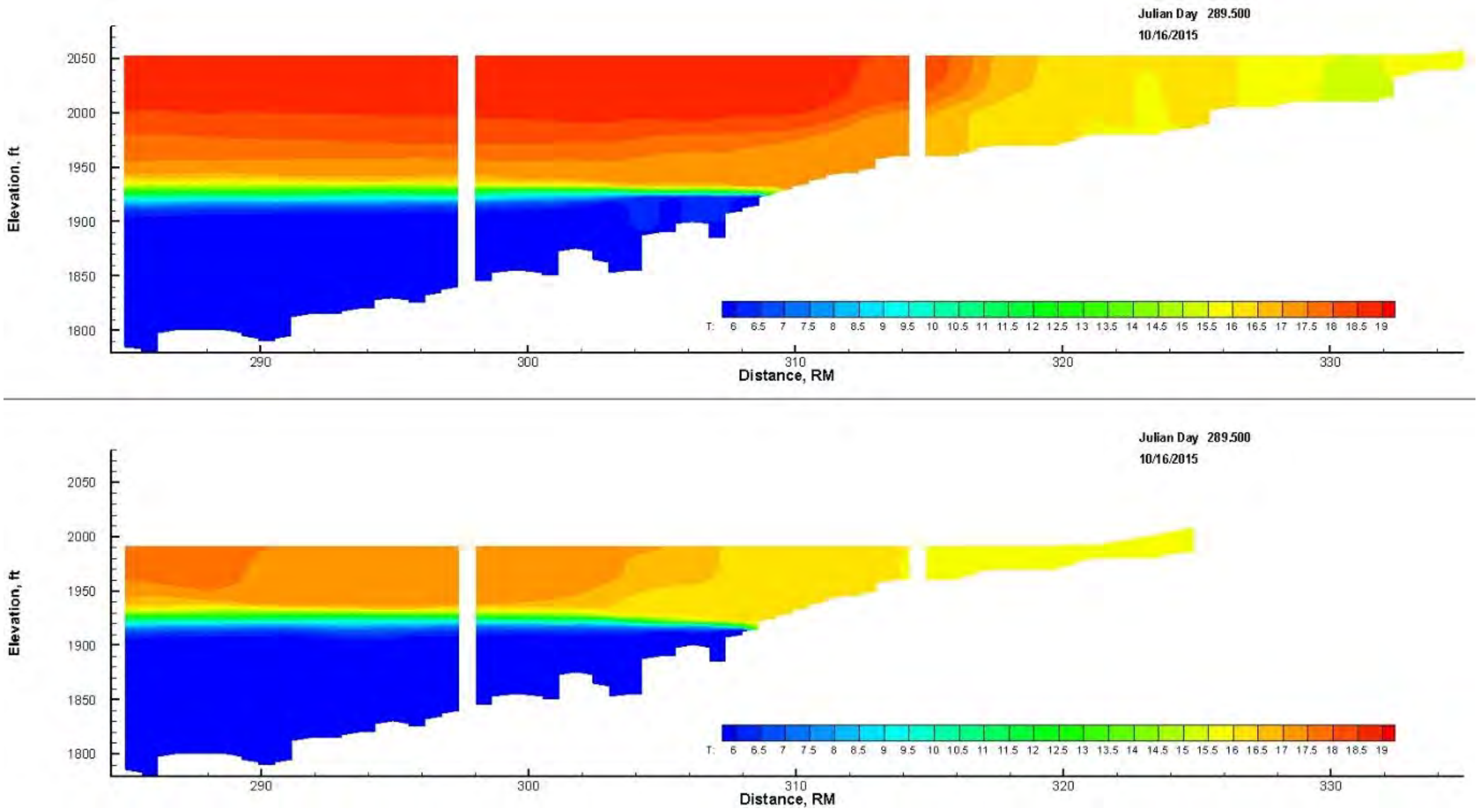
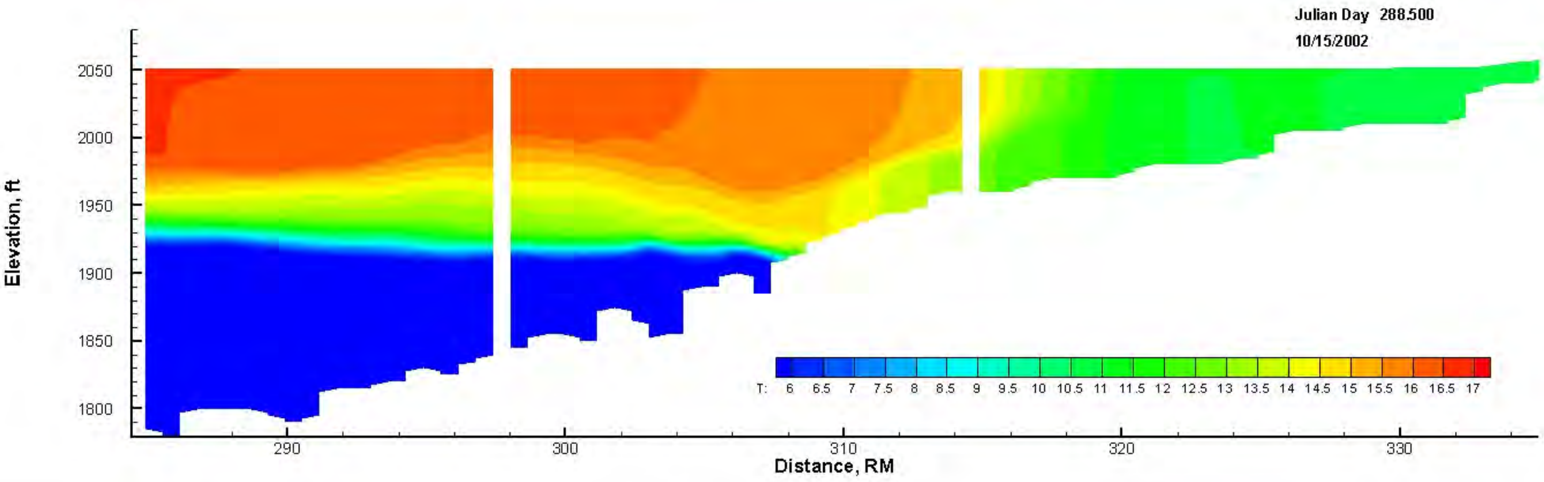


Figure 12
CE-QUAL-W2 Brownlee Reservoir temperature contour plot on October 16, 2015 comparing operations baseline (top plot) with an operations model drafting Brownlee lower in the fall to an elevation of 1990.



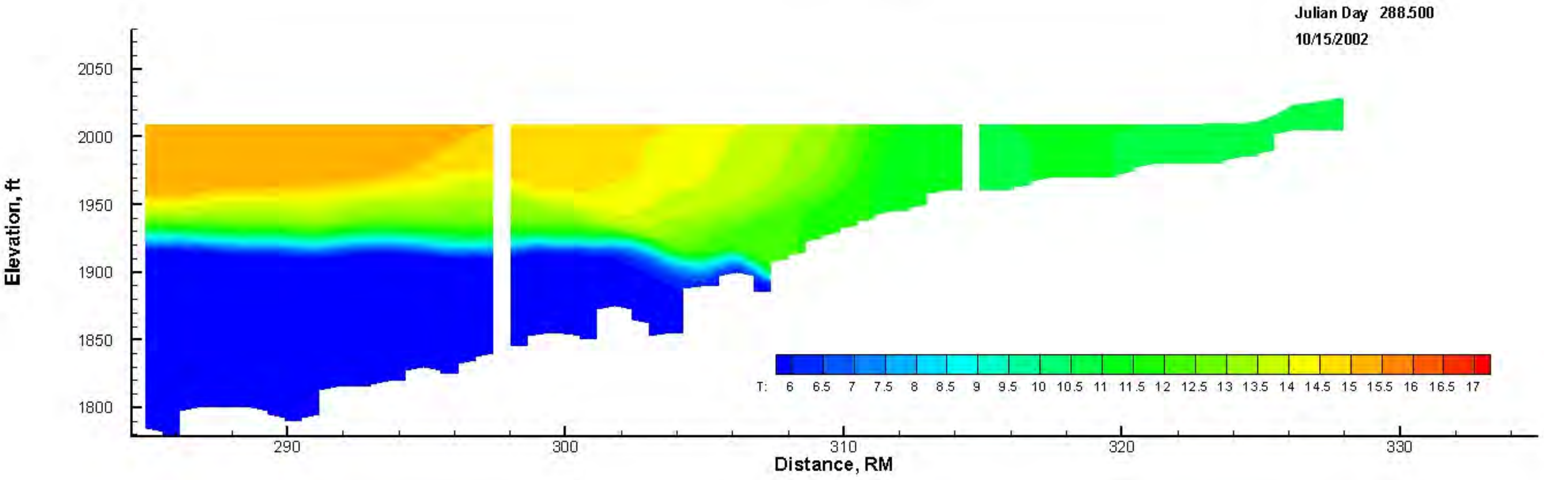


Figure 13
CE-QUAL-W2 Brownlee Reservoir temperature contour plot on October 15, 2002 comparing operations baseline (top plot) with an operations model drafting Brownlee lower in the fall to an elevation of 2010.

2.3.3. Coincidental Effects on DO

DO modeling in the 2002 model showed similar positive effects as temperature. During the period when Brownlee was being drafted, Hells Canyon outflow DO was very similar to baseline. Once the minimum water surface in Brownlee was reached, Hells Canyon outflow DO began to improve, by 1.0 to 1.5 mg/L, compared to baseline (Figure 14). These increases are due primarily to the same factors as the temperature decreases. The reduced epilimnion volume creates reduced residence time of inflowing water with higher DO and less volume that needs to be reaerated (Figure 15). In addition, increased turbulence and mixing through the lower reservoirs from higher flow may contribute to DO increases at the outflow from Hells Canyon.

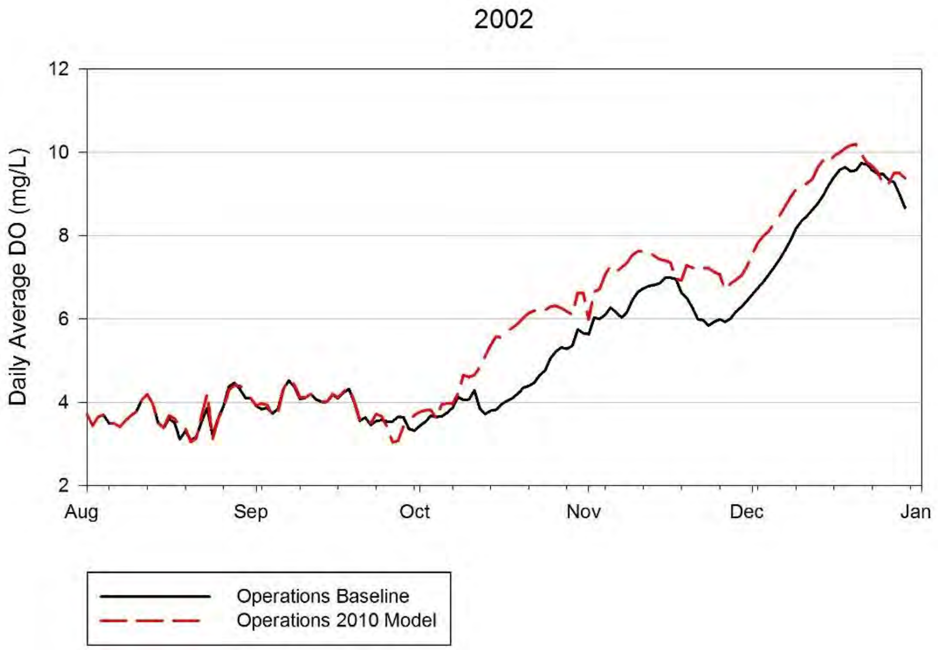


Figure 14
CE-QUAL-W2 modeled Hells Canyon outflow daily average dissolved oxygen (DO) compared between operations baseline and the 2010 draft scenario for 2002.

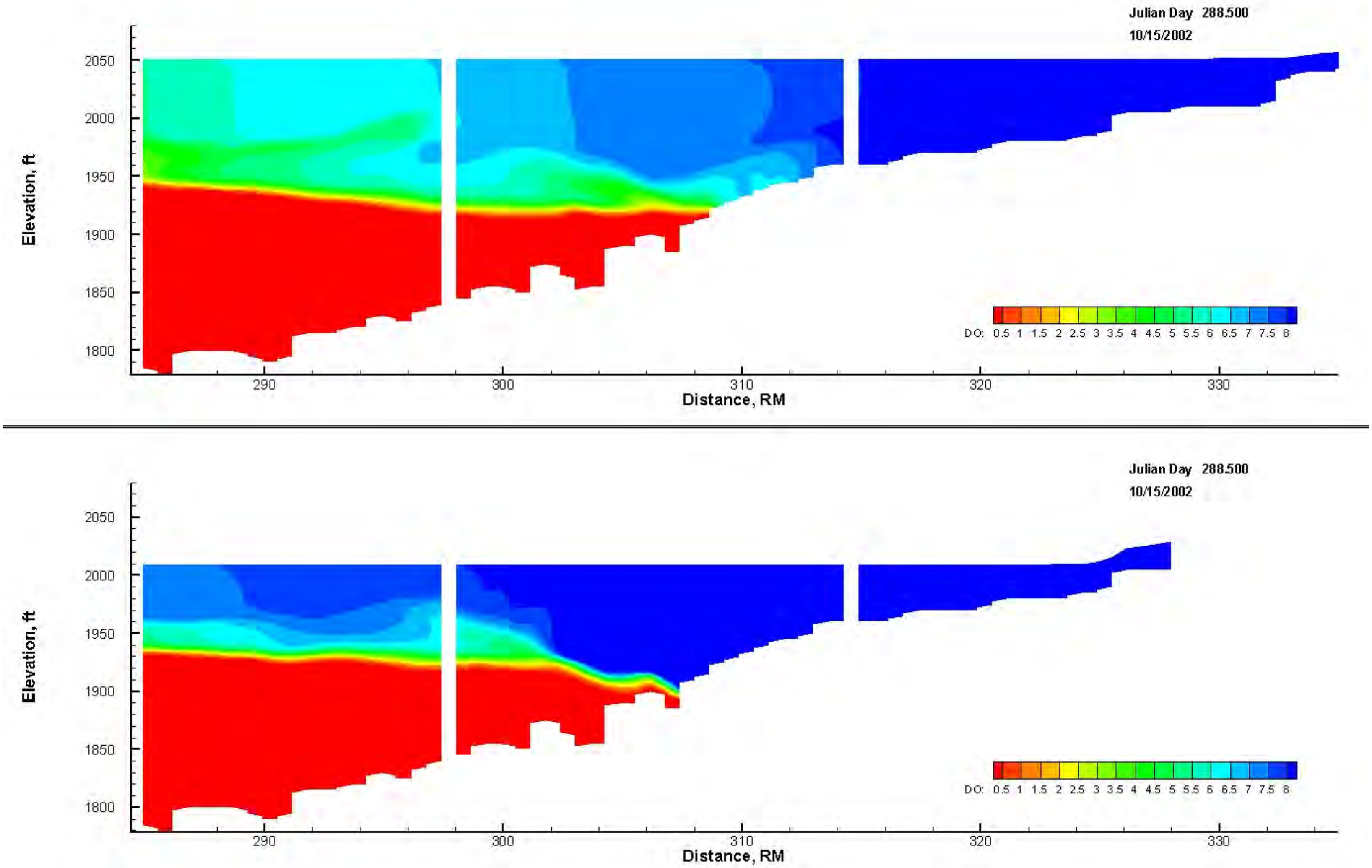


Figure 15
CE-QUAL-W2 Brownlee Reservoir dissolved oxygen contour plot on October 15, 2002 comparing operations baseline (top plot) with an operations model drafting Brownlee lower in the fall to an elevation of 2010.

2.4. CE-QUAL-W2 Modeling Conclusions

After completing the CE-QUAL-W2 modeling to evaluate the Brownlee operational alternative we drew the following conclusions.

- On average, model predictions of temperature are within 1°C.
- CE-QUAL-W2 can reproduce many of the hydrodynamic processes occurring in the reservoirs.
- Model predictions for DO in 2002 were generally within 2 mg/L.
- Deeper fall drafts of Brownlee than would otherwise be necessary for the SRFC Flow Program can cool October temperature and improve DO throughout the HCC and at the HCC outflow.

3. MULTIPLE REGRESSION MODEL

The Brownlee operational component would be implemented in years when there is a high probability that temperature will exceed 16.5°C in the beginning of the salmonid spawning period. This condition will be based on forecasting. There is a rich historic dataset of water quality, flow and operational conditions for the HCC and the inflow to the HCC that provides information to explore statistical tools for forecasting and the potential uncertainty associated with forecasting. To utilize this dataset, we first correlated measurements related to flow, water temperature and Met conditions over various time frames and from various locations. Based on this correlation analysis, we selected the variables that were strongly correlated with the HCC outflow 7-DAM temperatures on October 29. These included Brownlee inflow temperature, Brownlee inflow flow, Brownlee water surface elevation, and air temperature. We then used the selected variables to develop a multiple regression model which was used to explore potential forecasting accuracy and uncertainty. We used the SigmaPlot software application (SigmaPlot version 12.5, Systat Software, Inc. 2011) for correlation and multiple regression analysis.

3.1. Correlation Analysis

3.1.1. *Meteorological Conditions*

The correlation analysis included HCC outflow 7-DAM temperature on October 29 and 57 other Met variables, where available, for each year from 1991 through 2017. Of the 57 variables, 48 were monthly average Met conditions from 5 locations near the HCC (Table 6). Correlation analysis indicated that the station where all the variables of interest were available and with the strongest correlations with the HCC outflow 7-DAM was the Ontario, OR Agrimet station. In addition, the correlation analysis showed that only the air temperature variables were significantly related to the HCC outflow 7-DAM (Table 7) Based on these results, we selected October average air temperature from the Ontario, OR Agrimet station as the Met condition variable for the remainder of the analysis.

Table 6
Description of weather data used in the correlation analysis prior to selecting variables for a multiple regression model

Location	Measurements			
Brownlee Dam IPC Met station	Monthly average air temperature (Aug, Sept, Oct)	Na	Na	Na
Ontario, OR Agrimet station (ONTO)	Monthly average air temperature (Aug, Sept, Oct)	Monthly average daily max air temperature (Aug, Sept, Oct)	Monthly average daily min air temperature (Aug, Sept, Oct)	Monthly average solar radiation (Aug, Sept, Oct)
Parma, ID Agriment station (PMAI)	Monthly average air temperature (Aug, Sept, Oct)	Monthly average daily max air temperature (Aug, Sept, Oct)	Monthly average daily min air temperature (Aug, Sept, Oct)	Monthly average solar radiation (Aug, Sept, Oct)
NOAA, Brownlee	Monthly average air temperature (Aug, Sept, Oct)	Monthly average daily max air temperature (Aug, Sept, Oct)	Monthly average daily min air temperature (Aug, Sept, Oct)	Na
Modeled, Brownlee Dam (historic forecasted data)	Monthly average air temperature (Aug, Sept, Oct)	Monthly average daily max air temperature (Aug, Sept, Oct)	Monthly average daily min air temperature (Aug, Sept, Oct)	Monthly average solar radiation (Aug, Sept, Oct)

Note: Na indicates data not available

Table 7
Pearson correlation results for Ontario, OR Agrimet monthly average weather conditions and the HCC outflow 7-DAM temperature on October 29 of each year from 1992 through 2017. Statistically significant correlations are in bold.

Variable	Pearson correlation coefficient	p
August average air temperature	0.13	0.5
September average air temperature	-0.01	0.9
October average air temperature	**0.76**	**<0.001**
August average daily max air temperature	-0.05	0.8
September average daily max air temperature	0.00	1.0
October average daily max air temperature	**0.69**	**<0.001**
August average daily min air temperature	0.27	0.2
September average daily min air temperature	-0.14	0.5
October average daily min air temperature	**0.64**	**<0.001**
August average solar radiation	-0.11	0.6
September average solar radiation	0.21	0.3
October average solar radiation	-0.13	0.5

3.1.2. Flow and Brownlee Water Surface Elevation

Since the minimum fall Brownlee water surface elevation (WSEL) is proposed to be altered during some years by the Brownlee operational component we included that as a variable in the correlation analysis. Without the proposed alterations, the minimum fall WSEL is driven primarily by forecasted inflow volumes and the level of HCC outflows planned during the stable flow period for the SRFC Flow Program. Therefore, fall inflow flow and Brownlee WSEL in October are highly correlated together in the historic dataset.

We summarized Brownlee inflow flow and Brownlee water surface elevation (WSEL) over various periods to determine which variables and time frame showed the strongest correlation with the HCC outflow 7-DAM. Based on the correlations we selected Brownlee WSEL on October 15 as the variable to include in the remainder of the analysis because it showed the strongest correlation and is the focus of the Brownlee operational alternative (Table 8).

Table 8
Pearson correlation coefficients between the HCC outflow 7-DAM on October 29 and selected Brownlee inflow flow and Brownlee fall minimum water surface elevations for each year from 1991 to 2017. All correlations were significant ($p<0.001$).

Variable	HCC outflow 7-DAM	Oct 15 WSEL	Oct minimum WSEL	Average Aug flow	Average Sept flow
Oct 15 WSEL	0.68				
Oct minimum WSEL	0.67	0.99			
Average Aug flow	-0.62	-0.87	-0.85		
Average Sept flow	-0.61	-0.92	-0.90	0.91	
Average Oct flow	-0.58	-0.90	-0.86	0.90	0.97

3.1.3. Brownlee Inflow Temperature

The CE-QUAL-W2 analysis presented previously shows the importance of fall Brownlee inflow temperature to the HCC outflow 7-DAM temperature. We averaged inflowing temperature over various time periods to explore which time frames were most strongly correlated with the HCC 7-DAM. In contrast to other variables, high frequency (i.e., hourly) Brownlee inflow temperature data was not available from 1991 through 1995, or in 2001, so the correlations are based 1996 through 2017, excluding 2001. Based on the correlations we selected the average inflow temperature over the August 1 through October 15 period (Table 9). While this was not the variable with the strongest correlation it was selected after considering the Brownlee operational alternative and forecasting needs. The more strongly correlated period of August 1 through October 29 (as with the October average) would likely be more difficult to forecast accurately as it includes later parts of October.

Table 9
Pearson correlation coefficients between the HCC outflow 7-DAM on October 29 and various averaging periods of Brownlee inflow temperature for each year from 1996 to 2017, excluding 2001. Significant correlations are in bold ($p<0.05$).

Variable	HCC outflow 7-DAM	Average Aug-Oct 29	Average Aug-Oct 15	Average Aug	Average Sep
Average Aug-Oct 29	**0.59**				
Average Aug-Oct 15	**0.45**	**0.98**			
Average Aug	0.33	**0.78**	**0.80**		
Average Sep	-0.06	**0.66**	**0.74**	**0.51**	
Average Oct	**0.85**	**0.71**	**0.59**	0.33	0.02

3.2. Multiple Regression Model

We conducted multiple regression using the variables selected through the correlation analysis. All the variables were available for each year for 1996 through 2017, excluding 2001, so the regression analysis includes 21 years. The multiple regression analysis included HCC outflow 7-DAM temperature on October 29 as the dependent variable and the three following independent variables (Table 10):

- Inflow Temperature
    - As the average Brownlee inflow temperature over the August 1 through October 15 time frame
- Brownlee WSEL
    - As the Brownlee WSEL on October 15. This variable is highly correlated with HCC outflow 7-DAM (Table 8). It is also highly correlated with inflow flow. Inflow flow was also well correlated with HCC outflow 7-DAM. Therefore, either inflow flow or Brownlee WSEL could be included in a multiple regression model. Including both would lead to complications because of multicollinearity in the model. Brownlee WSEL was selected because it showed the strongest correlation with HCC outflow 7-Dam and is the focus of the Brownlee operational alternative
- Air Temperature
    - As the average October air temperature. This variable is highly correlated with HCC outflow 7-DAM (Table 7). In a natural system, air temperature and inflow temperature would be expected to be correlated, thereby also causing multicollinearity problems in the multiple regression analysis. However, October average air temperature and August through October 15 inflow water temperature did not show a high correlation during our period of interest (Table 11, Figure 16).

Table 10
Data used in the multiple regression analysis.

Year	HCC 7-DAM (°C)	Brownlee WSEL (ft. elevation)	Inflow Temperature (°C)	Air Temperature (°C)
1991	16.4	2056	Na	Na
1992	15.8	2056	Na	12.2
1993	15.7	2029	Na	11.3
1994	15.5	2060	Na	10.1
1995	14.6	2037	Na	9.1
1996	14.8	2034	19.3	11.0
1997	13.3	1996	19.9	10.6
1998	14.0	2006	20.7	10.5
1999	14.5	2029	19.3	10.9
2000	15.0	2040	19.3	10.5
2001	15.8	2051	Na	10.9
2002	15.3	2040	19.0	9.9
2003	16.8	2039	20.7	13.5
2004	16.3	2053	20.2	11.4
2005	15.7	2055	19.7	10.7
2006	15.3	2047	19.3	10.0
2007	14.5	2048	19.4	10.2
2008	14.9	2044	19.4	10.1
2009	14.6	2033	19.8	8.6
2010	16.8	2045	20.0	12.7
2011	15.4	2023	20.8	11.3
2012	15.8	2047	20.2	9.8
2013	15.3	2052	20.6	9.2
2014	17.2	2059	20.9	12.7
2015	17.9	2053	20.7	14.1
2016	16.0	2046	20.0	11.6
2017	14.4	2033	20.0	8.7

Note: Na indicates data not available

Table 11
Pearson correlation coefficients between the HCC outflow 7-DAM on October 29 and the variables selected for the multiple regression model.

	Brownlee WSEL	Inflow Temperature	Air Temperature
HCC 7-DAM	0.678 p<0.001	0.454 p=0.039	0.757 p<0.001
Brownlee WSEL		-0.001 p=0.980	0.207 p=0.311
Inflow Temperature			0.427 p=0.054

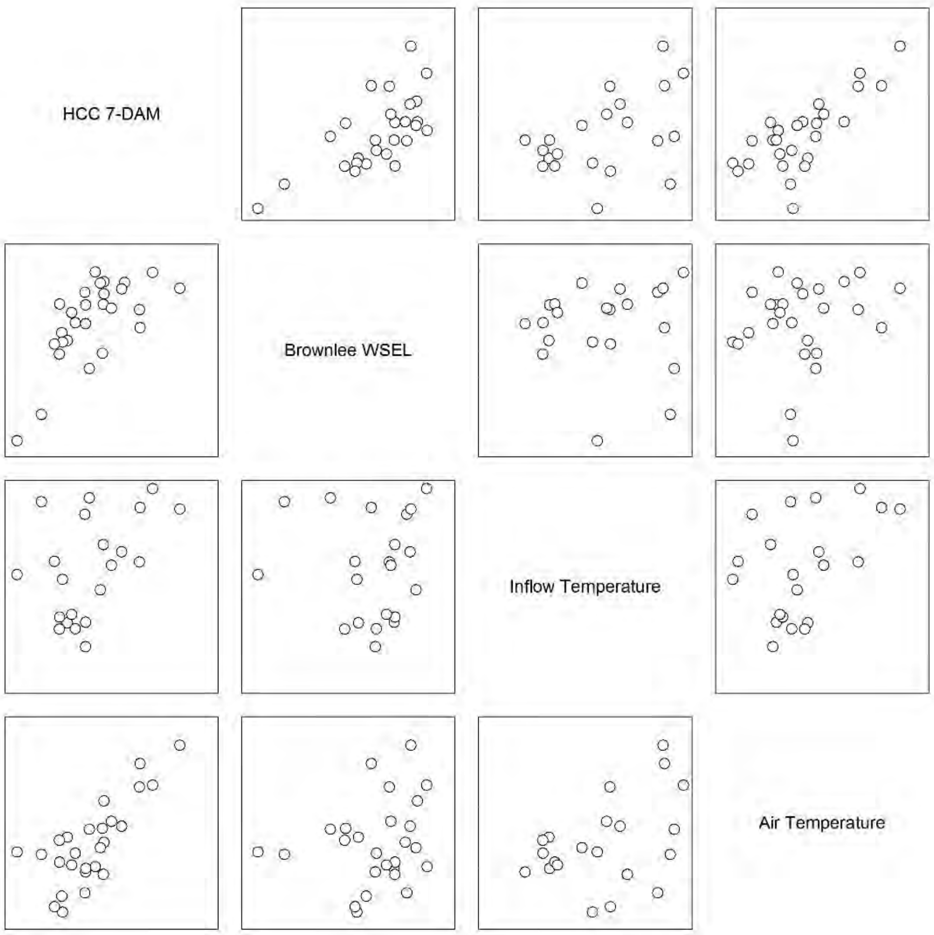


Figure 16
Scatter plot matrix showing relationships between variables used the multiple regression model.

The results of the multiple regression model showed that all three variables entered contribute to predicting the HCC outflow 7-DAM (Table 12), and explained 91.5% of the variability in the HCC outflow 7-DAM (adjusted R^2=0.915). The multiple regression analysis included output and analysis of residuals, 95% confidence and 95% prediction intervals around each of the predicted values (Table 13). We concluded that the multiple regression model showed a good fit with the data (Figure 17) and could be a useful tool in exploring the uncertainty in forecasting the HCC outflow 7-DAM.

Table 12
Results of multiple linear regression analysis using HCC 7-DAM temperature on October 29 as the dependent variable and Brownlee WSEL on October 15, average Brownlee inflow temperature from August 1 through October 15 and October average air temperature at Ontario, OR as independent variables.

Multiple Linear Regression Results

Equation. HCC 7-DAM = -82.474 + (0.0416 * Brownlee WSEL) + (0.429 * Inflow Temperature) + (0.413 * Air Temperature)

```
N  = 21                                Missing Observations = 6
R = 0.963                              Rsqr = 0.927        Adj Rsqr = 0.915
Standard Error of Estimate = 0.326
                                       Coefficient         Std. Error       t            P          VIF
Constant                               -82.474             10.186           -8.097       <0.001
Brownlee WSEL                          0.0416              0.00477          8.73         <0.001     1.066
Inflow Temperature                     0.429               0.136            3.149        0.006      1.239
Air Temperature                        0.413               0.0577           7.158        <0.001     1.304
Analysis of Variance:
                                        DF                  SS               MS           F           P
Regression                             3                   23.035           7.678        72.47      <0.001
Residual                               17                  1.801            0.106
Total                                  20                  24.836           1.242

Column                                 SSIncr              SSMarg
Brownlee WSEL                          12.405              8.075
Inflow Temperature                     5.201               1.05
Air Temperature                        5.429               5.429

The dependent variable HCC 7-DAM can be predicted from a linear combination of the independent variables:
                                        P
Brownlee WSEL                          <0.001
Inflow Temperature                     0.006
Air Temperature                        <0.001

All independent variables appear to contribute to predicting HCC 7-DAM (P < 0.05).
Normality Test (Shapiro-Wilk)          Passed              (P = 0.704)
Power of performed test with alpha = 0.050: 1.000
```

Table 13
Multiple regression output for predicted HCC 7-DAM values, residuals, 95% confidence and prediction levels for each year.

Year	Predicted	Residual	95% Confidence-Lower	95% Confidence -Upper	95% Prediction -Lower	95% Prediction-Upper
1996	14.98	-0.227	14.73	15.24	14.25	15.72
1997	13.46	-0.117	13.01	13.91	12.64	14.28
1998	14.21	-0.177	13.79	14.62	13.40	15.01
1999	14.70	-0.166	14.41	14.99	13.95	15.44
2000	15.02	-0.0328	14.77	15.26	14.29	15.74
2002	14.65	0.616	14.37	14.94	13.91	15.40
2003	16.77	0.0374	16.44	17.10	16.01	17.53
2004	16.30	-0.0118	16.09	16.51	15.58	17.02
2005	15.91	-0.221	15.68	16.13	15.18	16.63

Year	Predicted	Residual	95% Confidence-Lower	95% Confidence-Upper	95% Prediction-Lower	95% Prediction-Upper
2006	15.12	0.154	14.88	15.36	14.39	15.85
2007	15.25	-0.703	15.02	15.47	14.52	15.97
2008	15.09	-0.206	14.87	15.30	14.37	15.81
2009	14.16	0.459	13.87	14.46	13.42	14.91
2010	16.46	0.328	16.20	16.71	15.72	17.19
2011	15.28	0.0921	14.98	15.59	14.53	16.03
2012	15.44	0.33	15.18	15.70	14.71	16.17
2013	15.53	-0.278	15.13	15.93	14.73	16.33
2014	17.43	-0.274	17.08	17.78	16.66	18.20
2015	17.63	0.295	17.25	18.01	16.84	18.41
2016	16.00	0.0033	15.82	16.17	15.29	16.71
2017	14.30	0.0995	14.00	14.59	13.55	15.04

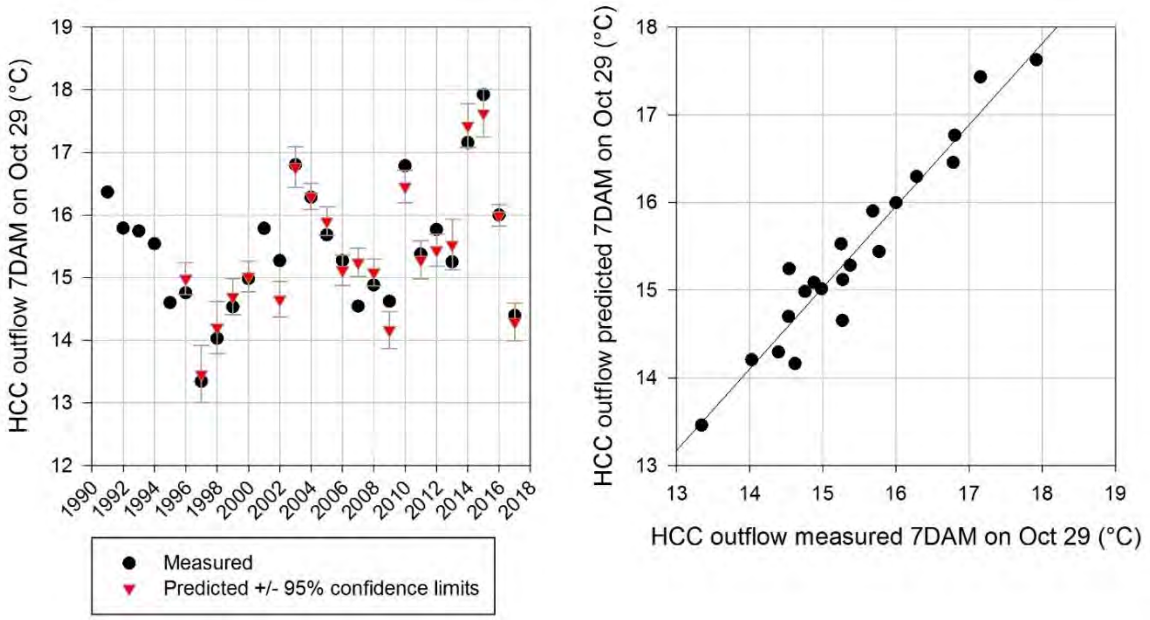


Figure 17
multiple regression predicted values compared with measured values of the HCC outflow 7-DAM on October 29 for the years 1996-2017, excluding 2001 (21 years).

3.3. Multiple Regression and Forecasting

We used the multiple regression model along with variability around the inputs to explore the uncertainty in forecasting the HCC 7-DAM with this model. This analysis is similar to a Monte Carlo analysis in that the parameters (e.g., mean, maximum, minimum) of each input variable were defined (Table 14) and the input variables were then permutated within realistic limits to develop many predicted HCC outflow 7-DAM values for each year. The analysis differed from a Monte Carlo analysis in that the permutations of the inputs were not random but rather represented what we anticipate would be known relative to the inputs, and realistic minimums or maximums representing the variability, on September 1 as decisions are made on whether to implement the Brownlee operational alternative in that year.

Table 14
Descriptive parameters for the multiple regression input variables.

Input Variable	N	Mean	Minimum	Maximum	Standard deviation
Brownlee WSEL (ft.)	27	2041.2	1996.1	2059.5	15.3
Inflow Temperature (°C)	21	20.0	19.1	21.0	0.6
Air Temperature (°C)	26	10.8	8.6	14.1	0.7

3.3.1. Input Variables and Uncertainty

For each input variable we estimated a "known" and potential minimum and maximum value each year. We then permutated these variables and utilized each permutation in the multiple regression model.

3.3.1.1. Inflow Temperature

The Brownlee inflow temperature variable is the average inflow temperature during the August 1 through October 15 time frame. This means that by September 1, one month of the time frame would be measured already. As expected, the average inflow temperature for the month of August is related to the inflow temperature input variable so we used a linear regression to estimate a "known" value for the inflow temperature variable for each of years (Figure 18). The regression analysis output included 95% confidence and 95% prediction intervals around each of the predicted values. To describe minimum and maximum range around the "known" inflow temperature variable we used the regression predicted value plus or minus the 95 prediction intervals resulting in 3 potential forecasted values for the inflow temperature variable for each year.

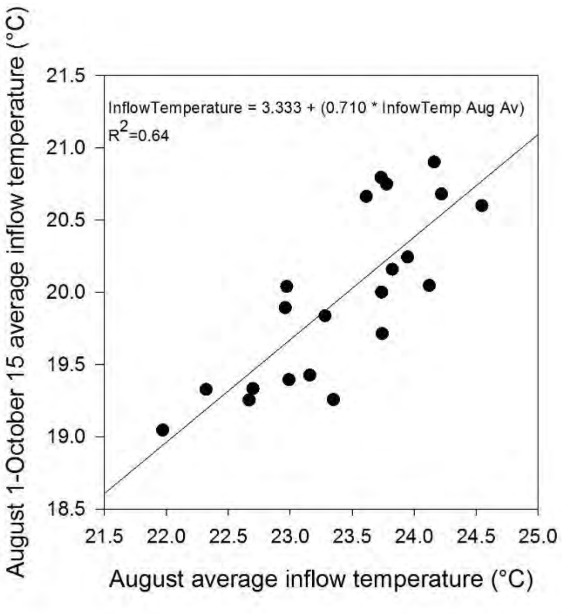


Figure 18
Linear regression between August average inflow temperature and August 1 through October 15 average inflow temperature for 21 years 1996-2017, excluding 2001

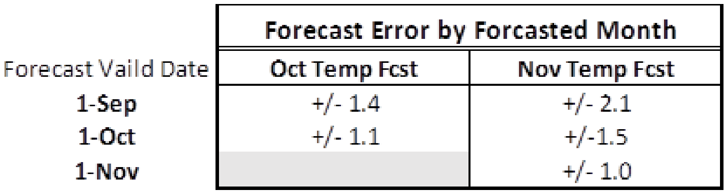
3.3.1.2. Brownlee WSEL

The Brownlee WSEL variable is essentially set in early September based on forecasted inflow volumes and the level of HCC outflows planned during the stable flow period for the SRFC Flow Program. Therefore, we treated the measured Brownlee WSEL for each year as the “known” value for this variable. To describe the minimum and maximum range around this “known” value we used the standard deviation with a realistic upper limit of 2060 ft. resulting in 3 potential forecasted values for the Brownlee WSEL variable. The upper limit was based on the maximum October 15 WSEL (2059.5 ft.) that occurred in the 27-year dataset since the beginning of the SRFC Flow Program in 1991.

3.3.1.3. Air Temperature

The air temperature variable is the October average air temperature. IPC’s Atmospheric Sciences Group (AtSci) developed an ensemble method utilizing 3 methods (as described below) to predict the 1, 2, and 3 month(s) ahead temperatures for the Ontario, OR Agrimet weather station. These forecasts were specifically focused on the October and November temperatures and were developed using data available prior to the last day of the month from selected sources (e.g., data available on September 1 to forecast October average air temperature). AtSci developed a temperature forecast from each of the following methods and then blended them as a weighted bias corrected average to provide the sub seasonal to seasonal temperature forecasts. Weightings and bias are based upon the methods previous months skill in producing the desired temperature forecasts. The weighted temperature forecasts where developed in a hind cast format for the period 2008-2017. During this historical reconstruction, the weighted temperature forecast performed well with average monthly errors between +/- 1.0 and 2.1 degrees depending upon forecast date and month forecasted (Table 15).

Table 15
Average forecast error by forecast date and forecasted month based on a combination of 3 weather forecasting methods.



	Forecast Error by Forcasted Month	
Forecast Vaild Date	Oct Temp Fcst	Nov Temp Fcst
1-Sep	+/- 1.4	+/- 2.1
1-Oct	+/- 1.1	+/-1.5
1-Nov		+/- 1.0

The 3 forecast development methods for the ensemble temperature outlook developed by AtSci include:

- Method 1: Climatic Indexes based Multivariate Linear Regression (MLR)
    - Utilizing a progressive “best selector” method that is updated with each forecast, AtSci selects the best predictors from available climate indexes (e.g. ENSO, PNA, PDO, QBO, etc.), these selected predictors are then applied in a Monte Carlo based MLR routine to produce a prediction of the temperatures for the desired month(s).
- Method 2: Single Value Decomposition based Multivariate Linear Regression (MLR)
    - Using Single Value Decomposition (SVD), predictors sets are selected from oceanic and atmospheric variables from NCEP North American Regional Reanalysis (NARR) data. These selected predictors are then applied in a Monte Carlo based MLR routine to produce a prediction of the temperatures for the desired month(s).
- Method 3: MPAS
    - The Model for Prediction Across Scales (MPAS) is a physically based model that has been developed for developing atmosphere, ocean and other earth-system simulation components for use in climate, regional climate and weather studies. AtSci runs this model on the Boise State University R2 research cluster to produce a prediction of the temperatures for the desired month(s).

We used the measured October average air temperature as the “known” value for each year and described the minimum and maximum range around this “known” value as plus or minus 1.8°C resulting in 3 potential forecasted values for the air temperature variable. The error estimated in Table 15 suggests that 1.4°C would also be a valid assumption of variability, we incorporated additional variability by using 1.8°C.

3.3.1.4. Permutations

After estimating “known”, high-end and low-end values for the three input variables we developed a collection of permutations (Table 16) and used the multiple regression model to output a predicted HCC outflow 7-DAM for each permutation which resulted in 27 HCC 7-DAM predictions per year. This was further expanded to 81 HCC 7-DAM predictions per year by applying the upper and lower 95% prediction intervals from the multiple regression analysis (Table 13) for an additional 2 predictions per year for each permutation.

Table 16
Description of input variable permutations used along with the multiple regression for HCC outflow 7DAM predictions. This collection of permutations was developed for each of the 21 years in the multiple regression dataset. For each input variable, "=" indicates the "known" value, "-" indicates the low estimate and a "+" indicates the high estimate.

Permutation number	Brownlee WSEL	Inflow Temperature	Air Temperature
1	=	=	=
2	=	+	=
3	=	-	=
4	=	=	+
5	=	=	-
6	=	+	+
7	=	-	-
8	=	+	-
9	=	-	+
10	+	=	=
11	+	+	=
12	+	-	=
13	+	=	+
14	+	=	-
15	+	+	+
16	+	-	-
17	+	+	-
18	+	-	+
19	-	=	=
20	-	+	=
21	-	-	=
22	-	=	+
23	-	=	-
24	-	+	+
25	-	-	-
26	-	+	-
27	-	-	+

3.4. Multiple Regression Conclusions

Incorporating estimates of values based on information that would be available on September 1 on any year and then incorporating ranges representative of the uncertainty around those values, and uncertainty in the multiple regression model itself, allows a realistic examination of forecasting the HCC 7-DAM with this multiple regression tool. The distribution of the 81 predictions each year shows that even with these estimates of uncertainty incorporated into the inputs there is enough resolution in the forecasting to support decisions related as to whether there is a high probability that HCC 7-DAM temperature on October 29 will exceed 16.5°C (Figure 19). This supports that a reasonable level of forecasting capability exists now, however, future forecasting will utilize the best available tools and methodology including further development of tools as needed.

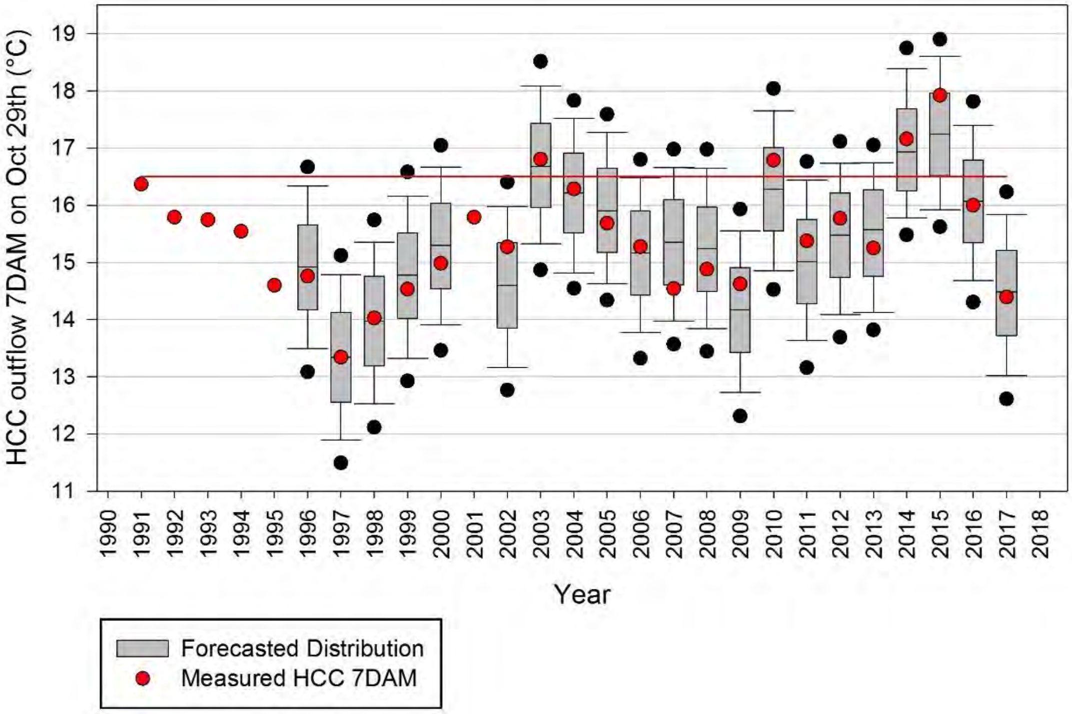


Figure 19
Measured HCC outflow 7DAM temperature on October 29 compared with a distribution of predicted temperatures from a multiple regression model with 81 permutations of forecasted input conditions for years when data were available. The boxes show the 25th and 75th percentile while the whiskers and dots show the 10th and 90th and 5th and 95th percentiles of the 81 predictions, respectively

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Exhibit 7.1-2
Technical memorandum estimating the potential downstream temperature effects of the Brownlee operational component during September and early October.

IDAHO POWER®
An IDACORP Company

DATE: May 18, 2018

SUBJECT: Technical memorandum estimating the potential downstream temperature effects of the Brownlee operational component during September and early October.

Introduction

On February 23, 2018, IPC submitted its proposal to address project related effects on temperatures downstream of Hells Canyon dam during the fall chinook spawning period beginning on Oct 23. The proposal identified deeper fall drafts of Brownlee Reservoir in years when outflow temperatures would be expected to exceed a 7 Day Average Maximum Temperature (7-DAM) of 16.5°C during the salmonid spawning period. The intent of the proposal is to cool water being released from the HCC during the late October and early November period of the fall chinook spawning period. The February 2018 submittal demonstrated that the proposal could accomplish cooling during fall chinook spawning. Analysis presented in the February filing showed that deeper drafts of Brownlee Reservoir could have been employed in approximately 20-25 percent of the historic years to meet the goal of keeping the 7-DAM below 16.5°C during the spawning period.

During subsequent outreach meetings with stakeholders, questions were raised related to the downstream effects of the proposed periodic additional drafting of Brownlee reservoir from September 1 through the second Monday in October. Specifically, the February proposal did not include the effects of the drafting proposal on downstream water temperatures during the migration period. While the proposal was expected to cool temperatures in water being released from the HCC, the enhanced drafting of Brownlee Reservoir would also result in higher flows from September 1 through the second Monday in October. Because downstream tributaries, including the Salmon and Clearwater rivers, are cooler than the Snake River during September, higher Snake River flows have the potential to increase downstream Snake River temperature below the Salmon River. Basically, any increases in Snake River flows during September have the potential to reduce the cooling effect of the tributaries such as the Salmon and Clearwater rivers.

To evaluate the potential effects of the action on downstream temperatures, we conducted a flow-weighted mass balance analysis comparing baseline conditions in September 1 through October 12, 2015 with three potential drafting scenarios. The flow-weighted, mass balance approach applied temperatures from upstream sources as a relative proportion based on the relative proportion of flow from each source. The time of this analysis was limited to September 1 through October 12 because this is the period the proposal would alter flows during the fall migration period.

Methods and Results

In this analysis, data from the 2015 modeling conducted to support IPC's *CWA Section 401 Water Quality Certification Application as updated in February 2018* and *Technical information for Hells Canyon Complex Modeling Used in Development of the Brownlee Reservoir Operational Component* (submitted as additional information on May 11, 2018) were used with measured water temperatures and flows from select locations from Hells Canyon Dam (HCD) downstream to the Lower Granite Dam tailwaters. We used USGS data from:

- 13343595 Snake River (right Bank) BL Lower Granite Dam, WA,
- 13334300 Snake River near Anatone, WA,
- 13317000 Salmon River at White Bird ID,
- and 13342500 Clearwater River at Spalding ID.

For Hells Canyon Dam outflows, we used IPC measured and modeled flows (see May 11, 2018 additional information for modeled flows detail).

Tributary inflows from sources other than the Salmon River between HC Dam and Anatone were estimated by the difference between Anatone and HC Dam plus Salmon River flows (referred to as distributed flow). Salmon River water temperatures were used to represent all distributed flow into the Snake River between HC Dam and Anatone.

When estimating temperatures under the various operational scenarios, model predicted changes in temperatures were applied to measured data at the downstream locations. For HCD outflows, CE-QUAL-W2 modeling results were used to determine the modeled temperature change from the operational scenarios to apply to the measured data. For example, if the difference between the CE-QUAL-W2 modeled operational scenario (where a deeper fall draft was applied) was 0.5°C cooler than the CE-QUAL-W2 modeled operational baseline, then the measured HCD outflow temperature was lowered by 0.5°C. This approach was necessary and important because the downstream temperatures in this analysis are compared to temperature criteria and other measured data (i.e., Lower Granite tailrace) where model error and bias can cause issues with interpretation. By adjusting measured data using the difference between two modeled scenarios the model error and bias is much less influential on those comparisons. We used a similar approach when estimating temperatures at downstream locations where estimated temperature differences from the flow-weighted, mass balance method were applied to adjust the measured data before comparing with temperature criteria or other measured data.

Anatone and Lower Granite temperatures were based on a simple flow-weighted, mass balance method. No environmental cooling or warming as water flowed from the measured locations was applied. Also, in comparisons between locations, no adjustments were applied to account for water travel time between locations.

Water temperatures leaving Hells Canyon Dam are expected to be cooler under any additional fall drafting operational scenario (Figure 1). The expected cooling increases over time and is largest under the most aggressive drafting scenario.

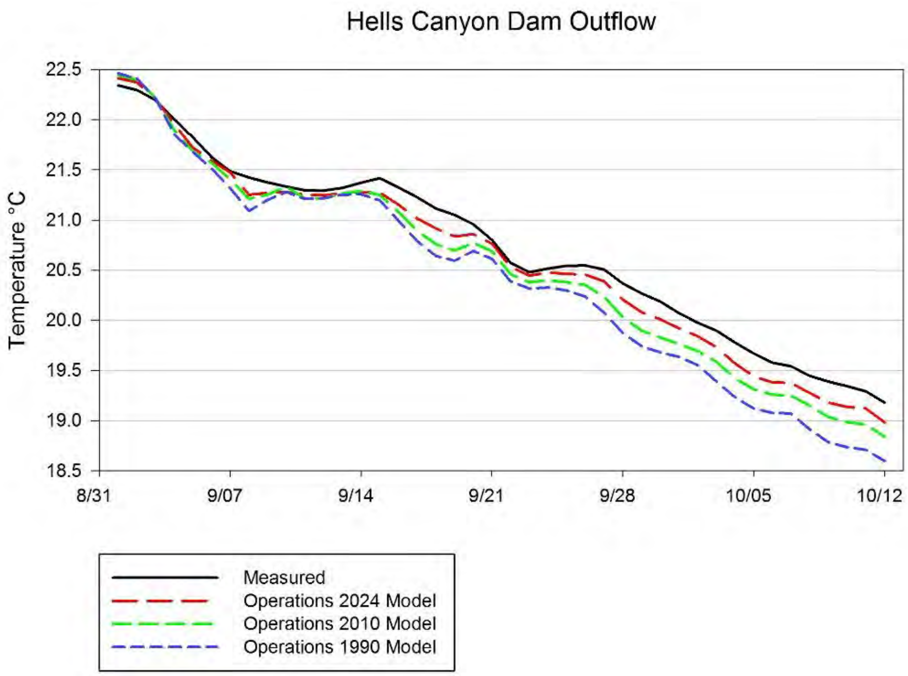

Figure 1. Hells Canyon Dam outflow temperature used in the flow weight, mass-balance method. Shown are measured conditions along with adjusted measured data based on applying a modeled CE-QUAL-W2 temperature difference between scenarios.

The simple flow-weighted, mass balance temperature estimates (measured HCD outflow temperatures and flow, Salmon River temperature, and flow and distributed flow and temperature) agreed with measured temperatures relatively well for the Snake River near Anatone (Figure 2). Maximum temperatures measured near Anatone during the period were 21.3°C and cooled to 17.6°C over the 42-day period. Similarly, estimated temperatures ranged from 21.6°C down to 17.8°C over the same 42-day period. On average, the flow-weighted, mass balance method predicted temperatures 0.3°C warmer than measured temperatures near Anatone. This can be explained because the flow-weighted, mass balance method does not account for any cooling that would be expected during that time of year as the Snake River flows downstream to Anatone. Generally, the Snake River is cooling as it flows from Hells Canyon Dam to Anatone during September 1 through October 12. Based on this analysis, we concluded that flow-weighted, mass balance approach is adequate for assessing the potential impacts of drafting scenarios on water temperatures near Anatone.

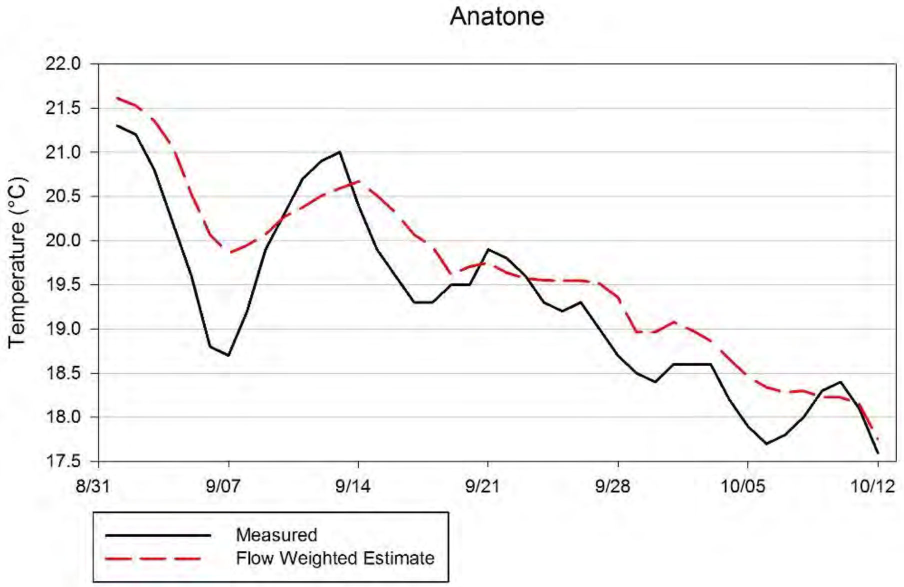

Figure 2. Daily average water temperatures from the USGS Gage near Anatone, WA. compared with temperature estimates using the flow-weighted, mass balance method.

To estimate the downstream effects of the drafting scenarios we used modeled HCD outflow rates. The CE-QUAL-W2 modeling for 2015 included an operational baseline and 3 scenarios where a deeper fall draft of Brownlee was modeled. The resolution of the operational planning model used to develop the flow conditions for this modeling was approximately monthly with interim dates included based on operational requirements (e.g., stable Fall Chinook flows beginning on the second Monday of October). Therefore, HCD outflow rates from the modeling are stable for relatively long periods. On average, over each period the baseline model flows are similar to the measured flows (as was the intent) but do not match on a daily basis. To compare among the scenarios, it was necessary to use HCD modeled outflow flows for the operational baseline and the 3 scenarios. The effect of this change is minor and when comparing the flow-weighted, mass balance method using measured HCD outflow flow and modeled baseline HCD outflow flow the absolute difference averaged 0.1°C.

During the period when flows would be increased, to accomplish deeper drafts of Brownlee Reservoir, the maximum temperature increase at Anatone under the range of potential drafts was 0.38°C on September 6 (Figure 3). We applied the differences from the flow-weighted, mass balance modeling to the measured temperature at Anatone to compare the impacts of the scenarios at Anatone. On September 6, the measured water temperature was 18.8, so the potential temperature on that date under an extreme operational scenario is estimated at 19.2°C.

Over the entire period of September 1 through October 12, measured temperature near Anatone in 2015 ranged from 21.3°C to 17.6°C. In 2015, water temperatures near Anatone dropped below the 20°C migration standard on September 5. Increases in Salmon river temperatures resulted in Anatone temperatures again rising above 20°C from September 10-14. The temperature patterns remained similar under all draft scenarios with the exception that under the 2010 and 1990 drafts temperatures did not return below 20°C until September 16 rather than on September 15. By October 1, the 2010 and 1990 scenarios were resulting in cooling at Anatone (Figure 4).

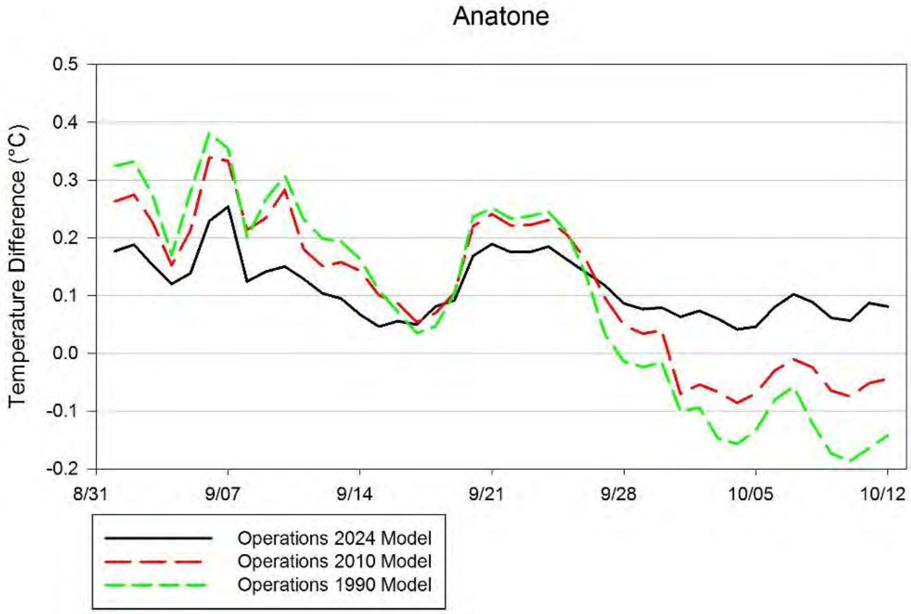

Figure 3. Net change in temperature under three operational scenarios.

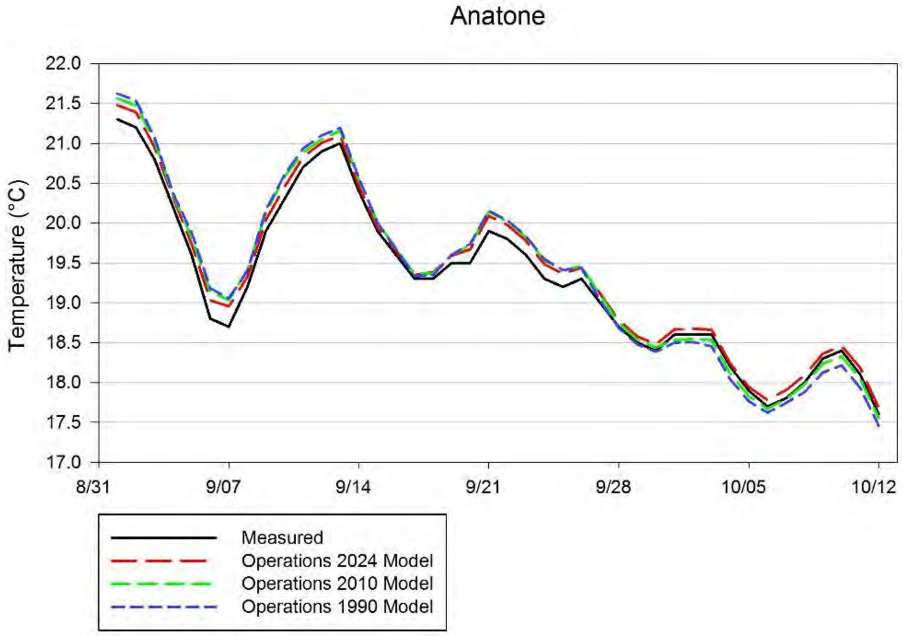

Figure 4. Measured temperature at Anatone compared with the 3 operational scenarios shown as adjusted measured data based on applying the temperature changes from the flow weighted mass balance calculations (Figure 3).

We conducted a similar analysis to assess the accuracy of the flow-weighted, mass balance method on predicting temperature below Lower Granite Dam as at the Anatone location. We used measured Anatone temperatures and flow and Clearwater River temperature and flow. The average temperature measured in the Lower Granite tailwater was 17.8°C over the 42-day period, while the flow-weighted mass balanced estimate was 17.5°C. The maximum difference between measured data and flow weighted, mass balanced estimates was 2.8°C on September 6 (Figure 5). Similar to Anatone estimates, lack of accounting for environmental cooling and warming, and travel time can be attributed to the period of differences even though the entire period matched well. In contrast to Anatone estimates, relatively complex mixing conditions between the Snake River and Clearwater River within Lower Granite Reservoir are the likely cause of much of the error in the simple flow weight, mass balance method. The inconsistencies in high temporal resolution analysis is likely due to the fact that the simple flow-weighted, mass balanced estimates do not account for travel time and the relatively complex mixing conditions within Lower Granite Reservoir and its tailwaters. The flow-weighted, mass balance method was not as effective in estimating Lower Granite temperature as it was in estimating temperature at Anatone. We determined that it was still useful to estimate the potential effects of the drafting scenarios at Lower Granite tailwater using this method.

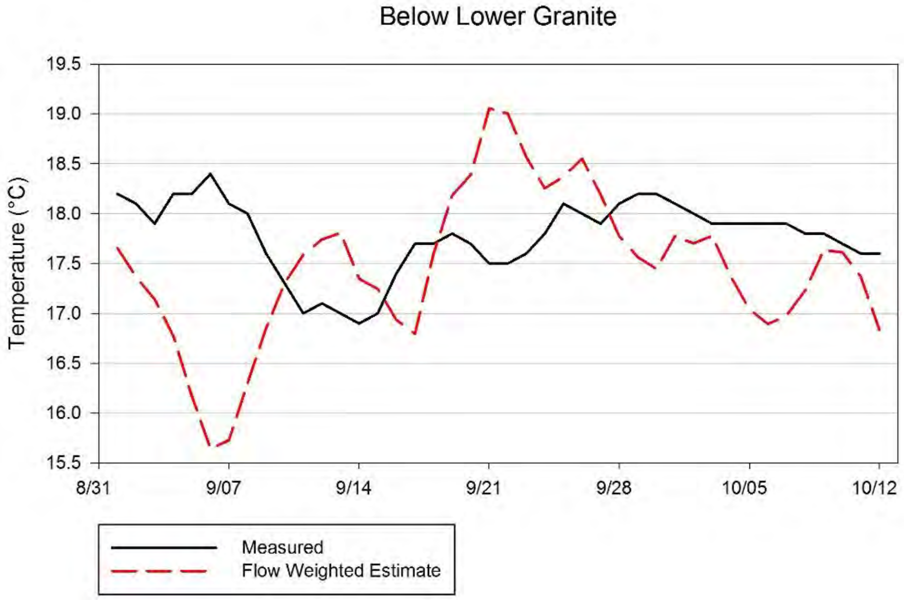

Figure 5. Daily average water temperatures from the USGS Gage below Lower Granite Dam, WA. compared with temperature estimates using the flow-weighted, mass balance method.

To estimate potential effects of the draft scenarios, we used the flow-weighted mass balance method with the temperature estimates at Anatone (Figure 4), along with Anatone flow that included HCD modeled outflow, and measured temperature and flow of the Clearwater River. During the period when flows would be increased, to accomplish deeper drafts of Brownlee, the maximum daily average water temperature measured in the lower Granite tailwater in 2015 was 18.4°C (September 6). The migration standard is 20°C. The analysis shows that even under the most extreme draft, the potential increase in temperature would not result in temperatures above the 20°C migration standard (Figures 6 and 7).

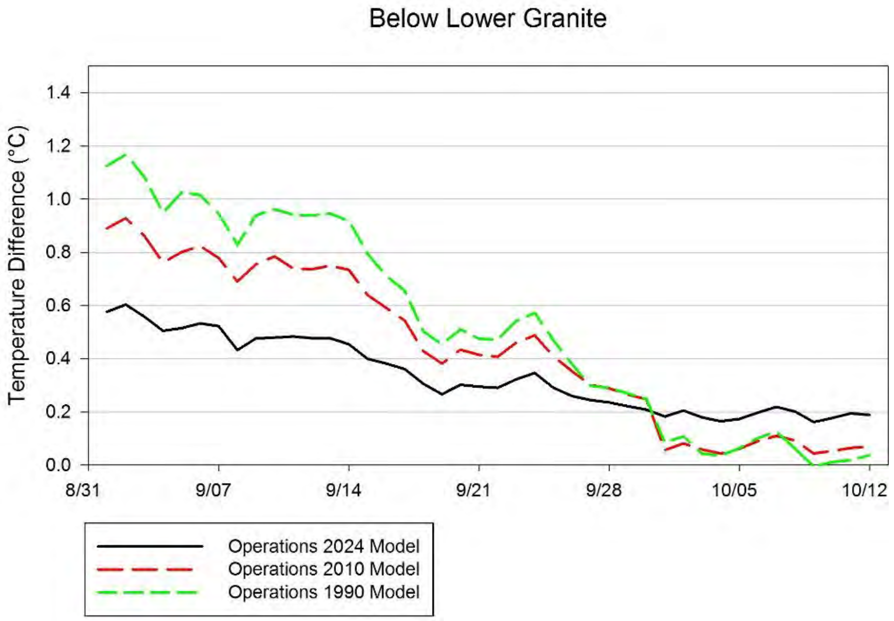

Figure 6. Net change in temperature below Lower Granite Dam under three operational scenarios.

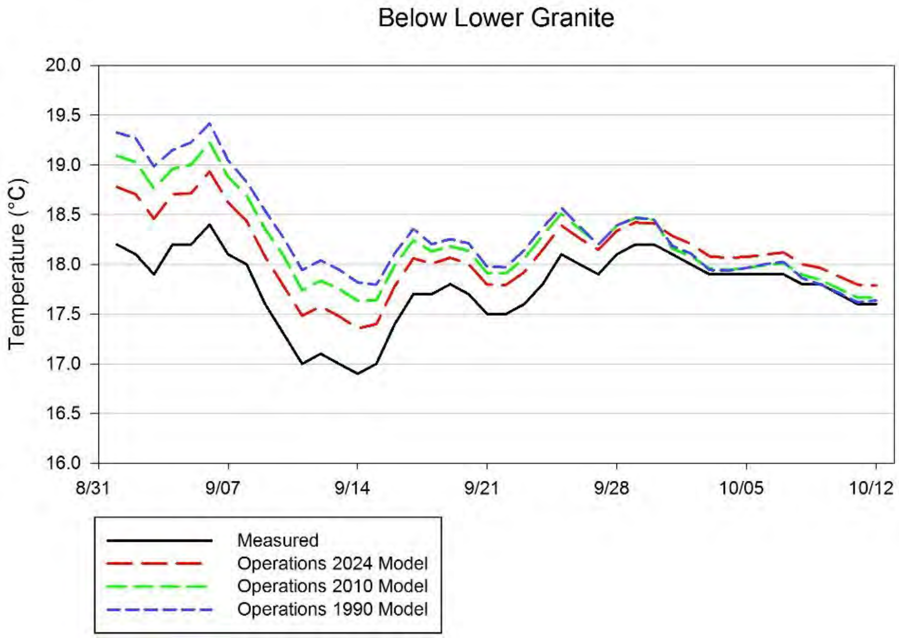

Figure 7. Measured temperature below Lower Granite compared with the 3 operational scenarios shown as adjusted measured data based on applying the temperature changes from the flow weighted mass balance calculations (Figure 6).

To further assess the potential effects of periodic additional fall drafting of Brownlee Reservoir on September migration temperatures at Lower Granite Dam, we summarized USGS monthly average temperatures from Gage 13343595 (Snake river (Right Bank) BL Lower Granite Dam (Table 1). In the 4 years we have identified as potential years when Brownlee drafts could have been implemented to improve spawning temperatures (the 4 years that allow comparison with monthly average Lower Granite measurements), September average temperatures were below 18°C. Further, these four years were the 4 coolest years for September temperatures for the period of record (2009-2017). This further supports the 2015 analysis and conclusion that the proposed Brownlee operations should not result in any exceedances of the 20°C migration standard.

Table 1. Summarized monthly average temperature available from below Lower Granite Dam (USGS gage #13343595).

Year	July	August	September	October
2009	NA	NA	19.3	14.7
2010*	18.2	18.8	17.1	16.4
2011	16.8	19.0	19.1	16.1
2012	18.8	18.9	18.2	15.4
2013	19.2	18.9	19.4	13.9
2014*	18.6	19.4	17.5	16.5
2015*	19.4	19.3	17.8	17.1
2016*	18.8	18.7	17.7	15.3
2017	19.9	19.9	18.8	14.5

Conclusion

Periodic additional drafting of Brownlee Reservoir in the fall has been identified as a potential tool for reducing water temperatures during the fall chinook spawning period. additional drafting of Brownlee Reservoir from September 1 through the second Monday in October could accelerate fall cooling of HCC outflows. However, while outflows from the HCC would be cooled, the increased quantity of HCC water that becomes mixed with tributaries downstream could result in slightly warmer conditions below the Salmon and Clearwater rivers. While slight increases in temperature could be expected in years of enhanced drafting of Brownlee Reservoir, our analysis of 2015 data indicates any increases should not result in exceedances of the migration standard below Lower Granite Dam. The most aggressive draft scenarios added one day to the original 8-days that temperature exceeded 20°C in the Snake River near Anatone. It is also notable that enhanced drafting of Brownlee Reservoir would likely occur in years with the coolest September water temperatures at Lower Granite Dam.

Exhibit 7.1-3

Technical memorandum estimating effects of the Brownlee operational component on emergence timing of SRFC

IDAHO POWER®
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DATE: June 7, 2018
SUBJECT: Technical memorandum estimating the effects of the Brownlee Operational proposal (Section 7.1 of the IPC 401 Application) to address temperature exceedance of a 7-DAM of 16.5°C during the salmonid spawning period.

Introduction

Although the current standard for salmonid spawning is a 13°C 7- Day Average Maximum Temperature (7-DAM) on October 29, there is evidence that Snake River fall Chinook salmon (SRFC), the primary beneficial use associated with this standard can successfully produce viable off-spring at initial spawning temperatures greater than this standard. In their recovery plan (NOAA 2017), NOAA Fisheries relied on Geist et al. (2006) to analyze effects of warm fall temperatures on spawning success. Generally, Geist et al. (2006) concluded that survival from egg fertilization to emergence with initial water temperatures up to 16.5°C do not significantly differ from the existing standard under a declining thermal regime that is typically observed during the SRFC spawning period in Hells Canyon. Survival of fertilized eggs declines significantly with temperatures between 16.5°C and 17°C, with no survival expected above 17°C. Warmer temperatures in the fall and during the incubation period accelerate emergence timing of SRFC. Early emergence is significant in maintaining the historically dominate subyearling life-history pattern associated with SRFC (NOAA 2017).

IPC submitted its proposal to address project related effects on temperatures downstream of Hells Canyon dam during the fall Chinook spawning period beginning on Oct 23 as part of its CWA 401 application on February 23, 2018 and will again on June 14, 2018. The proposal identified deeper fall drafts of Brownlee Reservoir in years when outflow temperatures below Hells Canyon Dam would be forecast to exceed a 7-DAM of 16.5°C during the salmonid spawning period (see Section 7.1.2.1 of the Application). The intent of the operations is to provide cooler water discharges from the HCC during the late October and early November period of the fall chinook spawning period. Analysis presented in the February filing showed that deeper drafts of Brownlee Reservoir could have been employed in approximately 20-25 percent of the historic years to meet the goal of keeping the 7-DAM below 16.5°C during the spawning period.

While a benefit is anticipated relative to lowering water temperatures during the spawning period in the years it would likely exceed the 16.5°C 7-DAM, the continuation of the cooler thermal regime into the incubation period raises concerns relative to the potential of delaying the emergence timing of SRFC. Fall chinook salmon development and emergence timing during the incubation period is temperature dependent. Later emergence and delay in the outmigration of juvenile fall Chinook salmon has been demonstrated to decrease survival during the outmigration period (Connor et al. 2003).

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Methods and Results

To evaluate the potential effect of the cooler spawning and incubation period, IPC conducted modeling to simulate the thermal conditions below the HCC resulting from deeper fall drafts of Brownlee Reservoir. Three potential draft elevation scenarios were evaluated relative to the measured condition: 1,990 ft msl (ops1990), 2,010 ft msl (ops2010) and 2,024 ft msl (ops2024). Full pool elevation of Brownlee Reservoir is 2,077 ft msl. A CE-QUAL-W2 model (See Exhibit 7.1-1 for more detail on the CE-QUAL-W2 modeling) was developed to model the temperatures in the discharge from the HCC from September 1, 2015 to June 20, 2016 (Figure 1). The fall of 2015 is the warmest spawning period relative to other spawning periods since monitoring began in 1991. The modeling demonstrated that even under the most extreme draft, the goal of the 16.5°C 7-DAM was not achieved. However, the number of days that exceeded 16.5°C was reduced. In less extreme years than 2015, operational scenarios would be more likely to achieve the goal of the Oct 29 7-DAM being 16.5°C or less.

A cumulative spawning distribution was developed using curvilinear regression techniques of the proportion of observed redds against the day of the year over several years to estimate the proportion of redds constructed each day during the spawning period. The spawning distribution was overlaid with the measured and modeled daily temperatures to estimate the percentage of redds exposed to temperatures greater than 16.5°C. Under the measured condition of 2015, an estimated 43 percent of the redds upstream of the Salmon River were constructed under temperatures that exceeded 16.5°C. Drafting to levels of 2,010 msl and 1,990 msl reduced this percentage to 32% and 22%, respectively (Table 1).

Because some survival is anticipated between 16.5°C and 17°C, total fry produced was estimated using a fecundity estimate of 3,800 eggs per female. The relationship between 16.5°C and 17°C and embryo survival from the Geist et al. (2006) study shows embryo survival decreases by 10.9 percentage points for every 0.1°C increase in Degree Days (DD) >16.5 (e.g., a daily temp of 16.8°C would equate to 0.3 DD [16.8-16.5=0.3 DD] or an equivalent of 10.9 x 3 = 32.7% reduction in survival). Redds produced in temperatures 16.5°C and less were assumed to have 100% survival relative to temperature. This relationship was applied to each day during the cumulative spawning distribution. An estimate of fry produced was calculated. Total fry produced was divided by 3,800 to estimate a female equivalency estimate among the different scenarios using the total number of redds observed as an estimate of total females. Female equivalency for the measured condition relative to fry produced was 64% of the total redds. The different operational scenarios resulted in increased female equivalence of 73%, 83% and 86% for the ops2024, ops2010 and ops1990 scenarios, respectively (Table 1). Total fry produced relative to the measured increased 13.6%, 29.4% and 35.2% for the ops2024, ops2010 and ops1990 scenarios, respectively (Table 1).

Emergence timing is calculated by accumulating DD's > 0°C (eg – 2 days at 10°C equates to 20 DD) from the day of fertilization until accumulated DD's equals 1,000. As expected, the cooler thermal regime from spawning through incubation resulted in a slower accumulation of DD's and delays in emergence timing relative to the measured condition. For the median spawn date of approximately Nov 1, emergence timing would be delayed 7, 11 and 18 days relative to the measured condition for the ops2024, ops2010 and ops1990 scenarios, respectively (Table 1). For subyearling migrants, emergence timing is important because maximum juvenile survivals occur nearest the peak of the spring freshet and decline throughout the summer as flows and turbidity levels decline and temperatures increase reducing travel time and increased exposure to more active predators. To evaluate the effect of delayed emergence, survival was estimated to the tailrace of Lower Granite Dam relative to emergence timing. A compilation of factors and mechanisms and their relationships to survival of juvenile fall Chinook salmon is in preparation (William Connor, USFWS, *in prep*; personal communication). These various relationships were used to provide some relative comparison on how the effect of the delayed emergence in these draft scenarios would differ from the measured condition. Some of the driving variables in these relationships include temperatures that influence parr growth following emergence in the early rearing areas between Hells Canyon Dam and the confluence of the Salmon River and the water temperature and discharges (flow volume) as measured in the tailrace of Lower Granite Reservoir that relate to migration success. These relationships were used to compare percent of fry produced that survive to the tailrace of Lower Granite Dam. The results demonstrate that the percent of fry arriving at Lower Granite Dam decreases with the delayed emergence. Under the measured condition, survival to the tailrace of Lower Granite Dam was estimated at 28.9% and dropped to 27.2%, 25.5% and 24.5% for the ops2024, ops2010 and ops1990 scenarios, respectively (Table 1). However, the total fry that arrived at Lower Granite increased under the operational scenarios relative to the overall increase in fry produced from the cooler spawning periods. Total fry arriving at the Lower Granite Dam tailrace increased 6.5%, 15.2% and 17.2% relative to the measured condition for the ops2024, ops2010 and ops1990 scenarios, respectively (Table 1), demonstrating a net benefit from the operational scenarios.

References

William P. Connor, Howard L. Burge , John R. Yearsley & Theodore C. Bjornn. 2003. Influence of Flow and Temperature on Survival of Wild Subyearling Fall Chinook Salmon in the Snake River, North American Journal of Fisheries Management, 23:362-375

NOAA (National Oceanic and Atmospheric Administration). 2017. ESA Recovery Plan for Snake River fall Chinook salmon (*Oncorhynchus tshawytscha*). NOAA National Marine Fisheries Service. Portland, OR. 366 pp.

Table 1. A comparison of Snake River fall Chinook salmon production metrics between the measured condition and three Brownlee Reservoir draft operational scenarios. OPS2024, OPS2010 and OPS1990 equate to a draft of Brownlee Reservoir to elevations 2,024 ft msl, 2,010 ft msl, and 1,900 ft msl, respectively. These elevations are relative to a full reservoir elevation of 2,077 ft msl.

METRIC	MEASURED	OPS2024	OPS2010	OPS1990
REDDS EXPOSED TO >16.5°C (PERCENT)	43	43	32	23
FEMALE EQUIVALENTS (PERCENT)	64	73	83	86
INCREASE FRY PRODUCTION AT EMERGENCE RELATIVE TO MEASURED (PERCENT)		13.6	29.4	35.2
DELAY IN MEDIAN EMERGENCE (DAYS)		7	11	18
SURVIVAL TO LOWER GRANITE TAILRACE (PERCENT)	28.9	27.2	25.5	24.8
INCREASE SMOLT PRODUCTION TO LOWER GRANITE DAM TAILRACE RELATIVE TO MEASURED (PERCENT)		6.5	15.2	17.2

Figure 1. Daily Average Temperatures representing outflow of the Hells Canyon Complex from measured data and modeled draft scenarios of Brownlee Reservoir from September 1, 2015 (Day 244) to June 20, 2016 (Day 537). OPS2024, OPS2010 and OPS1990 equate to a draft of Brownlee Reservoir to elevations 2,024 ft msl, 2,010 ft msl, and 1,900 ft msl, respectively. These elevations are relative to a full reservoir elevation of 2,077 ft msl.

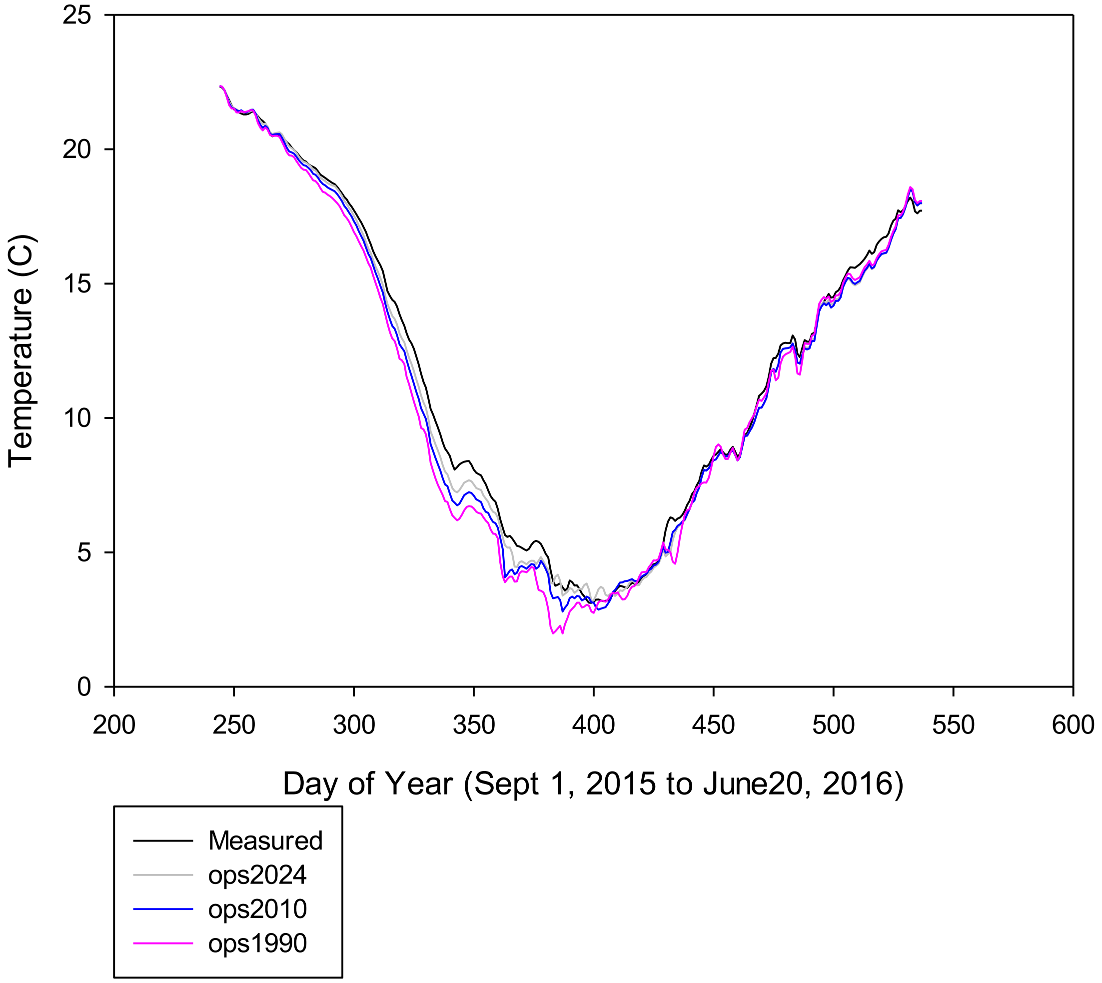

Exhibit 7.1-4

Supporting information and regulatory examples using statistics when selecting targets.

Exhibit 7.1-4
Supporting information and regulatory examples using statistics when selecting targets.

NPDES permit precedence

In the Oregon NPDES permit context, the implementation of the temperature criteria incorporates a statistically-based 90% exceedance probability. See OR. ADMIN. RULE 340.041.0028(12)(d) Low Flow Conditions ("An exceedance of the biologically-based numeric criteria in section (4) of this rule, … will not be considered a permit violation during stream flows that are less than the 7Q10 low flow condition for that water body"). In Oregon, a NPDES permit holder is not required to meet the temperature criteria under all environmental conditions. The rules recognize the possibility of extreme climatic conditions and do not require that the permittee meet the temperature criteria at all times. Specifically, flow-based wasteload allocations for heat are based on 7Q10 (7-day average low flow with a 10-year recurrence interval) low river flow conditions. The 7Q10 low flow represents the lowest 7-day average flow that occurs (on average) once every 10 years, meaning that the river flows are expected to be higher 90% of the time. NPDES permits incorporate 7Q10 low flows to calculate wasteload allocation. See, e.g., Oregon Dep't of Envtl. Quality, NPDES Permit No. 100985, City of Medford, Schedule A(1)(b) (2011); Oregon Dep't of Environmental Quality, Rogue River Basin Temperature TMDL, at 2-53 (2008). A NPDES permit holder is not considered to be in violation of the temperature criteria when river flows are lower than the statistically based 7Q10 low flow.

In other NPDES permit contexts, regulators have used 90% (or even less conservative statistical breakpoints) to determine the size of an obligation that needs to be addressed. For example, in the statewide stormwater permit issued to the California Department of Transportation, when determining the numeric sizing criteria for storm water BMPs, the California State Water Resources Control Board concluded that "the storm water runoff volumes and rates used to size BMPs shall be based on the 85th percentile 24-hour storm event." Cal. State Water Resources Control Bd., Order WQ 2012-0011-DWQ, NPDES Statewide Storm Water Permit Waste for State of California Dept. of Transportation, Permit No. CAS000003, ¶ E.2.d.2.b, 2012 WL 5306154, at *28 (2012) (updating other provisions as Order WQ 2014-0011-DWQ). Of particular import, the numeric size of the BMP offset need in this permit was pegged to a less stringent statistic than the current proposal under consideration from IPC (85% versus 90%). Use of the 7Q10 statistical flow estimation has also been upheld in NPDES permit reasonable potential analyses, and has been recommended by EPA to determine what effluent limits are necessary to protect water quality. Friends of the Rocky River v. North Carolina Dep't of the Envt. and Nat. Resources, N.C. Office of Admin. Hearings, 2009 WL 3460741, ¶¶ 38-40 (2009); see also U.S. Envtl. Prot. Agency, Flow 101, Design Flows: Definitions and Methods, http://water.epa.gov/scitech/datait/models/dflow/flow101.cfm#methods (last accessed June 25, 2015).

FERC licensing precedence

The 90th percentile is a conservative threshold for the purposes of assessing water quantity issues. In a FERC licensing context, 90% has been used as a mechanism for determining whether operations of a dam are likely to impact water quality and hydrology. For example, in the environmental effects analysis used to support a Duke Power Company request to increase its water withdrawal, FERC relied on 90% exceedance flows in the downstream river to determine that the amount of surplus water requested by the licensee would have “an insignificant effect on the hydrology and water quality” of the system. Duke Power Co., Order Approving Non-Project Use of Project Lands, 78 FERC ¶ 62067, 64144 (Feb. 3, 1997). Similarly, when reviewing applications for new water right permits, the Oregon Water Resources Department uses 80% exceedance flows to determine if there is water available. OR. ADMIN. RULE 690-400-010(11)(a)(A). If the total water requested in a stream is greater than the total available water in the stream assuming an 80% exceedance scenario, then OWRD will deny the permit application. Much like cumulative thermal load calculations that rely on the 90th percentile, exceedance curves are based on measured or modeled data accumulated over a period of years, and then statistically analyzed to identify particular thresholds.

Water Quality Standards process precedence

The 90th percentile is also a threshold sometimes used by regulators to trigger temporary variances from water quality standards. For example, in a license for the Wolverine Power Supply Company, FERC granted a revised license that includes a variance that allows average streamflow temperatures to be exceeded for short periods when air temperatures exceed the 90th percentile. Wolverine Power Supply Coop., Inc., Order on Rehearing, 85 FERC ¶ 61030, 61096 (Oct. 5, 1998). This approach is echoed in regional temperature standards that exempt temperature violations when ambient air temperatures exceed the 90th percentile. See OR. ADMIN. RULE 340.041.0028(12)(c) (exempting temperature exceedance violations when the daily air temperature exceeds the 90th percentile of a yearly series of the maximum weekly maximum air temperatures); see also IDAPA 58.01.02.080.03 (containing parallel language to the Oregon rule).

TMDL precedence

A 90% water quality criteria have also been used by regulators to develop margins of safety in a TMDL. In an appeal of a water right change application approved by the Depart of Ecology, the Washington Pollution Control Hearings Board considered the Washington Department of Ecology’s reliance on the Snohomish River Estuary TMDL for BOD and ammonia when determining whether the approval would adversely affect aquatic species. The Tulalip Tribes of Wash. v. Wash. St. Dept. of Ecology and Snohomish River Regional Water Auth., Findings of Fact, Conclusions of Law and Order, 2002 WL 1650503, PCHB No. 01-106, at *4 (Wash. Pollution Control Hearings Bd. 2002). To account for uncertainties in its TMDL modeling, Ecology incorporated several conservative assumptions in developing a TMDL margin of safety, including “us[e] of approximately the 90th percentile for most quality criteria[.]” Id. The Board upheld Ecology’s water right transfer approval, in part because “the assumptions and data used were quite conservative and were based on valid field testing and scientific literature.” Id.

Exhibit 7.1-5

Snake River Stewardship Program for thermal compliance with the relicensing of the Hells Canyon Complex

The Freshwater Trust®
Changing the course of conservation.

The Freshwater Trust is a 501(c)(3) not-for-profit organization that actively works to preserve and restore our freshwater ecosystems.

Snake River Stewardship Program for Thermal Compliance with the Relicensing of the Hells Canyon Complex

Prepared by The Freshwater Trust for

Idaho Power Company

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Glossary of Terms

401 Certification	As described in 33 U.S.C. § 1341(a)(1), when a federal permit or license applicant plans to undertake any activity (including facility construction or operation) that may cause any discharge into navigable waters, it must obtain a 401 certification. The certification must come from the relevant state and certify that the discharge will comply with select provisions of the CWA. The proposed SRSP is a part of IPC's application 401 certification for the HCC.
Additionality	A thermal benefit is considered additional (and therefore eligible to count toward achievement of IPC's cumulative thermal load exceedance) when the thermal benefit or restoration action from which the thermal benefit is realized is not already required by federal, state, tribal or local law or regulation, and the restoration action would not have been generated without funds or resources provided by IPC.
Aggregate Thermal Benefits	The total number of thermal benefits that must accrue at the inflow to the HCC over the aggregate thermal benefit time period. The aggregate thermal benefit total is sufficient to offset the cumulative thermal load exceedance, and accounts the SR-HC TMDL margin of safety and a reservoir attenuation factor. The thermal benefits generated from individual project sites are aggregated across the aggregate thermal benefit time period (i.e., the sum of thermal benefits generated from each site over the time period). Before aggregating, the thermal benefits are discounted by in-river attenuation factors to account for the attenuation of those benefits between the project site location and the inflow to the HCC.
Aggregate Thermal Benefit Time Period	Thermal benefits from a project site reflect the sum of the thermal benefits generated from that project site during the months of July, August, September and October (through October 29).
Attenuation	The change in thermal pollutant quantity as it moves between two points, such as from an upstream location to a downstream location, or through a reservoir.
Auditing	An annual independent review of a sample of SRSP project sites to confirm accuracy and completeness of records, adequacy of SRSP quality control measures, and compliance with laws and regulations.
Best Management Practices (BMPs)	BMPs referenced in the SRSP are agricultural actions to reduce sediment runoff such as improved irrigation practices or changes to nutrient management.
Cumulative Thermal Load Exceedance	The amount, expressed in billions of kcals/day (bkcal), by which the temperature of the water discharged at Hells Canyon Dam during the salmonid spawning period exceeds the 7-day average maximum temperature criterion. IPC will offset the cumulative thermal load exceedance by generating sufficient aggregate thermal benefits to account for this exceedance and the SR-HC TMDL margin of safety, and a reservoir attenuation factor.

Clean Water Act	Federal Water Pollution Control Act, 33 U.S.C. § 1251 et seq.
Departments of Environmental Quality (DEQ)	Idaho and Oregon are the state agencies responsible for issuing a 401 certification to IPC. These agencies share responsibility because the affected stream reach is a boundary water between the two states.
Feasibility	The process of establishing that an action is viable. For the purposes of the SRSP, establishing feasibility of achieving thermal benefits to offset the cumulative thermal exceedance at the outflow of HCC required demonstrating that more thermal benefits were available in the program area than were needed to offset the exceedance.
Federal Energy Regulatory Commission (FERC)	The FERC issues licenses to hydroelectric facilities, based in part on obtaining state DEQ 401 certifications.
Hells Canyon Complex (HCC)	Hells Canyon Complex refers to three dams (Hells Canyon Dam, Oxbow Dam, and Brownlee Dam) and Brownlee Reservoir operated by Idaho Power Company. IPC is in the process of applying for relicensing of the HCC.
Kcal/day	Kilocalories per day (a unit of heat).
Monitoring Metrics	Measureable indicators of changes to projects (such as plant growth, or surface area change) that will indicate project and program performance over time.
Nonpoint Source	Diffuse sources of water pollution such as stormwater and nutrient runoff from agricultural or forested lands. In contrast to “point sources,” as defined at 33 U.S.C. § 1362(14).
Offset	Reductions in thermal loading made upstream of the HCC meant to compensate for the HCC cumulative thermal load exceedance. The aggregate thermal benefits generated from SRSP projects must be greater than the cumulative thermal load exceedance, and any ratios and adjustment factors.
Performance Confirmation (initial and ongoing)	The formal approval process of the thermal benefits generated from a restoration action. This step occurs after a project is implemented and is the last step before registration. After initial approval, project sites are entered into an annual audit pool, and this step again occurs for those audited project sites.
Performance Objectives	Benchmarks for restoration projects over time. These recommended interim states will be informed by monitoring data collected over time and should help support adaptive management to promote healthy and successful restoration projects that achieve modeled conditions by the program’s conclusion.
Property/Tax lot	A parcel of contiguously owned land, with local tax authority defined ownership boundaries. Project sites are implemented in the riparian portions of the property.
Project/Project Site	The specific area(s) within the larger property that will be restored for the purposes of generating thermal benefits.

Qualitative Monitoring	Rapid project site assessment to confirm that projects remain in place and are continuing to demonstrate progress toward modeled conditions for achievement of thermal benefits.
Quantification	Scientifically-based method for determining the thermal load reduction associated with a given restoration action. Quantification methods can be grouped into three general types: pre-determined rates/ratios, modeling, and direct monitoring. Modeling has been used to estimate thermal benefits in advance of project implementation. Direct monitoring may demonstrate additional thermal benefits as projects are implemented.
Quantitative Monitoring	Detailed empirical review of a sample of SRSP project sites to assess progress toward performance objectives, confirm thermal benefit modeling assumptions, update monitoring tools, and to help improve SRSP project management.
Recruitment	The process of outreach and communication in order to enroll voluntary landowners into contracts for the implementation and stewardship of SRSP projects on their property.
Registration	After initial performance confirmation, information on project sites are uploaded (including supporting documents) to a publicly available program tracking website.
Restoration Quality Standards	Comprehensive descriptions of restoration action project site selection/eligibility, project design, implementation, thermal benefit quantification, monitoring, maintenance, project confirmation, tracking and reporting to ensure that projects implemented for the SRSP are of a high quality and are highly likely to produce thermal benefits over time. The quality standards are necessary to complete initial and ongoing performance confirmations. The standards are currently in draft form (Attachment 1), will be revised throughout the research phase of the SRSP, and finalized upon initiation of the FERC operating license for the HCC.
Snake River-Hells Canyon (SR-HC) TMDL	The scope of the TMDL extends from where the Snake River intersects the Oregon/Idaho border near Adrian, Oregon (Snake River mile (RM) 409) to immediately upstream of the inflow of the Salmon River (RM 188) (Hydrologic Unit Codes (HUCs) 17050115, 17050201 and 17060101, and a small corner of 17050103). This includes the HCC reservoirs: Brownlee, Oxbow and Hells Canyon.
Snake River Stewardship Program (SRSP)	The proposed watershed restoration program detailed in this Exhibit that includes instream and riparian revegetation projects that generate thermal benefits by reducing heat loading upstream of the Hells Canyon Dam.
Thermal Benefits	Thermal benefits are calculated estimates of the benefits that will accrue from an implemented restoration project once it fully matures. Thermal benefits are the difference between pre-project conditions and anticipated post-implementation conditions.

Total Maximum Daily Load (TMDL)	The amount of an identified pollutant that a specific stream, lake, river or other waterbody can accommodate without violating state water quality standards. TMDLs are watershed-based plans for restoration of designated beneficial uses in water quality limited waterbodies. These plans must identify the causes of designated beneficial use impairment and estimate reductions in pollutant loads necessary to meet water quality standards and restore impaired designated beneficial uses within a specified time.

1 Introduction

The Snake River and its tributaries have been substantially modified so that many natural processes no longer occur at the same frequency or rate. For example, river flows have decreased, vegetation has been removed, and large loads of nutrients and sediment enter the river. Idaho Power Company (IPC) plans to implement the Snake River Stewardship Program (SRSP), a watershed-scale restoration approach, for the purposes of Clean Water Act § 401 certification for temperature as part of the relicensing of the Hells Canyon Complex (HCC). In addition to addressing the temperature responsibility, the watershed approach is expected to help restore dynamism to the Snake River above the HCC by improving ecological conditions in the Snake River and its tributaries.[1] The restoration work implemented through the SRSP will help to restore dynamic processes to reaches of the Snake River and its tributaries, including increased riparian shade, increasing water velocity (and potentially volume), decreasing temperature and aquatic macrophyte proliferation, and providing cold-water habitat for native species. The thermal benefits of the SRSP will be quantified and used to offset IPC's cumulative thermal load exceedance (described in Sections 6.1 and 7.1 of the 401 application for certification) as part of the renewal of the HCC FERC license and Clean Water Act § 401 certification

The Snake River-Hells Canyon (SR-HC) Total Maximum Daily Load (SR-HC TMDL) contains a temperature load allocation for the HCC, concluding that the HCC has an obligation to address water temperature conditions below Hells Canyon Dam (HCD) during the salmonid spawning period when flows into Brownlee Reservoir meet the downstream temperature standard. IPC's thermal load allocation has been converted into a cumulative thermal load exceedance. IPC has chosen to implement the SRSP, as part of its Temperature Management and Compliance Plan (TMCP) in order to offset its cumulative thermal load from the SR-HC TMDL. Offsetting this cumulative thermal load exceedance will be accomplished through the aggregation of thermal benefits from multiple SRSP projects upstream of HCD.[2]

Section 2 of this document describes the key attributes of the SRSP such as: program area (2.1); eligible thermal benefit-generating restoration actions (2.2); the methodologies by which thermal benefits will be calculated for these restoration actions and a description of how thermal benefits from project sites will be calculated using these quantification methodologies (2.3); a summary of thermal benefit need, thermal benefit supply in the program area, SRSP feasibility, and suggested thermal benefit compliance milestones (2.4); implementation considerations, including restoration quality standards (draft restoration quality standards are attached as Attachment 1 to this document), an explanation of how the SRSP will demonstrate regulatory, financial, and project site-specific "additionality," research phase

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[1] For the purposes of 401 certification for temperature issued by the Oregon and Idaho DEQs, the ecological "benefits" from SRSP restoration actions implemented upstream of the HCC will only be quantified as thermal load benefits. Improvement in ecological conditions and aquatic habitat are expected from the SRSP. These ecological and habitat improvement considerations are integrated into project design, implementation and tracking quality standards. So long as projects are designed and implemented consistent with these standards, and continue to progress and function consistent with those criteria, IPC will deemed to have met its 401 certification compliance objectives and requirements associated with the relevant temperature water quality standards.

[2] While IPC's HCC load allocation has been translated into a "cumulative thermal load exceedance" at the outflow of the HCC, the upstream offsets that enter the HCC inflow are referred to as "thermal benefits," which will be aggregated for all projects, over the aggregate thermal benefit time period (July 1 – October 29), at the HCC inflow.

implementation objectives, a description of the characteristics associated with thermal benefits, including how long thermal benefits are expected to last (2.5); project stewardship and tracking, including project maintenance, three levels of project monitoring, project performance confirmation and tracking, auditing, and the public availability of information related to SRSP projects (2.6); and watershed improvement from upland sediment reductions (2.7). Section 3 of this document describes the adaptive management approach of the SRSP.

2 Snake River Stewardship Program

The Snake River system has been substantially altered over time, largely by human influences and development: natural disturbances to the ecosystem no longer occur with the same frequency or energy, flow and water velocities have decreased, riparian areas have been denuded or developed, and inputs of heat, sediments, and nutrients have increased over time. To help remedy these issues, The Freshwater Trust (The Trust) has worked with IPC to design a holistic, watershed restoration program intended to offset IPC's cumulative thermal load exceedance stemming from the SR-HC TMDL. In short, the SRSP will involve the implementation of restoration actions upstream of the HCC. Restoration actions will include a mix of emergent wetlands, island enhancements, island creation, inset floodplain development, and riparian revegetation, and may include other actions over time (e.g. instream flow augmentation could be considered). These actions will generate a large number of thermal benefits that will help to minimize the impact of solar loading to the system, and offset IPC's cumulative thermal load exceedance. While full implementation of all measures necessary to meet IPC's load allocation could take several decades (IDEQ and ODEQ 2004), the first phase of watershed restoration will help to ameliorate anthropogenic impacts, restore dynamism to the Snake River, and achieve thermal load reductions over time.

The SRSP has been designed as a "quantified conservation" program that incorporates many of the principles of "water quality trading." As described in the U.S. Environmental Protection Agency 2003 water quality trading policy, "[w]ater quality trading is an approach that offers greater efficiency in achieving water quality goals on a watershed basis."(EPA 2003). The 2003 U.S. EPA Policy notes that trading is allowable in areas covered by a TMDL, especially where trading will "achieve ancillary environmental benefits beyond the required reductions in specific pollutant loads, such as the creation and restoration of wetlands, floodplains and wildlife and/or waterfowl habitat." Trading is explicitly authorized in both Oregon and Idaho rules.[3] Moreover, in acknowledgment of the long time period over which restoration will occur, the SR-HC TMDL recommends that entities engage in trading consistent with state policies, including those "between a watershed-based agricultural BMP implementation project and the Idaho Power Company"(IDEQ and ODEQ 2004).

While the SRSP is not a trading program, many of the same principles have been used to develop the SRSP. As described below, IPC's cumulative thermal load exceedance has been quantified in billions of kilocalories. Likewise, the thermal benefits associated with proposed instream restoration and riparian revegetation project actions will be quantified in the same units, using the described quantification tools with sufficient layers of conservatism. All of these thermal benefits must be generated within a

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[3] OAR 340-041-0028(12)(f) (2015); IDAPA 58.01.02(55)(06) (2015).

geographically defined “program area.” The restoration actions contemplated for IPC’s thermal benefit portfolio will be designed and implemented according to ecologically-based restoration quality standards that are correlated with modeled thermal benefit estimation inputs, and that will also protect and support beneficial uses and generate ancillary benefits. The thermal benefits generated by restoration projects will be monitored and maintained over time to confirm that modeled kilocalorie per day benefits are on track to be produced from each project site by the end of the SRSP program. In addition, the DEQs and the public will be afforded appropriate levels of transparency for the purposes of tracking program progress. In the event that IPC relies on third-party contractors—such as soil and water conservation districts, watershed councils and private contractors—to implement, maintain, or oversee project sites, IPC will be fully responsible for the success of all project elements.

2.1 Program Area

IPC will implement restoration projects to generate thermal benefits in the Snake River watershed including its tributaries and associated subbasins. Thermal benefits may be generated from restoration actions located below Swan Falls Dam and upstream of HCD in the Snake River. As illustrated in Figure 1, tributaries and subbasins eligible for thermal benefit generation in this program area include, but are not limited to: Boise River, Brownlee Reservoir creeks, Burnt River, Malheur River, Middle Snake-Payette River, Owyhee River, Payette River, Pine Creek, Powder River, Succor Creek, and Weiser River. Thermal benefit modeling of riparian areas in these tributaries does not extend upstream beyond any reservoir or substantial impoundment.

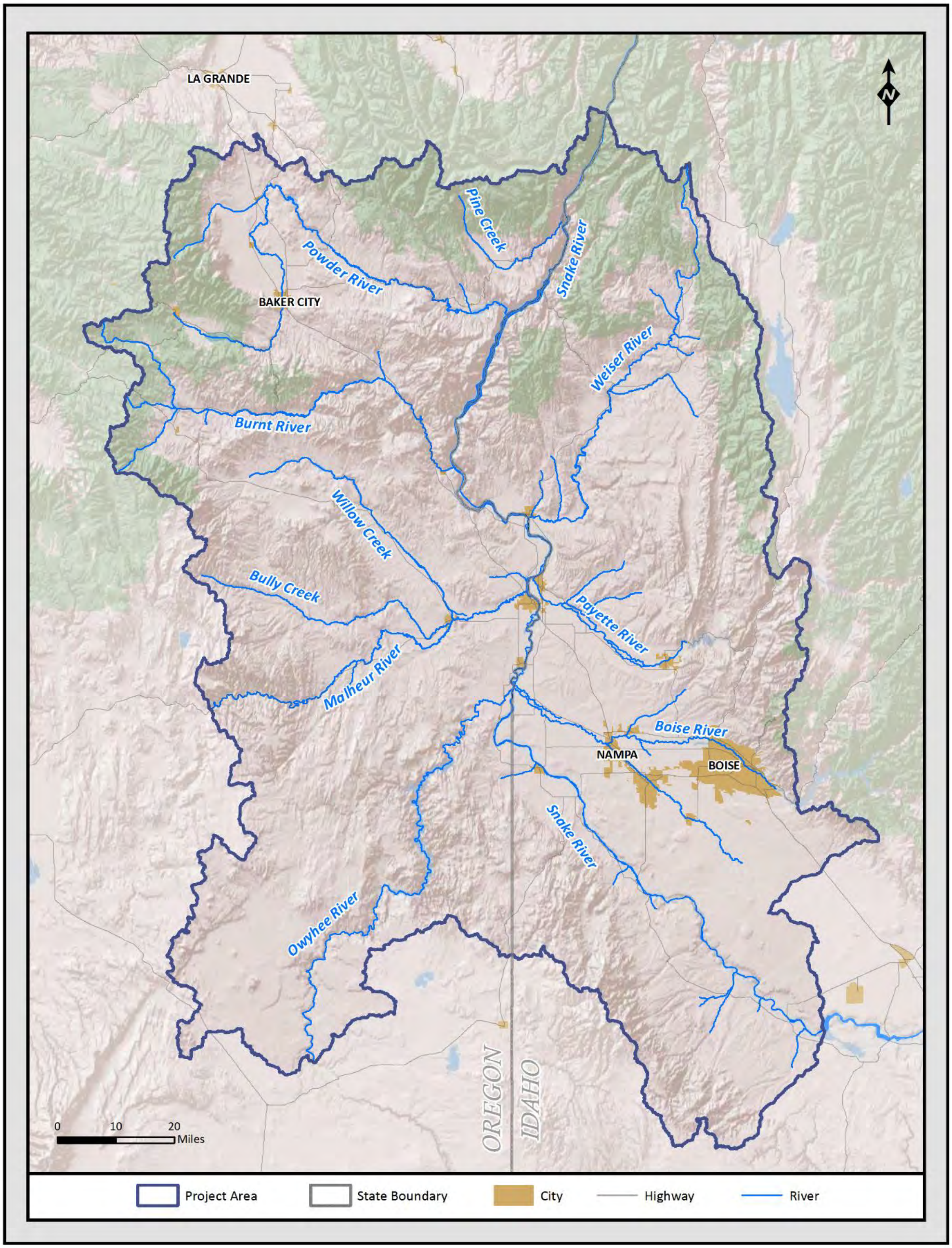


Figure 1: Map of Snake River Stewardship Program area.

2.2 Eligible Restoration Actions for Thermal Benefits

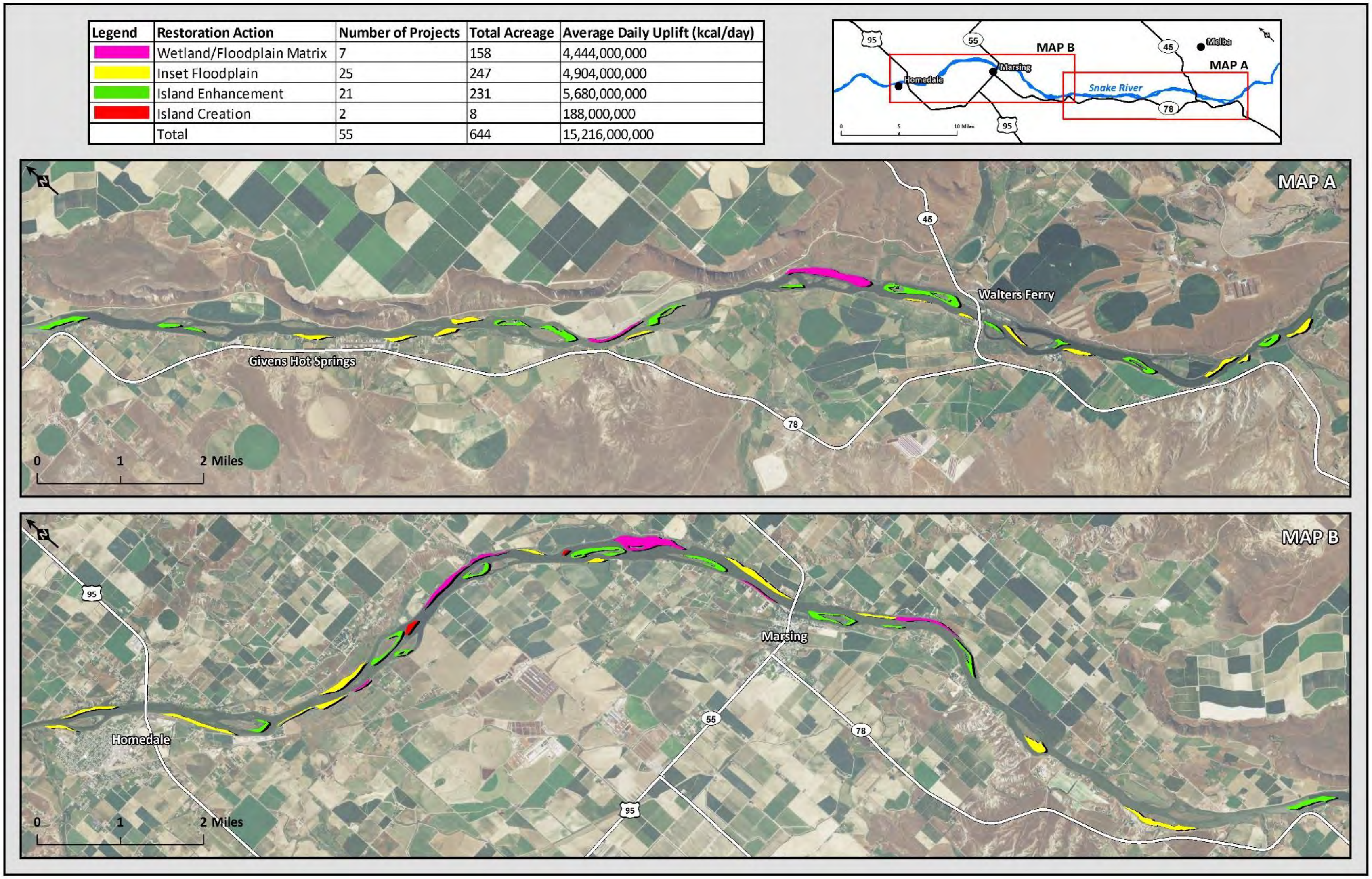
The SRSP will include a variety of restoration actions to generate thermal benefits; three actions are currently contemplated:

- Instream habitat restoration projects that will reduce surface area exposure to thermal loading from the sun, including island enhancements, island creation, inset floodplain development, and emergent wetland development;
- Riparian revegetation projects in the Snake River and its tributaries, that will produce shade and block thermal loading from the sun; and
- Other restoration actions as quantification methods are developed and approved (e.g. instream flow augmentation activities in tributaries of the Snake River could be used to increase thermal buffering capacity)

These restoration actions will generate the thermal benefits necessary to offset IPC's cumulative thermal load exceedance (see Section 7.1 of the 401). All restoration actions will be implemented in accordance with ecologically appropriate restoration quality standards that have been designed to provide significant ancillary habitat benefits. The restoration quality standards also include layers of assurance by requiring that projects are monitored, maintained, and tracked for performance over time. The thermal and ecological benefits associated with these restoration actions are further described in Section 2.2 of this document. Section 2.3 discusses the current quantification methods for thermal benefits as well as the additional thermal benefits that are currently unquantified.

2.2.1 Instream Restoration

Reducing water surface area, increasing water velocities and channel depths of the Snake River through instream restoration projects will reduce thermal loading from the sun. Implementation of instream restoration actions will therefore create substantial thermal benefits that will be credited toward IPC's cumulative thermal load exceedance. As illustrated in Figure 2, IPC and The Trust have identified 55 potential instream restoration projects in the mainstem of the Snake River between Walter's Ferry and Homedale.



Legend	Restoration Action	Number of Projects	Total Acreage	Average Daily Uplift (kcal/day)
🟪	Wetland/Floodplain Matrix	7	158	4,444,000,000
🟨	Inset Floodplain	25	247	4,904,000,000
🟩	Island Enhancement	21	231	5,680,000,000
🟥	Island Creation	2	8	188,000,000
	Total	55	644	15,216,000,000

Figure 2: Map and summary of 55 currently proposed instream restoration projects in the proposed project reach for instream restoration. The number of projects, total acreage and uplift by project type is provided in the legend. These are estimates based on current designs and will necessarily be adjusted as specific projects are implemented to account for more site specific design considerations.

In addition to generating thermal benefits, instream restoration work was designed to address limiting factors and yield habitat improvements for aquatic life. The five-year review of the Mid Snake River/Succor Creek Subbasin 2003 and 2007 TMDLs found that water quality in the Middle Snake River-Succor Creek watershed had declined (IDEQ 2011). The Snake River has entered an altered state in which degradation continues to worsen. Natural disturbances to the ecosystem (floods) are not present, flow and water velocities have decreased, and inputs of sediments and nutrients have increased. Low-flow conditions combined with high sediment and nutrient concentrations create ideal conditions for undesired aquatic macrophyte (aquatic plant) proliferation. The presence of aquatic macrophytes further decreases water velocities, consequently increasing water temperatures. Additionally, macrophytes retain nutrients and sediment from agricultural runoff, reinforcing the conditions for macrophyte growth and ecological impairment. Nonnative fish species are able to adapt to the altered habitat conditions and compete with native species for resources. This severely degraded ecosystem can be viewed as a cycle of impaired ecological processes, which will continue to deteriorate if left unaltered (Figure 3).

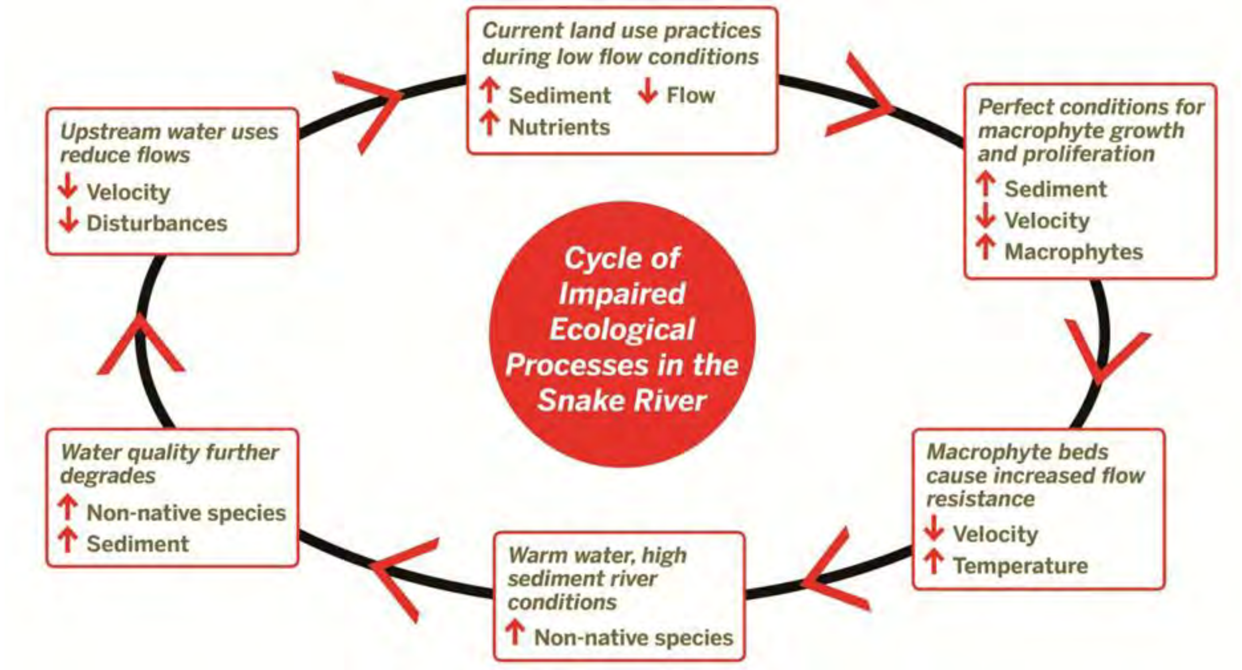


Figure 3: Cycle of impaired ecological processes in the Snake River.

The Snake River has reached an alternative state in which continued degradation reinforces a negative trajectory. To achieve desired ecosystem conditions, this cycle must be broken. Restoration actions that facilitate disturbance and minimize degradation from human activities can help return the Snake River to a functioning ecosystem.

Figure 3 further summarizes the impaired processes in the proposed project reach of the Snake River, the causes of these impairments and proposed restoration actions for restoring processes.

Table 1: Impaired processes in the Snake River, causal factors, and proposed restoration actions.

River processes create and maintain diverse river habitat types.

Snake River Process	Cause of Impairment	Restoration Actions
Shade, bank stabilization, sediment and nutrient uptake	Lack of riparian vegetation	Native vegetation planting on mainland and island riparian areas
Scour and deposition	Low water velocities	Wetlands Inset floodplains Island enhancements/creation
Hyporheic flows	Buildup of inorganic and organic materials in substrate	Agricultural BMPs Wetlands Inset floodplains Island enhancements/creation
Water quality	Low dissolved oxygen, high water temperatures, lack of connectivity	Emergent wetlands Inset floodplains Island enhancements/creation
Retention of upland sediments and phosphorus	Erosive farming practices	Agricultural BMPs Emergent wetlands

To guide the design and prioritization of instream restoration projects, IPC and other stakeholders selected four “focal” native species to represent a diversity of habitat needs: fall Chinook salmon[4], white sturgeon, mountain whitefish, and Snake River Physa (a federally-listed endangered snail). These four Snake River species have specific habitat requirements at different life stages; together, their habitat needs represent a diversity of instream conditions. Thus, if restoration projects benefit these four focal species, the diversity of positive ecological outcomes should prove beneficial for a wide range of aquatic species in these areas and promote a healthy river ecosystem. The four native focal species were historically present throughout the 40 miles of the proposed project reach in the mainstem Snake River.

Fall Chinook salmon were included as a focal species because they provide insight into historic Snake River conditions, as substantial research on this species was conducted prior to the completion of the HCC. Moreover, in connection with the relicensing of the HCC, IPC has conducted numerous studies and assembled data on fall Chinook habitat that will assist in the development of program measures. Research conducted prior to the construction of the HCC includes historic habitat availability data that has been used to develop a target for instream habitat distribution and abundance in the SRSP. As a result of the unique life history and habitat needs of fall Chinook, restoring processes that create fall

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[4] Although fall Chinook salmon are no longer found above the HCC, the abundance of historic data on this species has been used to inform the ecological potential for instream restoration in the SRSP including diversity and availability of habitat.

Chinook habitat should improve habitat conditions for the multiple life stages of many of the other native species in the Snake River.

Unlike fall Chinook, which bury their eggs, white sturgeon are long-lived broadcast spawners.[5] These two characteristics (longevity and broadcast spawning) result in unique habitat needs. IPC has developed substantial research and data on the habitat needs of white sturgeon. Mountain whitefish were included because they may be an indicator of general habitat health. Recent (2002) fish kills/mortality of mountain whitefish in the reach of the Snake River near the town of Marsing indicate that this species may be sensitive to habitat alterations. Finally, the Snake River Physa snail, has been chosen because of its limited presence in the proposed project reach of the Snake River and because it is listed as endangered under the Endangered Species Act (DOI 1992). Table 2 summarizes the habitat needs of these four focal native species of the Snake River.

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[5] As opposed to salmonids (which are benthic spawners that bury their eggs), sturgeon are broadcast spawners that do not build nests (redds). Rather, sturgeon release, or “broadcast,” eggs and sperm together into the water where they are fertilized. The eggs attach to the river bottom once fertilized.

Table 2: Biological habitat criteria organized by species.

Process-based restoration in the Snake River is designed to achieve habitat characteristics for fall Chinook salmon, white sturgeon, mountain whitefish, and Snake River Physa. Restoration actions designed for multiple species will increase overall habitat heterogeneity in the Snake River, increasing biodiversity and thus ecosystem resilience.

Species	Time Period	Water Depth Range (Max. Suitability) (ft)	Mean Water Column Velocity Range (Max. Suitability) (fps)	Bottom Velocity Range (Max. Suitability) (fps)	Substrate Range (Max. Suitability) (cm)	Shoreline Gradient (%)
Fall Chinook Salmon						
Spawning Habitat	Oct 15-Nov 30	0.65 – 21.0 (9.1) [1]	1.3 – 6.8 (3.6) [1]	0.3 – 6.5 (3.2) [1]	2.6 – 15	
Rearing Habitat	Mar 15-June 15	<4.9	<1.3		<15.1 – 22.5	<40
White Sturgeon						
Spawning Habitat	Mar 21-June 7	>7.8	>0.3 (>5.8)			
Incubation Habitat	Mar 21-June 13	9.7 – 77.7 (16.2)		2.6 – 9.4 (6.5)	>0.6	
Rearing Habitat	Year-round	>19.7 (>42.6)		0 – 8.4 (0 – 0.4)	All Substrates	
Adult Habitat	Year-round	All-depths (>22.7)	0 – 8.4 (0 – 1.3)	0 – 8.4 (0 – 1.3)	All Substrates	
Mountain Whitefish						
Spawning Habitat	Oct 1-Dec 31	0.4 - 0.9	0 – 3.2 (1.6 – 1.7)		0.6 – 7.5	
Fry Habitat	Mar 1-May 31	0.7 – 8.4 (2.0 – 2.5)	0 – 3.2 (0 – 0.4)		<22.5 (< 0.6)	
Rearing Habitat	Year-round	>0.5 (1.2 – 2.8)	0 – 3.9 (1.2 – 1.5)		0 – 256 (0.76 – 22.5)	
Adult Habitat	Year-round	>0.5 (>2.5)	0 – 4.2 (1.3 – 2.0)		0-256 (0.6 – 7.5)	
Snake River *Physa*						
Rearing/Adult Habitat	Year-round	<1.6 to >9.7 (4.9 – 8.1)	1.8		0.2 – 25.6 Minimal fines No macrophytes	

[1] = Mean Value

The instream restoration actions of the SRSP in the Snake River should improve habitat conditions by restoring dynamism to many of the ecological processes in the Snake River. Anthropogenic impacts in the Middle Snake River-Succor Creek watershed have disrupted riverine processes and functions. Sediment and phosphorus loading has also increased due to agricultural activities. Scour and deposition processes are impaired due to low water velocities, and hyporheic flows are restrained by the buildup of organic and inorganic materials in river substrate. These impaired functions have resulted in a loss of instream habitat for the four focal species and other native aquatic life. The same impaired functions that have resulted in a loss of instream habitat (i.e., sediment and phosphorus loading) could potentially threaten the continued effectiveness of the instream restoration projects. If the large sediment loads currently being delivered to the Snake River by agricultural return drains in the program area continue at the current rates, the sediment is likely to fill the interstitial spaces between gravels in the newly narrowed and deepened channels, causing streambed compaction and further limiting hyporheic exchange flows and associated benefits.

The goal of the SRSP is to generate thermal benefits through restoration actions that improve the riverine processes and therefore improve and sustain habitat for native aquatic life. Four specific instream restoration project types were identified to break this cycle of ecological impairment and to promote habitat characteristics for the four native focal species: 1) island enhancements, 2) island creation, 3) inset floodplains, and 4) emergent wetlands (some projects may contain two or even three of these actions in combination). Examples of these actions are portrayed in Figure 4. All of the proposed project types will alter the physical characteristics of the river channel by reducing channel width and increasing channel depth, with the goal of both generating thermal benefits and improving many of the natural river processes in the Snake River. These changes will also lead to increases in water velocities and channel scouring, and improve other channel forming processes. Projects will be designed in order to maintain current water levels in the reach.

Figure 4: Three of the proposed restoration actions for instream projects include (from left to right): island enhancement, inset floodplains, and emergent wetlands.

Instream restoration projects implemented as part of the SRSP will benefit from upstream sediment reduction from irrigation upgrades. In order to demonstrate reasonable assurance for meeting DO requirements (401 Section 7.2), IPC is proposing to quantify sediment and phosphorus reductions from irrigation upgrades in the Grand View, Idaho area. By reducing agricultural runoff for phosphorus benefits, IPC will also improve conditions for instream restoration projects by reducing sedimentation.

2.2.1.1 Island Enhancement and Island Creation

Island enhancement projects will expand the size of existing islands in the Snake River to create channel constrictions and areas for further development of floodplain vegetation. Island creation will create new land mass in the Snake River to create channel constrictions and new areas for development of floodplain vegetation. Figure 5 is a conceptual drawing of an island enhancement project showing a 100% increase in island size and reducing the overall channel width by 50% in an area that is currently dominated by aquatic macrophytes. The island expansion will create faster flowing water, deeper water depths, and better overall habitat for target species while eliminating areas of macrophytes.

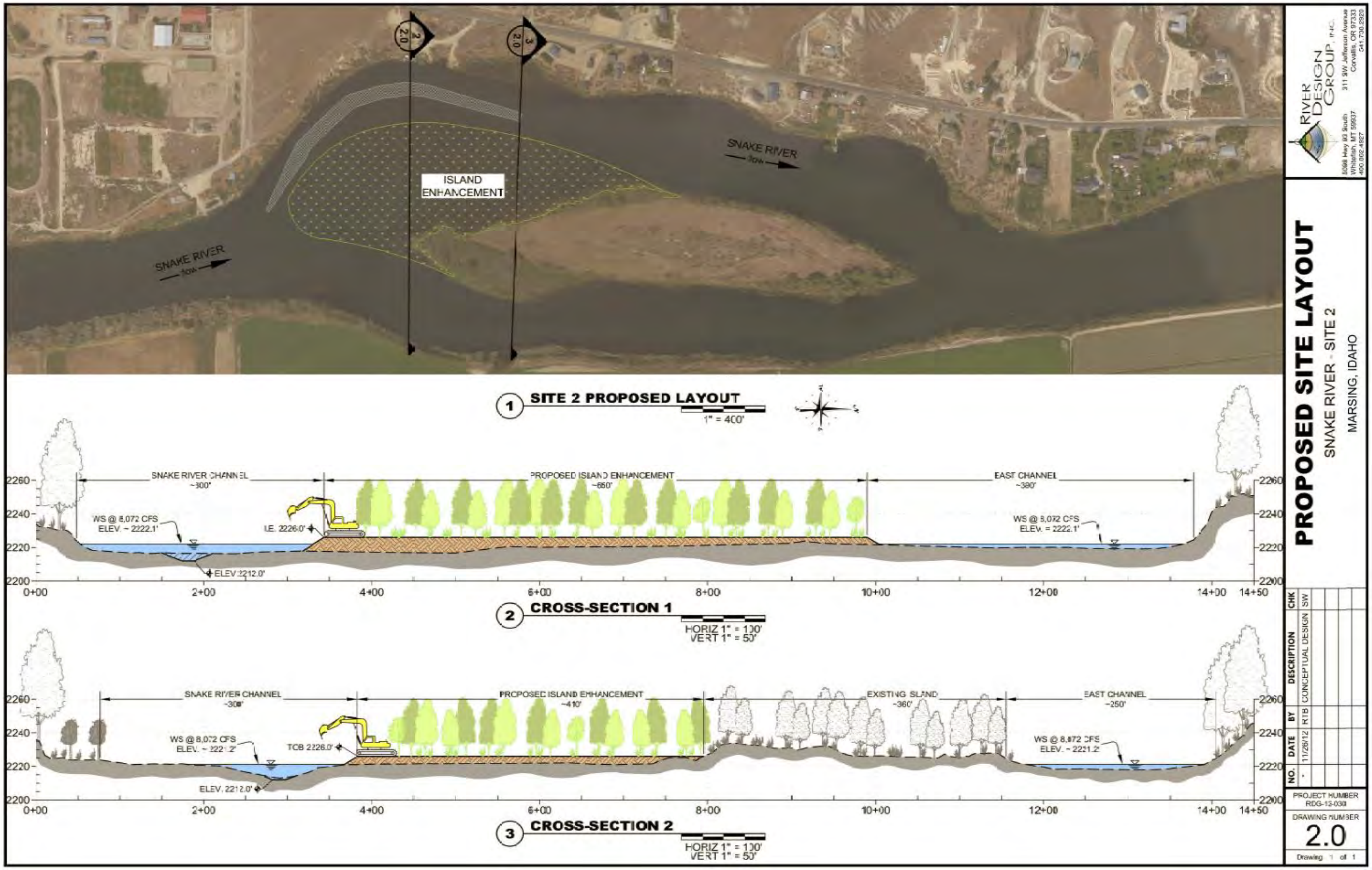

Figure 5: Example of an island enhancement project that constricts the channel and reduces solar loading.

Island enhancements and island creation projects can be constructed by dredging material from the existing active river channel (or importing it as needed) and using that material to create floodplains, thus increasing the depth of the channel while reducing the overall width of the wetted channel. The increased depth and velocities will create conditions that are less favorable for vascular macrophyte establishment. By reducing macrophyte areas, the water quality and overall health of the river will improve and favor conditions that are conducive to the target species. In addition to creating favorable channel conditions, island enhancements will provide areas for additional vegetative planting and reduce solar inputs to the river. Island enhancement and creation projects will be implemented so as to fall below the "ordinary high water mark" in the Snake River.

2.2.1.2 Inset Floodplains

Similar to island enhancements and island creation projects, inset floodplains are low-rise, permanent features attached to the banks of the river that constrict the mainstem channel width at all flows less than the annual "bankfull" flow. At flows greater than bankfull, water is allowed to disperse and flow across the inset floodplain for flow conveyance. Figure 6 provides an example of an existing inset floodplain within the proposed project reach of the Snake River.

Figure 6: Example of existing inset floodplain feature on the Snake River.

The goal of inset floodplain projects is to reduce overall channel widths and depths by changing the river dimensions while maintaining adequate capacity for large flow events such as a 100-year peak flow. By reducing the channel width (Figure 7), mainstem flows become deeper with faster velocities and less solar gain. In addition, the floodplains can be vegetated with various shrubs and tree communities to provide additional shading and terrestrial habitat. These inset floodplain features provide multiple benefits, such as mobilization and transport of fine sediments, cooler water temperatures, and reduction of vascular macrophytes.

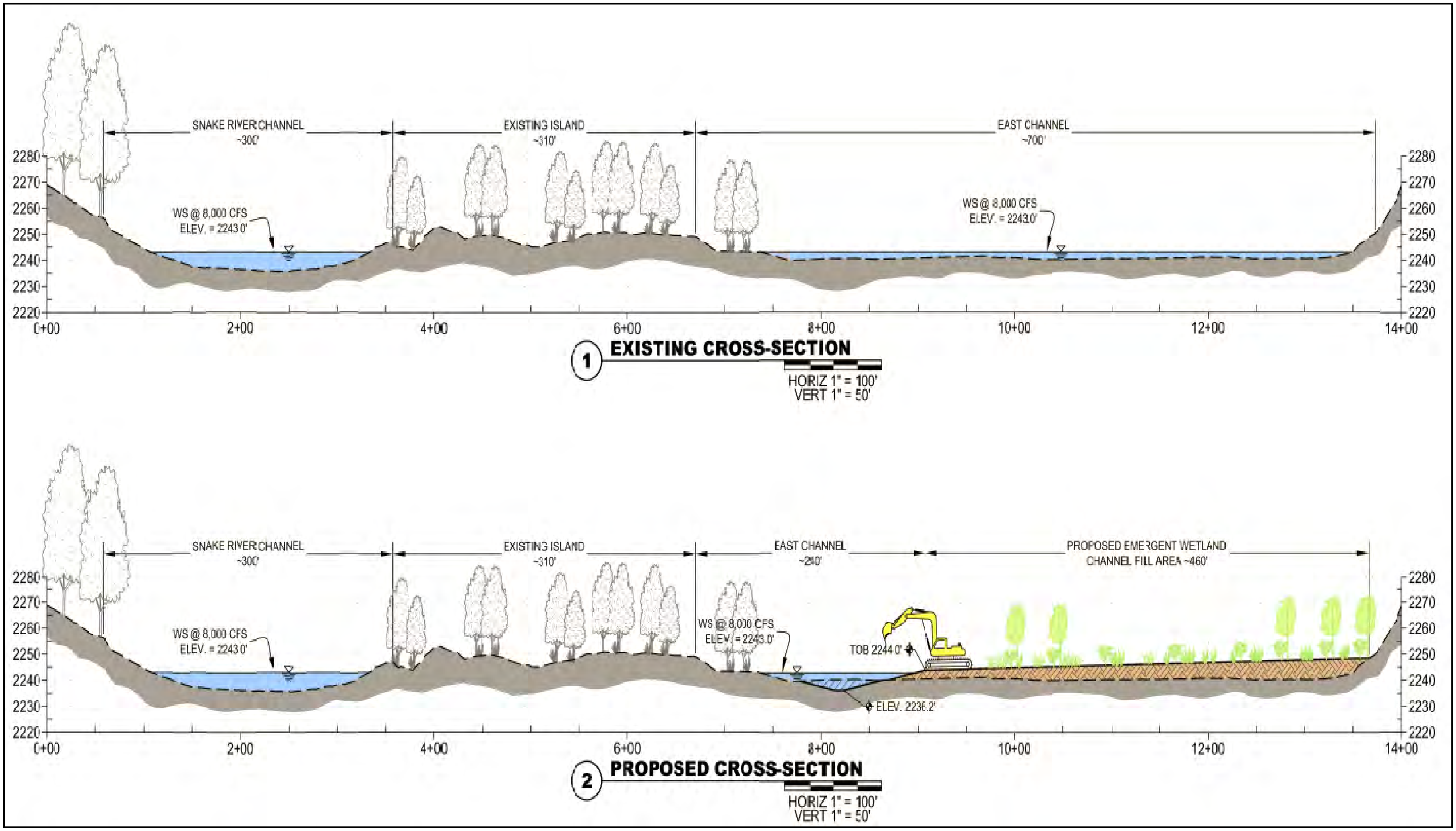

Figure 7: Existing cross-section of Snake River and the proposed inset floodplain/emergent wetland on river right that constricts the channel and reduces the overall wetted width.

Inset floodplains can be designed at various elevations, as determined by a combination of hydraulic flow models and vegetation recruitment desires for locations throughout the Snake River. For example, in very wide channel locations (i.e., >800 ft) the inset floodplains can encroach on the active channel further and could potentially have multi-stage elevations for variable flows and recruitment of different vegetative communities. The proposed Snake River instream project reach from Walter's Ferry to Homedale has several stretches where significant improvement to river function can be realized by installing instream channel modifications to improve flow.

2.2.1.3 Emergent Wetlands

In situations where agricultural drains deliver large sediment loads into the Snake River, it can be beneficial to install areas of emergent wetlands. Wetlands provide a diversity of functions that benefit watershed and ecosystem integrity, including flood storage and attenuation, water quality improvement through sediment retention and wetland plant biochemistry, and wildlife habitat (Novitzki et al. 1996, Mitsch and Gosselink 2007). Natural emergent wetlands on Snake River floodplains are limited in large part due to altered flow regimes resulting from upstream water uses and flow alterations. In addition, agricultural development throughout the watershed has modified hydrologic inputs to the river, dramatically increasing sediment and nutrient loading through agricultural runoff. The creation of emergent wetlands at drain outlets would provide filtration and treatment of agricultural runoff prior to the flow entering the Snake River, and create additional habitat for plants and wildlife.

Wetlands utilized to treat point source and non-point source pollution like agricultural runoff can be classified as natural wetlands, surface-flow wetlands, or subsurface-flow wetlands (Mitsch and Gosselink 2007). The use of natural wetlands in the treatment of polluted water is often impractical, as the distribution of naturally-occurring wetlands may not coincide with optimal location for treatment, and as the discharge of polluted water into these wetlands is heavily regulated. Constructed sub-surface flow wetlands can be utilized to treat municipal and industrial wastewater; however, they may require a heavier engineering approach and maintenance schedule than surface-flow wetlands. Closely resembling natural wetlands, water quality in constructed surface-flow wetlands benefits from the physical retention of sediments, microbially-mediated reactions, and plant uptake of nutrients (Lee et al. 2009).

Surface-flow wetland creation at the interface of agricultural drains and mainstem Snake River could reduce nutrient and sediment loading into the river, as well as create wildlife habitat for a variety of wetland and upland species. A large number of agricultural drains flow into the Snake River between Walter's Ferry and Homedale. To the extent practicable, project sites will be identified as potential locations for surface-flow treatment wetlands where channel modifications would also effectively reduce channel widths and alter river hydraulics to support target aquatic species habitat.

As an example, Figure 8 provides a design schematic for a potential surface-flow, emergent wetland at a drain outlet near Walters Ferry; a similar concept could be applied for other identified drain locations. The surface-flow wetland is designed for an average 0.25 cfs constant inflow, assuming that future agricultural efficiency programs will reduce drain discharge by approximately 50%. If this project is installed, the drain would be re-routed into the constructed wetland, flowing along the wetland/upland interface and discharging flow into the wetland at pour points 500 to 1,000 feet apart. This potential wetland is designed to be overtopped by the Snake River at approximately 2-year (approximately 18,000 cfs) flows, providing for periodic scouring of accumulated sediment from the wetland and enhancing natural river processes.

In this hypothetical design, an impermeable wetland liner of clay or geosynthetic clay material could be applied to the upstream 80% of the wetland area, providing the necessary conditions for wetland hydrology. In accordance with Army Corps wetland definitions, this translates to periodic inundation or soil saturation within 12 inches of the surface for part of the growing season (Environmental Laboratory 1987). Conversely, at the downstream 20% of the wetland, a semi-permeable wetland liner would allow infiltration through the subgrade media and a dispersed outflow into the mainstem Snake River. On top of the wetland liner, an average of 6-12 inches of topsoil would be utilized for growth media to support hydrophilic plants, and microtopography would create a more heterogeneous surface environment. The interior and vast majority of the wetland is designed as an herbaceous emergent bulrush complex that includes hardstem bulrush (*Schoenoplectus acutus*) and common three-square (*Schoenoplectus pungens*), both currently found in the drain area in dense arrays. A one to two-foot tall berm on the riverside edge of the wetland would maintain the hydrology within the complex, and the incorporation of willows (*Salix exigua, Salix amygdaloides*) and other scrub/shrub wetland species could result in thermal loading reductions via shading.

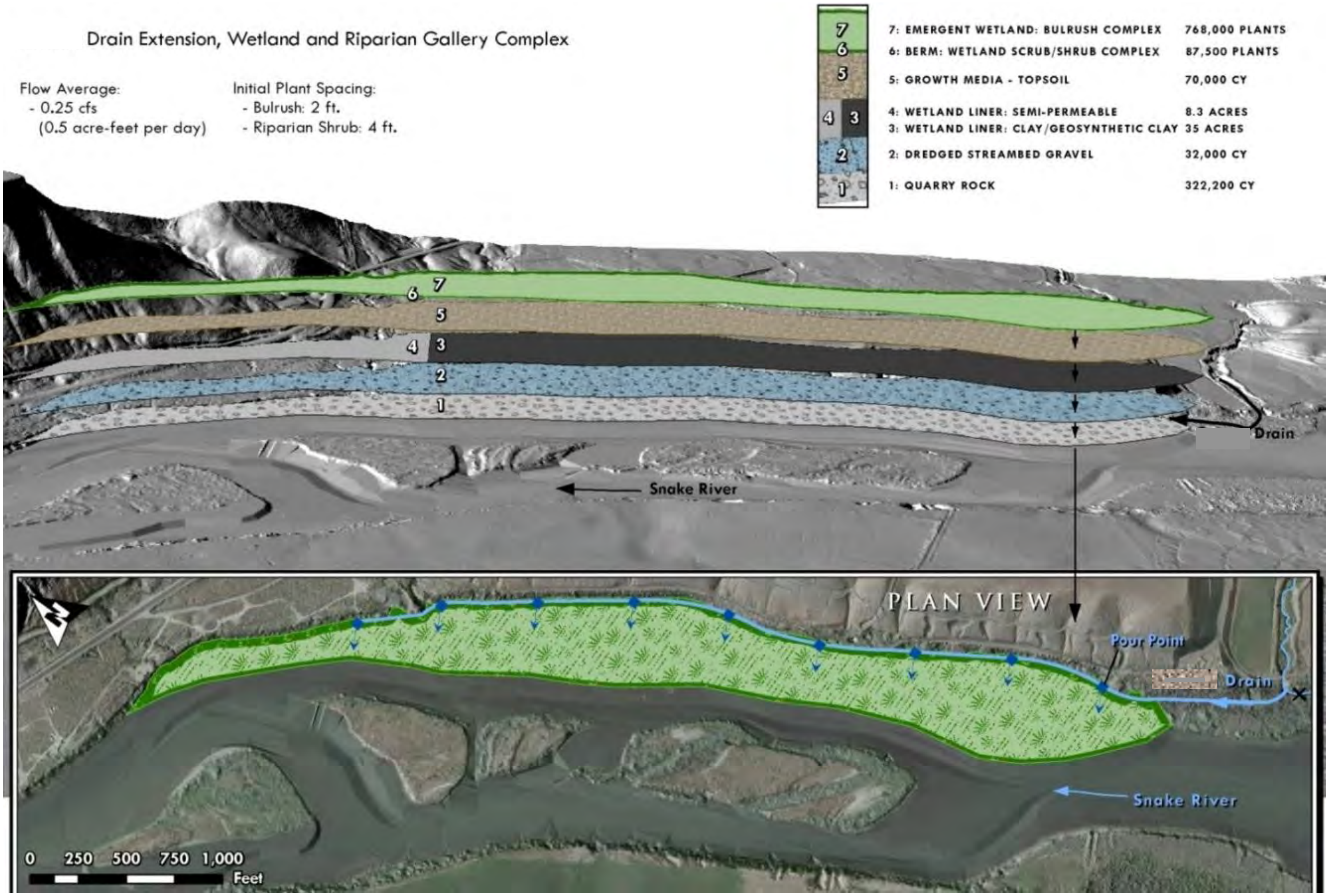

Figure 8: Potential emergent wetland with surface flow at a drain site near Walters Ferry (RM 440).

Diagram provides section properties for potential materials used for wetland structure.

2.2.2 Riparian Revegetation in the Snake River and its Tributaries

Riparian revegetation projects will occur within some or all of the subbasins identified in Figure 9.

Across the twelve subbasin region upstream of the HCD, riparian vegetation has been dramatically altered over the last 175 years. This alteration has occurred as a result of beaver trapping, fire suppression, logging, cattle grazing, recreation such as off-road vehicle use, anthropogenic modifications to channel morphology (armoring, straightening and entrenchment), agriculture, exotic plant invasion, and dam building (IDEQ 2003, 2006; ODEQ 2010). In addition to on-land and in-channel alterations, agricultural and domestic water diversions are common sources of impact to aquatic resources and often cited as a primary limiting factor for water quality in the region (Dixon and Johnson 1999; IDEQ 2003). In particular, dams and flow diversions may have reduced the frequency and magnitude of floods and changed sediment depositional patterns. Flood reductions have, in turn, reduced willow and cottonwood propagule dispersal and colonization (Dixon and Johnson 1999; ODEQ 2010). Although new riparian vegetation has established in some irrigated areas associated with agriculture (Dixon and Johnson, 1999; ODEQ 2010), many native riparian communities dominated by willows (Salix spp.), black cottonwood (Populus trichocarpa), and other species are thought to have been lost to agriculture and changes in flow regimes (IDEQ 2006; ODEQ 2010).

As a result, restoration of riparian vegetation will help restore ecological function in the Snake River and tributary areas. By increasing the amount of vegetation along these key waterways, less thermal load from the sun will reach the water. Riparian revegetation will help to restore microclimates and functional ecological conditions to the riparian ecosystem. Restoration will provide needed habitat for fish migration and spawning, promote habitat complexity, and facilitate the exchange of organic material and food supply between the terrestrial and aquatic ecosystems. The Trust confirmed the need for riparian revegetation in SRSP watersheds using available literature (including TMDLs, watershed assessments, biological opinions), and by surveying watershed council staff, soil and water conservation district staff, and restoration professionals.

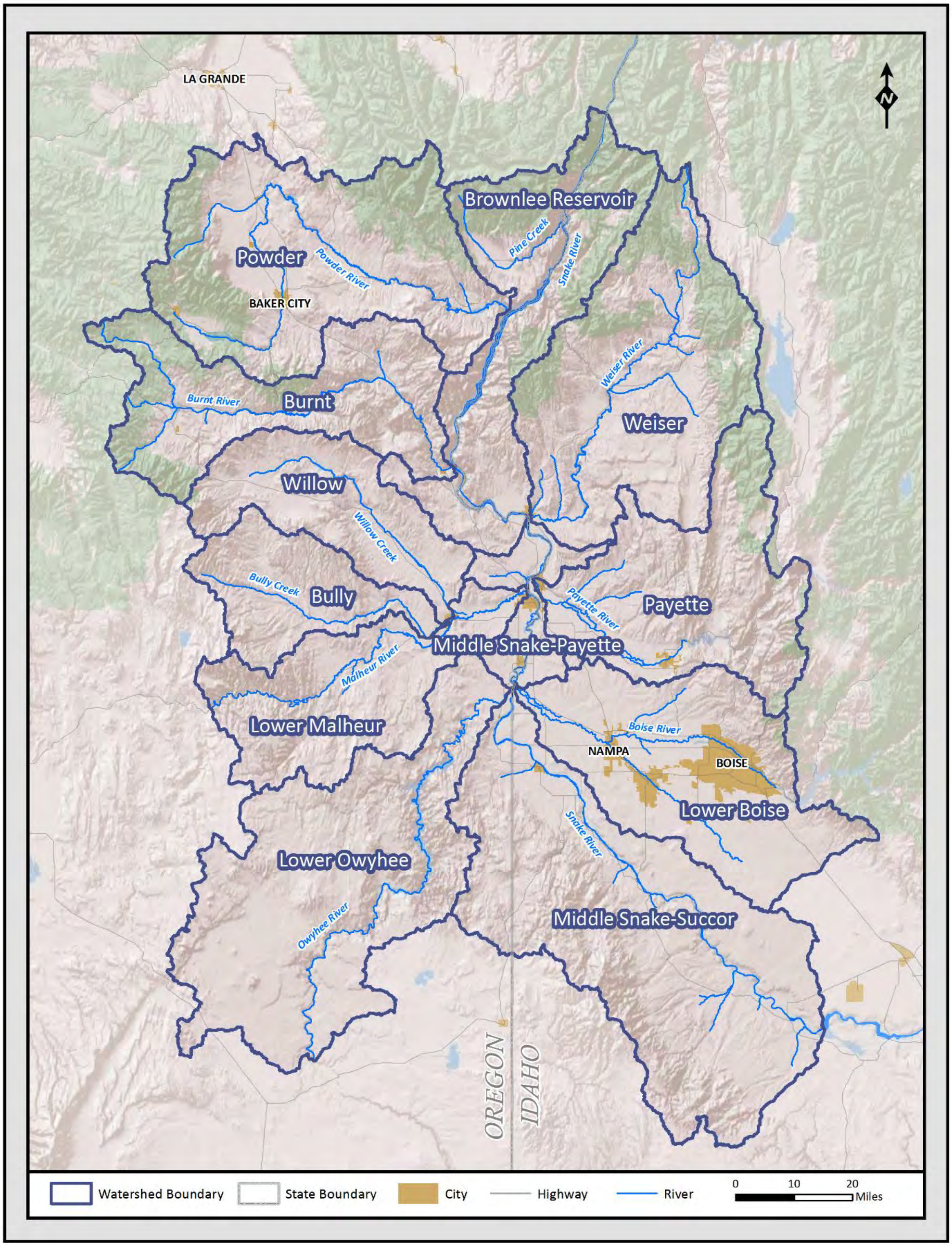

Figure 9: Twelve subbasins considered for Snake River Stewardship Program.

2.2.3 Approving New or Modified Restoration Actions

As lessons are learned through implementation of research projects and as quantification methodologies improve, it may be appropriate to include additional restoration actions in the SRSP portfolio if they are ecologically suitable and the benefits can be quantified as thermal load units. If new restoration actions are approved for use in Idaho or Oregon, IPC may incorporate these actions into the SRSP after review and approval from the DEQs, and as required by FERC.

An example of a potential new restoration action for thermal benefits is flow augmentation in the Snake River and its tributaries. As described in Section 2.2.2, agricultural and domestic water diversions are common sources of impact to aquatic resources and often cited as a primary limiting factor for water quality in the region (Dixon and Johnson 1999; IDEQ 2003). In addition to its impacts on riparian vegetation, stream flow reductions are an important determinant of water quality and aquatic habitat conditions. High water temperature, low levels of dissolved oxygen, and deleterious levels of toxins can all be exacerbated by low stream flow (Beechie et al. 2008, 2010; Hester and Gooseff 2010). Moreover, the quantity, quality and connectivity (e.g., fish migration) of aquatic habitats are also influenced by stream flow.

Therefore, if more instream flow is added to these subbasins in the future, the impact of solar heat loading can be buffered. Efforts to augment flows will be consistent with existing property rights and associated water rights, and will rely on voluntary landowner participation in an incentive program. At this point, the thermal benefits of flow augmentation are not appropriately valued by available models. While not yet effectively quantified, IPC and The Trust are working with stakeholders to better estimate the thermal benefit that instream flow augmentation would generate, as well as the positive impact it would have on the aquatic communities in tributary streams and in the Snake River. If these efforts prove fruitful, IPC may seek approval of a quantification methodology that would allow for the thermal benefits from flow augmentation to be counted toward IPC's cumulative thermal load exceedance (see Section 2.3.3). Such a method is likely to be a physically or statistically based temperature model, or another technically defensible methodology, that translates water quantity augmentation into units of thermal benefit.

2.3 Currently Available Quantification Methods

The thermal benefits generated by the SRSP restoration project represent a reduction in thermal loading at project sites as a result of the restoration action. Thermal benefits from SRSP restoration projects will only be claimed if they are quantified using approved tools and models, using consistent inputs and assumptions. The thermal benefits generated from surface area changes associated with island enhancement, inset floodplain island creation, and emergent wetland restoration work can be estimated using a suite of currently available models. The thermal benefits of riparian revegetation can be estimated using the Shade-a-lator module of the Heat Source model. The Shade-a-lator module has a long history of use, including use and approval for credit quantification in National Pollutant Discharge

Elimination System (NPDES) permit-based trading programs.[6] Energy budgets can also be used to calculate the thermal benefits of wetland enhancement that are in addition to the water surface area reductions. Additional thermal benefits, including the benefits from increased hyporheic exchange, are not currently estimated, but may be quantified and counted in the future after approval of the new quantification methodologies (see Section 2.3.3).

2.3.1 Shade-a-lator

Shade-a-lator, a module of the Heat Source model,[7] can be used to calculate thermal benefits from a variety of restoration actions, including the instream and riparian revegetation actions proposed for the SRSP. The modeling process captures multiple physical characteristics of a system, including: the upstream and downstream boundaries of the modeled stream reach, water surface area (based on the wetted width), local topography, bank slope, stream orientation, and geographic location (latitude and longitude). The model then calculates the sun angle every 25 meters—these calculation points are referred to as “nodes”—along the center of the modeled reach for every model time step (once per minute). At each node, Shade-a-lator calculates the total load of incoming solar radiation by considering the physical characteristics surrounding the node and the characteristics of the vegetation present on the streambanks (see Figure 10).

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[6] *See* 33 U.S.C. § 1342 (2012).

[7] Developed in collaboration with Oregon State University and ODEQ, this model relies on geospatial data inputs for baseline conditions. Future conditions are informed by local vegetation type, assemblage, and growth rates.

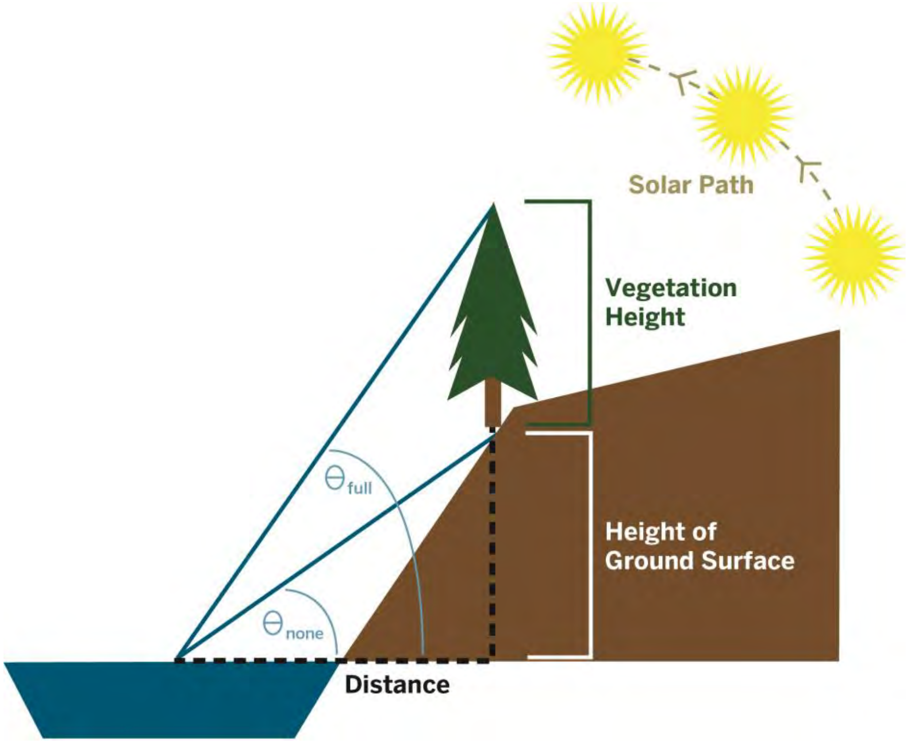
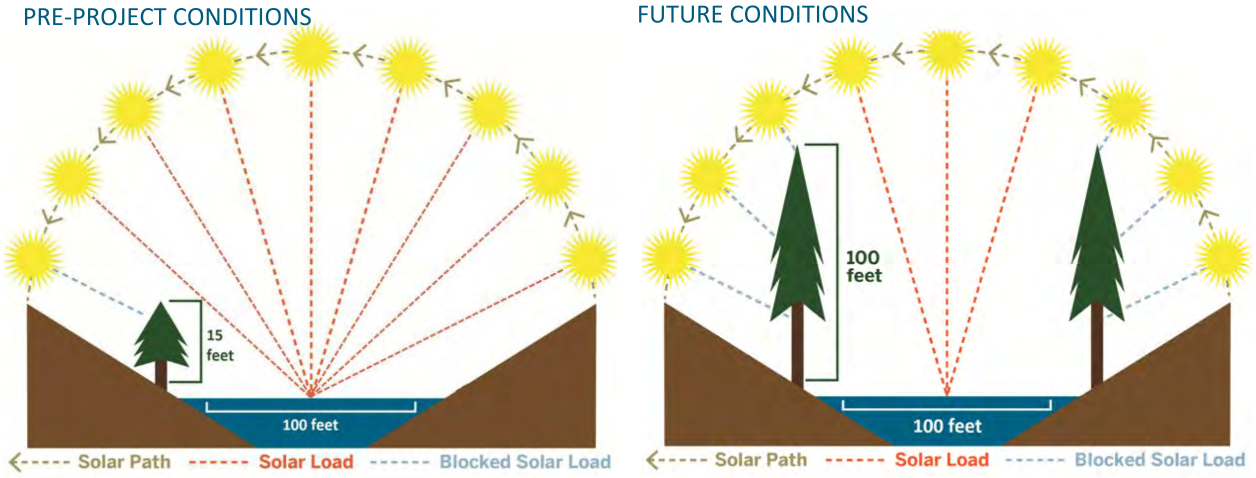


Figure 10: A cross-section schematic of the physical characteristics included in Shade-a-lator modeling.

When the sun angle is smaller than Ɵnone all incoming solar radiation is blocked by the local topography. When the sun angle is greater than Ɵfull all incoming solar radiation reaches the surface of the stream. When the sun angle is between Ɵnone and Ɵfull the vegetation present attenuates a portion of the incoming solar radiation.

Thermal load reduction values, or thermal benefits, represent the change in the thermal loading that occurs as a result of planted riparian vegetation blocking solar load. The stream reach of interest is modeled twice: once using the current “pre-project” vegetation conditions, and then again by altering only the riparian vegetation parameters to reflect a mature, future vegetation that is anticipated to be the “post-project” condition. The difference between these two model scenarios represents the thermal load reduction, or the total thermal benefit, from an individual riparian revegetation project. Figure 11 illustrates the two modeling scenarios.



PRE-PROJECT CONDITIONS

FUTURE CONDITIONS

Figure 11: Illustration of solar load attenuation from different riparian vegetation conditions: 1) current conditions, and 2) future conditions.

Taller, mature vegetation can intercept more of the incoming load of solar radiation, thus reducing the total load of solar radiation that reaches the surface of the stream.

Since the use of the Shade-a-lator incorporates the water surface area to calculate thermal loading, it can also be used to calculate kilocalorie per day reductions from changes in the channel dimensions. Introducing channel complexity will often reduce the surface area of water that is exposed to the sun, thus reducing the amount of energy entering the aquatic system. Less solar energy entering the system helps to keep the water from warming. Currently, it is possible to calculate the thermal benefits from instream restoration actions using surface area reductions using both Shade-a-lator and direct measurement of incoming solar radiation. By understanding a proposed change in the river channel, it is possible to model the expected thermal benefit from reduced solar inputs in units of kilocalories per day. Vegetation that is installed, monitored and maintained per the requirements outlined in the restoration quality standards can be modeled for thermal benefits using the same approach that is described above and used for riparian revegetation projects. The thermal benefits from vegetation and changes in surface area from instream projects will be combined and registered.

2.3.2 Wetland Energy Budget

As part of the SRSP, new emergent wetlands may be created; wetland restoration projects will reduce surface area of the Snake River and associated thermal loading. Additionally, thermal benefits from emergent wetlands can be measured in kilocalories per day using an “energy budget,” as demonstrated in Figure 12.

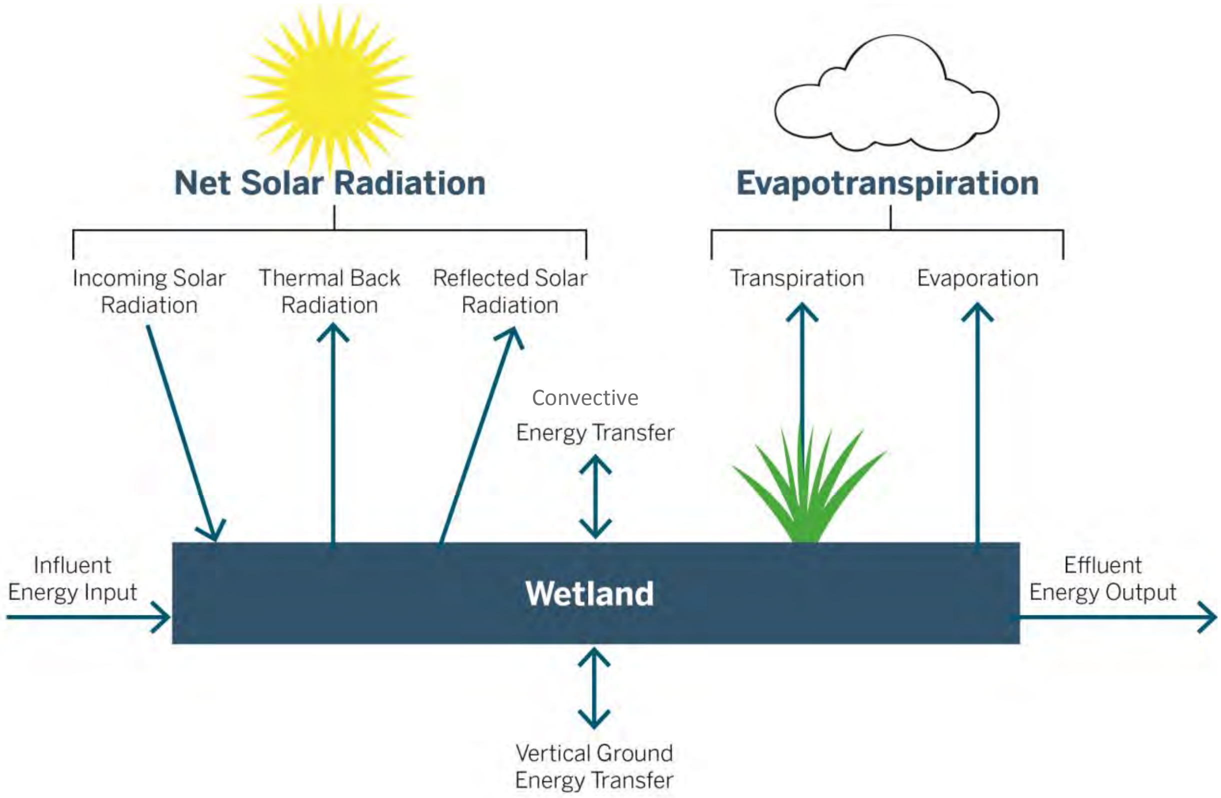


Figure 12: Energy gains and losses in the wetland system. (Adapted from Kadlec and Wallace 2009).

An energy budget identifies potential thermal "sources" (places that contribute heat) and "sinks" (places that lose heat) within a wetland, and the magnitude of each in kilocalories per day. Incoming solar radiation drives wetland processes, particularly evaporation and transpiration. Incoming solar radiation (R_S) is typically the largest source of energy to a wetland. Not all of the incoming energy remains in the wetland system. A portion of the incoming solar radiation is immediately reflected by the wetland. The reflected fraction of the solar radiation is calculated using the reflection coefficient, or albedo (α). Additional solar radiation is lost as radiated heat, or thermal back radiation (R_b).

The largest loss of energy from the wetland system comes from the combination of evaporation and transpiration (evapotranspiration, ET). Depending on ambient weather conditions, convective energy (H_a) can transfer energy from the air to the wetland or from the wetland to the air. Vertical ground energy transfer (G) can also act as both an energy source and sink to the wetland system.

Energy also enters the wetland with the influent water (U_{wi}). Water that leaves the wetland system carries energy away from the system (U_{wo}). The wetland energy budget can be expressed using kilocalories per day. The energy budget associated with wetlands, can be written as follows:

$$R_N + H_a + U_{wi} = \lambda_m \rho ET + G + U_{wo}$$

where λ_m = latent heat of vaporization, and ρ = density of water.

2.3.3 Currently Unquantified Benefits

The benefits of restoration actions planned for SRSP implementation are currently undervalued, as the models for benefit quantification are largely limited to the quantification of reduced thermal loading from the sun. Many additional benefits from physical changes to instream and riparian habitats have been documented—such as increased thermal buffering capacity and availability of thermal refugia, changes to microclimates, increased floodwater storage, and increased hyporheic exchange flow—all of which promote a more natural thermal regime supportive of coldwater species. Therefore, estimated potential thermal load reduction in the SRSP program area likely only represents a portion of the benefits that will eventually be generated from the proposed restoration actions. For example, it is currently not possible to predict the thermal load reductions that will occur as a result of increased hyporheic flow through modified channel dimensions or changes to water velocities even though the research consistently documents positive thermal impacts (Hester and Gooseff 2010). Future temperature data collected from research projects such as the Bayha Island research project (see Section 2.5.4.1) will be used to evaluate the additional thermal benefits from instream restoration projects and could be used to develop a model capable of estimating additional thermal benefits from restoration actions.

Similarly, while the literature demonstrates positive thermal impacts associated with instream flow augmentation (Caissie 2006), the methods to accurately convert this augmentation into thermal benefits are not currently developed and approved for use in the SRSP (see Section 2.2.3). Additional thermal benefits, such as improved thermal buffering capacity in the river or microclimate changes in the riparian areas, are also commonly understood (Naiman, et al., 2000), but the ability to calculate the magnitude of these benefits in kilocalories per day units is currently lacking. With the development of new models, and through program implementation and monitoring, the additional thermal benefits of restoration projects in the SRSP will be quantified and documented in the future. The SRSP contemplates that any additional quantification or application of thermal load benefits will be subject to appropriate review and approval from the DEQs, and as required by FERC.

2.4 SRSP Feasibility Assessment

To ensure that the proposed SRSP is in fact achievable and reasonable, IPC worked with The Trust to study the total thermal benefit supply from restoration actions in the program area, as compared to IPC’s thermal benefit need. The total potential thermal benefit supply in the program area can be compared with IPCs cumulative thermal load exceedance at the HCC outflow to evaluate overall feasibility of the program based on an evaluation of demand and supply. The methodology and results of the feasibility study are described in this section, including a description of how The Trust identified and filtered potential supply, and how it considered property ownership constraints when assessing recruitment likelihoods. Ultimately, the results of this analysis inform the thermal benefit implementation milestones described in Section 2.4.4. Many of the assumptions underlying this study are based on The Trust’s 32-year history of restoration project implementation and engagement in water quality trading programs across the west that require comprehensive program design and a high rate of project implementation in order to achieve NPDES compliance. The Trust’s experience in program design, recruitment, implementation, maintenance and monitoring as well as the professional judgement of local watershed councils, agencies, and IPC's experience with local landowners has been incorporated in the analysis of feasibility.

2.4.1 Thermal Benefit Need

IPC's cumulative thermal load exceedance at the outflow of HCC is detailed in Section 7.1 of the 401 application. For the purposes of assessing feasibility, The Trust assumes that the size of IPC's cumulative thermal load exceedance, after accounting for in-reservoir attenuation, the SR-HC TMDL margin of safety, and in-river attenuation, equates to approximately 12 to 15.5 billion kcal/day (July-October average) of thermal benefits from project sites.

2.4.2 Total Supply of Thermal Benefits

In order to determine the total potential thermal benefit "supply" in the program area, The Trust conducted a comprehensive assessment of the landscape. Aerial photography or light detection and ranging (LiDAR) data were used to establish current conditions and to highlight the potential acreage available for project implementation. This involved digitizing the areas of interest and evaluating the current vegetation or habitat (depending on the action) and modeling the current, "pre-project" thermal load. Acres available for restoration were then re-modeled to reflect a future, "post-project" condition. The appropriate quantification method, as described in Section 2.3, was used to estimate the current thermal load. The difference in the two modeled loads formed the thermal benefit or "uplift" potential on that project site.

The Trust conducted a feasibility assessment for each restoration action type within the SRSP program area (see Figure 13).

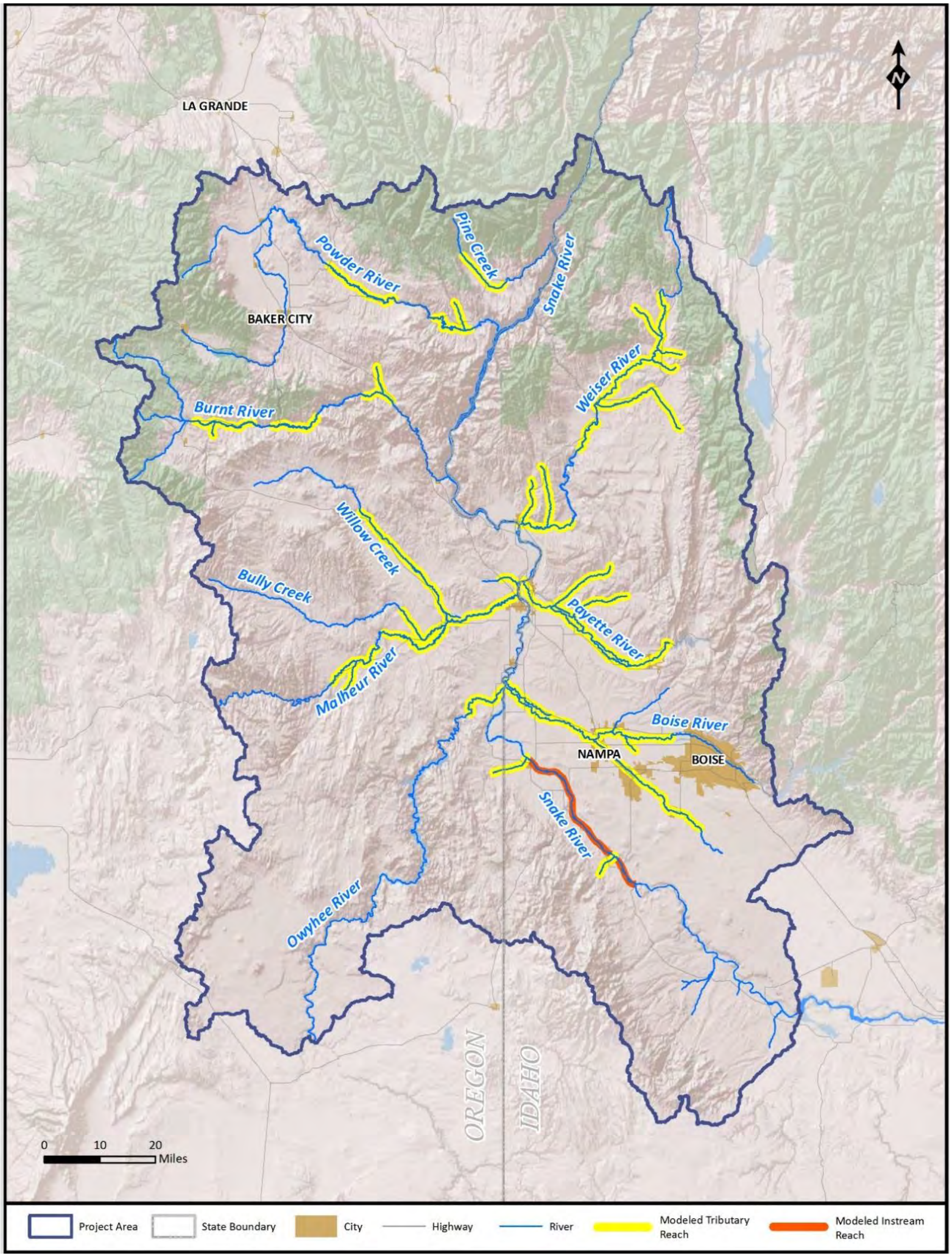


Figure 13: Map of SRSP area with thermal benefits modeled for restoration project implementation highlighted.

Some areas on this map were excluded from thermal benefit modeling due to topographic shade constraints, or because the land is publicly owned. While public land may be eligible for SRSP restoration projects, there is not currently adequate information to assign kilocalorie per day reduction estimates to these properties.

Supply of instream projects was evaluated by River Design Group (RDG), licensed hydrological engineers. These engineers scoped potential project sites to meet the ecological criteria described in Section 2.2.1 so as to improve habitat for the four focal species in the Snake River. As a result of this process, 55 potential instream project sites were identified and preliminarily designed between Walter's Ferry and Homedale. The Trust estimated the thermal benefits from the 55 currently scoped instream projects—which include a mix of wetlands, inset floodplain project, island enhancement and island creation projects—using surface area calculations and energy budgets. Based on the 55 instream project sites scoped in the program area, The Trust estimates a total of 15.2 billion kilocalories per day (averaged from July-October) are the available thermal benefits from these 55 potential instream project sites.

The supply evaluation of thermal benefits from riparian revegetation projects in the tributaries of the Snake River relied on geospatial analysis of potential project areas. A total of 554 miles of riparian areas across 12 subbasins were digitized from aerial photographs. All digitized areas were then screened for basic thermal benefit criteria to determine whether they are well suited for riparian revegetation projects to improve shade conditions. Not all riparian areas in this program area were modeled for shade potential due to topographical and land ownership constraints. Steep slopes or canyon topography conditions can make riparian revegetation difficult and the topographic shade minimizes the thermal benefits of shade from vegetation (Figure 14).

Figure 14: Situations where steep slopes and topographic shade, respectively, would lead to exclusion from thermal modeling.

A slope of greater than 30 degrees over the entire planting area would be an impediment to implementation, so this criterion was used to exclude areas via remote sensing. Identifying areas with topographic shade issues is a more involved process. When the primary data source is aerial photography (which is typically flown during the late spring or summer under clear skies around mid-day), visible topographic shadows—such as the shadow seen in the right panel—are a good indicator that a potential project should be excluded from riparian revegetation for thermal benefits. When time of day or year precludes this, steep rises (determined using Google Earth elevation visualization) in elevation immediately to the SW/S/SE of the stream are also viable indicators.

Areas with substantial topographic shade, such as reaches with canyon topography or steep slopes, were not modeled for thermal benefit potential from riparian revegetation. Similarly, although they are eligible, thermal benefits were not estimated for potential projects sites on federally-owned property in this feasibility analysis because the management and modeling assumptions associated with these potential project sites are not as easily standardized for a landscape-level analysis at this point.[8] Finally, potential riparian revegetation project sites were not modeled above any major impoundments that might require an additional attenuation factor (e.g., thermal benefits are estimated below Thief Valley dam on the Powder River).

After excluding these categories for the purpose of a more conservative feasibility analysis,[9] the remaining stream mileage was then modeled for potential thermal benefits. For the purposes of thermal benefit modeling, remaining riparian areas were defined as the area within 50 feet of the edge of the streambank.[10] Consistent with Section 2.3, the Shade-a-lator module of Heat Source model was used to estimate the thermal benefits available from revegetation projects within these riparian areas. Current conditions such as tree height and canopy density were estimated using remote sensing data and values from relevant literature. Restored vegetation conditions were estimated using historical conditions, values from the literature, and the best professional judgment of local restoration professionals as inputs for future mature vegetation conditions.

Through literature (Hoag 2012; IDEQ & ODEQ 2004; IDEQ 2011) and interviews with riparian professionals, The Trust identified two primary reference communities for riparian vegetation in the program area to inform the thermal benefit modeling: 1) riparian vegetation dominated by hardwood species such as black and narrow leaf cottonwoods, and aspen, and 2) riparian shrubs including willows, mountain alder, and hawthorn. The mature characteristics (height and canopy density) of these two vegetation communities differ. The mature heights of cottonwood dominated riparian communities are reported in the U.S. Department of Agriculture's PLANTS database to be 100 feet (USDA, NRCS 2015), which was also incorporated into Oregon DEQ TMDL assumptions for 2010 (ODEQ, 2010). Mature heights of willow species range from 15 to 45 feet depending on the species (USDA, NRCS 2015).

Based on the available information, The Trust developed two future conditions for Shade-a-lator modeling to reflect the potential variability in planting.[11] The first future condition represents a mature riparian community dominated by black cottonwoods and includes tree heights of 100 feet and a canopy density of 80% for use in the Shade-a-lator model (ODEQ, 2010).[12] The second future condition represents a mature riparian community dominated by shrubs and willow species and includes tree

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[8] Prior to modeling thermal benefit potential on a project site located on publicly owned land, The Trust would need to understand the management actions, if any, which are already required by the applicable federal or state management statute and plans. Public lands are eligible for the SRSP, but will likely require agency-by-agency review prior to calculating thermal benefits. Excluding these potential thermal benefits is an appropriately conservative choice for the purposes of assessing feasibility at this juncture.

[9] While these project sites were excluded for the feasibility analysis due to suboptimal characteristics, all project sites within the program area remain eligible for SRSP implementation.

[10] Fifty feet was selected as the uniform buffer width for modeling purposes as the first fifty feet of riparian vegetation has the greatest impact on shade potential.

[11] The characteristics of the future conditions that are represented by the model parameters are the future vegetation height and future canopy density. In the Shade-a-lator model, the canopy density parameter represents the lateral attenuation of solar radiation as it passes through the riparian canopy.

[12] Black cottonwood landcover model parameters as defined in the Malheur River Basin Temperature TMDL, Appendix B, Table B-8 (ODEQ, 2010).

heights of 15 feet and a canopy density of 70%.[13] These two future conditions scenarios represent the range of potential riparian conditions. The difference between current and restored conditions in these scenarios would be the thermal benefit from the restoration project.

Multiple project-level characteristics will determine the composition of a plant community that can be supported at a project site, including depth to the water table, soil type, bank angle, and pests. Remote sensing and GIS can provide much of the necessary information, but not all project-specific information for each mile assessed. To estimate the availability of thermal benefits from riparian revegetation project, The Trust assumed (based on aerial photography and review of TMDLs) that only half of the riparian miles assessed will be able to support tall hardwood species, while the other half of the miles would be well suited for shorter willow species. This assumption was incorporated by modeling the riparian miles twice, once for each future condition scenario. The result sets from the two scenarios were then combined into one programmatic feasibility analysis scenario to represent the range of potential future riparian conditions. To reflect this combined scenario, all project site future conditions were modeled at 50 feet tall and 75% density. Based on the 554 stream miles analyzed for riparian revegetation in the program area in this scenario, The Trust estimates a total of 14.9 billion kilocalories per day (averaged from July-October) are potentially available.

In total, the instream restoration and riparian revegetation project sites assessed in the development of the SRSP in the Snake River and its tributaries can currently provide an estimated total thermal load reduction of approximately 30.2 billion kilocalories per day (averaged from July-October). Table 3 provides the total thermal benefits available from currently identified restoration project sites according to the type of restoration project.

Table 3: Summary of potential total thermal benefits from restoration actions proposed in the SRSP. The combination of potential thermal benefits from instream restoration projects and riparian revegetation projects represents the potential total thermal benefits available within the SRSP program area. There is more potential thermal benefit supply in the SRSP program area than will be needed by IPC.

Restoration Action	Total Available	July-October Mean Daily Thermal Benefit (kcal/day)	Total Thermal Benefit from July-October (kcal)
Riparian Revegetation	554 miles	14,939,000,000	1,799,455,000,000
Instream Modifications	644 acres	15,216,000,000	1,849,767,000,000
Total SRSP		30,155,000,000	3,649,222,000,000

Table 4 provides the total thermal benefits available from currently modeled riparian restoration projects by subbasin and major tributaries. This total is based on thermal benefit modeling using the currently available quantification methods described in Section 2.3 of this document. The thermal

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[13] Willow dominated shrub landcover model parameters as defined in the Malheur River Basin Temperature TMDL, Appendix B, Table B-8 (ODEQ, 2010).

benefits of voluntary flow augmentation projects are not yet quantified, and additional thermal benefits may also be quantified in the future.

Table 4: Programmatic estimate of available thermal benefits by subbasin and major tributaries.

Mean Daily Thermal Benefit (kcal/day)					
Stream	July	August	September	October	July-October Average
Brownlee Reservoir					
Pine Creek	212,000,000	238,000,000	229,000,000	186,000,000	216,000,000
Bully					
Bully Creek	349,000,000	346,000,000	358,000,000	298,000,000	338,000,000
Burnt					
Burnt River	1,717,000,000	1,832,000,000	2,058,000,000	1,760,000,000	1,842,000,000
Camp Creek	36,000,000	35,000,000	34,000,000	28,000,000	33,000,000
Pritchard Creek	37,000,000	35,000,000	34,000,000	26,000,000	33,000,000
Lower Boise					
Fifteenmile Creek	78,000,000	76,000,000	73,000,000	59,000,000	72,000,000
Indian Creek	459,000,000	511,000,000	648,000,000	611,000,000	558,000,000
Lower Boise River	531,000,000	629,000,000	1,067,000,000	2,009,000,000	1,059,000,000
Sand Hollow Creek	263,000,000	407,000,000	430,000,000	402,000,000	376,000,000
Lower Owyhee					
Owyhee River	291,000,000	329,000,000	427,000,000	420,000,000	367,000,000
Malheur					
Cottonwood Creek	43,000,000	41,000,000	38,000,000	30,000,000	38,000,000
Malheur River	1,367,000,000	1,789,000,000	2,841,000,000	2,968,000,000	2,241,000,000
Middle Snake-Payette					
South Fork Jacobsen Gulch	47,000,000	49,000,000	49,000,000	38,000,000	46,000,000
Middle Snake-Succor					
Reynolds Creek	58,000,000	55,000,000	52,000,000	43,000,000	52,000,000
Succor Creek	247,000,000	250,000,000	250,000,000	194,000,000	235,000,000
Payette					
Big Willow Creek	495,000,000	537,000,000	623,000,000	547,000,000	551,000,000

Mean Daily Thermal Benefit (kcal/day)					
Stream	July	August	September	October	July-October Average
Little Willow Creek	535,000,000	539,000,000	545,000,000	452,000,000	518,000,000
Payette River	376,000,000	397,000,000	578,000,000	1,008,000,000	590,000,000
Payette Side Channel	123,000,000	142,000,000	212,000,000	234,000,000	178,000,000
Sevenmile Slough	279,000,000	346,000,000	585,000,000	643,000,000	463,000,000
Powder					
Eagle Creek	95,000,000	90,000,000	89,000,000	63,000,000	84,000,000
Powder River	1,291,000,000	1,646,000,000	2,249,000,000	2,058,000,000	1,811,000,000
Weiser					
Cottonwood Creek	73,000,000	72,000,000	63,000,000	43,000,000	63,000,000
Hornet Creek	159,000,000	158,000,000	154,000,000	111,000,000	145,000,000
Little Weiser River	559,000,000	658,000,000	839,000,000	732,000,000	697,000,000
Lower Weiser River	436,000,000	474,000,000	730,000,000	1,156,000,000	699,000,000
Mann Creek	228,000,000	221,000,000	219,000,000	176,000,000	211,000,000
Middle Fork Weiser River	117,000,000	136,000,000	134,000,000	88,000,000	119,000,000
Monroe Creek	93,000,000	90,000,000	86,000,000	68,000,000	85,000,000
Upper Weiser River	518,000,000	620,000,000	805,000,000	841,000,000	696,000,000
Willow					
Willow Creek	551,000,000	546,000,000	553,000,000	440,000,000	523,000,000
Total	11,663,000,000	13,294,000,000	17,052,000,000	17,732,000,000	14,939,000,000

2.4.3 Project Site-Level Thermal Benefits Assessment & Effect on Thermal Benefit Supply

As described in Section 2.4.2, The Trust identified a total of 14.9 billion total kilocalories per day that could be generated from riparian revegetation projects, and 15.2 billion kilocalories per day that could be generated from instream work in the SRSP area. Not all of these kilocalories can or will be recruited successfully. Because the SRSP will ultimately require the successful recruitment of landowner properties to host project sites, not kilocalories, The Trust applied tax lot ownership boundaries to all of the modeled thermal benefits from riparian revegetation (this exercise was not needed for the instream projects, which were specifically designed as discrete projects, and so the thermal benefits from the project sites were already disaggregated). This step makes the aggregate numbers meaningful for the purposes of assessing recruitment feasibility because thermal benefit potential has been constrained by the realities of land ownership (see Table 5). While this subsection describes the methods and results of The Trust's feasibility analysis, it does not establish compliance obligations, or commitments to recruit any particular properties.

Table 5: Thermal benefits per acre.

This example includes both riparian and instream project site potential by property. Each uniquely owned "tax lot" property is given an identification number, and is geo-located (these fields have been redacted from this document to protect landowner privacy). The modeled acreage and thermal benefits from potential project sites at the property are then attributed to each tax lot. The thermal benefit per acre value of each property was calculated to determine how efficiently the acreage at a particular property could be expected to produce thermal benefits. This is important information for the purposes of recruitment and prioritization. Red (high), yellow (medium), and green (low) colors symbolize the thermal benefit production potential of specific tax lots relative to others. Green sites are not shown in the example excerpted table, but can be seen in the geospatial representation (Figure 15).

River	Action Type	Site Acreage	Thermal Benefits (July – Oct average)	Thermal Benefits per Acre
Burnt	Riparian	18.34	133,044,962	7,253,635
Powder	Riparian	14.11	121,035,068	8,579,078
Powder	Riparian	13.46	120,200,295	8,929,135
Burnt	Riparian	15.37	105,918,472	6,890,650
Powder	Riparian	11.83	104,562,713	8,840,831
Powder	Riparian	11.32	94,264,387	8,328,775
Burnt	Riparian	10.19	85,166,764	8,359,996
Burnt	Riparian	11.58	80,235,910	6,930,431
Big Willow	Riparian	13.50	77,041,691	5,707,109
Burnt	Riparian	9.28	78,502,537	8,455,301
Burnt	Riparian	10.40	74,664,228	7,182,418
Powder	Riparian	8.18	75,328,732	9,205,450
Powder	Riparian	8.67	70,624,033	8,144,541
Powder	Riparian	7.70	69,928,557	9,078,182
Burnt	Riparian	7.94	68,985,512	8,685,908
Powder	Riparian	6.86	70,673,593	10,306,542
Powder	Riparian	8.17	67,842,654	8,305,060
Powder	Riparian	8.82	66,250,265	7,514,634
Snake River	Instream	52.00	1,231,490,000	23,682,500
Snake River	Instream	50.00	1,184,125,000	23,682,500
Snake River	Instream	32.00	757,840,000	23,682,500
Snake River	Instream	29.00	686,792,500	23,682,500
Snake River	Instream	25.00	592,062,500	23,682,500
Snake River	Instream	22.00	521,015,000	23,682,500
Snake River	Instream	23.00	544,697,500	23,682,500

The property-specific thermal benefits per acre information is also available in a geospatial format (see Figure 15), which can help to more easily identify recruitment priorities in comparison to other implementation realities (i.e., proximity to other high potential properties, distance or proximity to labor and material supplies, etc.).

JOHN DOE SAND & GRAVEL COMPANY

OWNER: John Doe
ADDRESS: 1234 A Street
ACRES: 1.12
KCAL: 10,600,000
KCAL/ACRE: 9,500,000

Figure 15. Data at the tax lot can be visually represented and used for prioritization according to thermal benefit per acre potential.

After applying tax lot boundaries to the modeled thermal benefits such that each property has estimated thermal benefit potential and planting acreage for project sites on the property, the next step in The Trust's feasibility study was to exclude individual riparian tax lots that are either too small to be effectively implemented or that do not have sufficient potential to generate thermal benefits. Importantly, exclusion of these properties from the feasibility study because of their suboptimal characteristics does not mean that these properties are ineligible for the SRSP. They can still be recruited and implemented, but have been excluded from this analysis to reflect an added layer of conservatism in supply availability. After completing this step, The Trust tallied the total "prioritized" thermal benefits (in kilocalories per day) remaining for the purposes of this feasibility assessment (Table 6):

Table 6: Total Prioritized Thermal Benefits.

The "Available Total" column reflects the results of the broad thermal benefit supply assessment described in Section 2.4.2. The "Prioritized Total" column reflects the tax lot-delineated thermal benefits that have been prioritized for the purposes of this feasibility assessment.

	Total Available Thermal Benefits (kcal/day)	Prioritized Thermal Benefits (kcal/day)
Riparian	14,939,000,000	10,349,000,000
Instream	15,216,000,000	15,216,000,000

Because the success of the SRSP depends on the availability of prioritized thermal benefit supply recruited from individual properties, The Trust studied the feasibility of recruitment and timing of implementation for individual properties under multiple scenarios in order to provide confidence in the program as a viable compliance approach (see Subsection 2.4.3.1). To be feasible, the supply of thermal benefits associated with the potentially available restoration actions within the SRSP program area must be substantially greater than IPC's cumulative thermal load exceedance, after applying the SR-HC TMDL margin of safety factor, as well as in-reservoir and in-river attenuation. The total available thermal benefits must be substantially greater because only a proportion of the available thermal benefit supply can be reasonably assumed to be "implementable" (due to property recruitment constraints, and the fact that some property-specific characteristics may preclude implementation, some portion of properties will inevitably not be implemented. Inclusion of this reality in the supply analysis represents an additional layer of conservativism when evaluating feasibility of program implementation).

Once adequate supply has been identified (i.e., the program is feasible), the next concern is the time period and sequencing over which to generate those thermal benefits. Subsection 2.4.3.2 addresses SRSP implementation timing and sequencing. To answer this question, The Trust relied on its recruitment experience, implementation rate modeling, and labor and material supply chain considerations. The analysis, numbers and conclusions in this subsection illustrate what The Trust considers to be a likely potential scenario for the purposes of testing feasibility and informing the development of thermal benefit milestones; this subsection does not establish IPC's final compliance targets (which will be set by the DEQs pursuant to the final 401 certification process), or commit IPC to a particular implementation portfolio or annual property recruitment objectives.

2.4.3.1 Feasibility of Generating Sufficient Thermal Benefits

For the purposes of evaluating the feasibility of implementation given the total supply of prioritized thermal benefits identified in Section 2.4.2, The Trust considered the proportion of each action that it believed could likely be recruited over the course of the SRSP. In order to estimate likely recruitment success rates, The Trust reviewed its own success and lessons in contracting with landowners for riparian revegetation project sites, instream habitat project sites, and for leasing instream flows. In The Trust's experience, there are a number of important variables involved in landowner recruitment including incentive structure for participation, contractual framework, contract duration, outreach approach and timing, outreach resources, momentum, and perception of the program from potential landowner participants. In addition, because every potential project site is not always paired with an willing landowner, successful programmatic recruitment depends on having more than enough potential properties with sufficient project sites and enough time to engage landowners. Many landowners may be reluctant to participate in a restoration program at first but become more amenable through further conversation and with access to additional information. Annual recruitment conversion rates (the annual recruitment required for enrollment in a program compared to overall thermal benefit need; lower conversion rate means fewer landowners must participate in order to achieve program goals) can be lower when significant implementation time is available. There is more opportunity to build relationships in the community and establish rapport with individual landowners. Participation levels in the program and the experience of early participants will impact opinions throughout a community. The dynamic landscape of land ownership is also an important factor (typically between 1–2% of properties change ownership each year). The response from a single outreach effort, such as in person individual home visits or phone calls, only provides a snapshot of overall landowner interest and is not the basis for predicting the overall recruitment success of a program. There may be other factors outside of a landowner's control that also affect recruitment success on a program level. For example, in the arid west, it is reasonable to assume that some portion of otherwise eligible land has been recently burned or is suffering from pest infestation, which could make near term restoration challenging or infeasible.

In its water quality trading programs, The Trust has previously assumed that approximately 25% of available riparian kilocalories can be successfully recruited within a watershed. In the case of the SRSP, The Trust and IPC both have extensive experience recruiting landowners in the program area, and broad experience recruiting landowners for the specific restoration actions contemplated under the SRSP.[14] In addition, IPC will dedicate significant staff resources and time to recruitment, and will be flexible in terms of creating helpful incentive structures for landowners. Moreover, because of the 30-year implementation window, the SRSP has an important buffer against the inevitable years where recruitment is lower than planned, and allows for land ownership and landowner opinion to change in favor of recruitment. On the other hand, a significant portion of eligible land will not be leased and restored under the SRSP. Some properties will not be recruited due to lack of landowner interest, and some will not be recruited due to conditions that preclude successful restoration (such as fire, pest, and insufficient connectivity to water table). Based on these considerations as applied to the proposed SRSP, The Trust identified 40% as a reasonable programmatic recruitment percentage for the prioritized thermal benefits from riparian revegetation projects. This is the equivalent of approximately 29% of total available modeled thermal benefits from riparian revegetation projects in the SRSP program area.[15] As described in Section 2.4.3.2, strategic recruitment of specific high-value properties could reduce the effective success rate with prioritized landowners to a level well below 40%.

The variables influencing recruitment success for the creation of thermal benefits through instream restoration actions are slightly different. In addition to being less geographically disperse (allowing for a greater concentration of recruitment effort), a number of these projects involve land owned by the public. Therefore, once a particular agency or entity has been successfully recruited once, the same process should be more easily repeated for subsequent project sites on land managed by the same agency. In addition, for private landowners, the completion of instream work will likely augment the value of their property without removing any arable land from production. Instream work will help stabilize eroding banks, a benefit to landowners. Additionally, the required instream work permits could provide an opportunity for landowners to complete their own projects, such as upgrading pumping intake systems for irrigation equipment that would otherwise require their time and effort to permit. These potential benefits to landowners provide incentive for participation in SRSP in addition to the financial incentives. Based on these factors, The Trust identified 75% as a reasonable recruitment percentage for prioritized thermal benefits from instream project properties. IPC agricultural recruitment staff familiar with this region agree that this recruitment goal is reasonable.

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[14] For thirty years, The Freshwater Trust has been engaged with working lands conversation in the Northwest. Since establishing the nation's first water trust in 1993, The Trust has engaged hundreds of agricultural landowners in voluntary water rights transactions in Oregon—including the Oregon subbasins in the SRSP program area. The Trust has also engaged in large-scale instream restoration efforts, including a 10-year, multi-million dollar effort to reshape the Sandy River Basin through the restoration of in-stream habitat for native salmonids. Over the last decade, The Trust has developed and recruited landowners to participate in riparian revegetation programs throughout the state of Oregon. In addition to City of Medford water quality trading compliance program, The Trust has also developed a riparian program to help the Port of St. Helens offset its thermal load discharge, as well as two pre-compliance riparian restoration programs with the Metropolitan Wastewater Management Commission and the Oregon Watershed Enhancement Board, respectively. The Trust is also actively working with several municipalities in the Boise area to develop thermal and nutrient compliance programs.

[15] As a percentage of total kilocalories, the recruitment success rate would be even lower. Forty percent of prioritized kilocalories is 4.14 billion kilocalories per day; 4.14 billion is 29% of the total available kilocalorie per day pool

The Trust applied these reasonable thermal benefit recruitment percentages to the prioritized total column in Table 6. The result of this process is the target volume of thermal benefits to achieve for through recruitment and implementation for each action type in this feasibility assessment (Table 7):

Table 7: Target volume of thermal benefits for recruitment.

The "Available Total" column reflects the results of the broad assessment described in Section 2.4.2. The "Prioritized Total" column reflects the tax lot-delineated thermal benefits that have been prioritized for the purposes of this feasibility assessment. The kcal/day from projects total in this figure does not represent IPC's needed offset. Rather, it reflects total assumed thermal benefits generated by modeling project implementation for the purposes of this feasibility assessment.

	Total Available Thermal Benefits (kcal/day)	Prioritized Thermal Benefits (kcal/day)	Success Rate of Thermal Benefit Recruitment	Total Thermal Benefits in Recruitment Scenario (kcal/day)
Riparian	14,939,000,000	10,349,000,000	40%	4,139,600,000
Instream	15,216,000,000	15,216,000,000	75%	11,412,000,000
Total				15,551,600,000

For the purposes of conservatively comparing thermal benefit supply and recruitment feasibility, The Trust assumed that IPC will need to generate approximately 12–15.55 billion thermal benefits,[16] which will be produced from individual project sites (which will then be discounted to account for river attenuation). Compared to this assumed thermal benefit need, The Trust identified approximately 30.2 billion kilocalories per day (averaged from July-October) in available thermal benefits, almost twice the benefits needed to meet the CTLE. Even when restricting the thermal benefit supply to the prioritized 25.6 billion kilocalories per day from project sites on properties in the Snake River and its tributaries for this feasibility assessment (see Section 2.4.2), the available supply of thermal benefit is far greater than the required obligation, meaning that the proposed SRSP is feasible.

Of the total available thermal benefits identified in the feasibility study, successful recruitment and implementation of roughly 40–50% of total estimated thermal benefits should be achievable. The total thermal benefit need can be achieved through a mix of restoration actions; for example, implementation of a higher proportion of instream restoration projects reduces the need for recruitment of riparian restoration actions and vice versa. The Trust considered a variety of thermal benefit portfolio scenarios that included different project mixes, landowner recruitment rates, and thermal benefits to evaluate the feasibility of implementation of the SRSP to meet CTLE needs for compliance. While the obligation is significant, The Trust's best professional judgment is that restoration at the watershed scale is feasible in this instance and that sufficient thermal benefits can be generated

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[16] The most straightforward way of expressing the thermal benefit of specific project is in kilocalories per day over the July-October period. However, expressing IPCs obligation as a per-day value is dependent on the actual mix of instream and riparian projects implemented because the river attenuation factors to be applied are different for the two project types (see Section 7.1 of the 401 application). While the distribution of potential project types is not fixed, The Trust's feasibility assessment identified a program composition that includes 4.14 billion kcal/day modeled from riparian revegetation projects and 11.41 billion kcal/day modeled from instream projects.

to meet compliance needs. The research phase implementation of instream restoration actions and riparian revegetation projects in different subbasins will help to develop outreach approaches, streamline implementation, and identify challenges or questions before full program implementation.

2.4.3.2 Timing of Thermal Benefit Implementation

In addition to determining the feasibility of achieving the overall needed thermal benefits, The Trust also identified a reasonable timeframe and sequence for successfully implementing the SRSP. Successful recruitment and generation of up to 15.55 billion prioritized kilocalories per day[17] requires the build-up of a supply chain and labor capacity, especially for the geographically dispersed riparian program. In order to ramp up the scale of both the riparian and instream programs appropriately, The Trust considered several recruitment "arcs" for implementing the SRSP. In developing recruitment arc scenarios, The Trust considered annual conversion rates for both landowners and kilocalories. When a program is first introduced, conversion rates are lower. In these formative years, recruiters spend most of their time establishing an accurate understanding of the program within the landowner community and seeking out early adopters. For example, The Trust's Medford water quality trading program recruitment efforts relied on focus groups with local conservation organizations and some of their partner landowners. In this program, the first contract signed was a landowner invited to a focus group by the local Council of Governments. The second phase of outreach involves building on the success of early adopters to recruit as many priority landowner properties as possible. Landowner-to-landowner recruitment will help accelerate recruitment during this period. For example, in the Medford program, three properties with priority project sites were recruited simultaneously as a result of successfully engaging one neighbor. The third phase of recruitment is a combination of completing the obligation with lower priority properties and contracting with landowners of priority properties who may have been slow to commit or had a favorable change of ownership. The Trust's recruitment efforts for the Medford program are currently transitioning from the second to third phase. About half of the kilocalorie obligation has been delivered and most priority properties with willing landowners have been signed.[18]

For the purposes of the SRSP, recruitment arcs on both sides of the spectrum are described. The first recruitment arc is based on median project site characteristics and incremental implementation rates

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[17] While the distribution of potential project sites is not fixed, The Trust's feasibility assessment identified a program composition that includes 4.14 billion kcal/day modeled from riparian revegetation projects and 11.41 billion kcal/day modeled from instream projects.

[18] Annual recruitment success rates for Medford:

	Year 1 2012	Year 2 2013	Year 3 2014	Summary
Properties recruited	1	6	1	8 (total)
Kilocalories recruited	27,600,000	210,700,000	52,700,000	291,000,000 (total)
Percent of overall obligation recruited during year	4.6%	35%	8.8%	16.2% (average)

(see Figure 16). To build this arc, The Trust assumed that a percentage of the riparian and instream thermal benefit subtotals from Table 7 would be achieved in a particular year. The “percentage kcals recruited in year” value was then multiplied by the action-specific subtotals summarized in Table 7 of the feasibility assessment. Next, The Trust used the median project site size and thermal benefit per acre characteristics identified from the tax lot-level assessment to convert the yearly kilocalorie total into the number of new properties (“# new properties”) that would need to be recruited in a given year. Based on this exercise and its best professional judgment, The Trust determined that a 30-year recruitment and implementation time period would appropriately balance the size and scope of the program with the need to successfully generate as many thermal benefits as quickly as possible. An example of a reasonable recruitment arc is presented in Figures 16 (tabular format), 17 (visual format, % of total thermal benefit total needed each year), 18 (number of new properties per year), and 19 (overall kilocalorie totals accumulated over time).

HYPOTHETICAL MEDIAN RECRUITMENT SCENARIO										
	RIPARIAN				INSTREAM				TOTAL	
Year	% Kcals Recruited in Year	New Kcals in Year	# New Properties	Kcals Running	% Kcals Recruited in Year	New Kcals in Year	# New Properties	Kcals Running	Kcal Running	% of Total
Year 1	1%	41,393,649	3.3	41,393,649	2%	228,245,625	1.1	228,245,625	269,639,274	1.7%
Year 2	1%	41,393,649	3.3	82,787,299	2%	228,245,625	1.1	456,491,250	539,278,549	3.5%
Year 3	1%	41,393,649	3.3	124,180,948	2%	228,245,625	1.1	684,736,875	808,917,823	5.2%
Year 4	2%	82,787,299	6.6	206,968,246	3%	342,368,438	1.6	1,027,105,313	1,234,073,559	7.9%
Year 5	2%	82,787,299	6.6	289,755,545	3%	342,368,438	1.6	1,369,473,750	1,659,229,295	10.7%
Year 6	3%	124,180,948	9.9	413,936,493	3%	342,368,438	1.6	1,711,842,188	2,125,778,680	13.7%
Year 7	3%	124,180,948	9.9	538,117,441	3%	342,368,438	1.6	2,054,210,625	2,592,328,066	16.7%
Year 8	3%	124,180,948	9.9	662,298,389	3%	342,368,438	1.6	2,396,579,063	3,058,877,451	19.7%
Year 9	3%	124,180,948	9.9	786,479,337	3%	342,368,438	1.6	2,738,947,500	3,525,426,837	22.7%
Year 10	4%	165,574,597	13.2	952,053,934	4%	399,429,844	1.9	3,138,377,344	4,090,431,277	26.3%
Year 11	4%	165,574,597	13.2	1,117,628,531	4%	399,429,844	1.9	3,537,807,188	4,655,435,718	29.9%
Year 12	5%	206,968,246	16.5	1,324,596,777	4%	399,429,844	1.9	3,937,237,031	5,261,833,809	33.8%
Year 13	7%	289,755,545	23.1	1,614,352,322	4%	399,429,844	1.9	4,336,666,875	5,951,019,197	38.3%
Year 14	7%	289,755,545	23.1	1,904,107,867	5%	570,614,063	2.7	4,907,280,938	6,811,388,805	43.8%
Year 15	7%	289,755,545	23.1	2,193,863,412	5%	570,614,063	2.7	5,477,895,000	7,671,758,412	49.3%
Year 16	6%	248,361,896	19.8	2,442,225,308	5%	570,614,063	2.7	6,048,509,063	8,490,734,371	54.6%
Year 17	6%	248,361,896	19.8	2,690,587,204	4%	456,491,250	2.1	6,505,000,313	9,195,587,516	59.1%
Year 18	5%	206,968,246	16.5	2,897,555,450	4%	456,491,250	2.1	6,961,491,563	9,859,047,013	63.4%
Year 19	5%	206,968,246	16.5	3,104,523,697	4%	399,429,844	1.9	7,360,921,406	10,465,445,103	67.3%
Year 20	4%	165,574,597	13.2	3,270,098,294	4%	399,429,844	1.9	7,760,351,250	11,030,449,544	70.9%
Year 21	4%	165,574,597	13.2	3,435,672,891	4%	399,429,844	1.9	8,159,781,094	11,595,453,985	74.6%
Year 22	4%	165,574,597	13.2	3,601,247,488	4%	399,429,844	1.9	8,559,210,938	12,160,458,426	78.2%
Year 23	3%	124,180,948	9.9	3,725,428,436	4%	399,429,844	1.9	8,958,640,781	12,684,069,218	81.6%
Year 24	3%	124,180,948	9.9	3,849,609,384	4%	399,429,844	1.9	9,358,070,625	13,207,680,009	84.9%

HYPOTHETICAL MEDIAN RECRUITMENT SCENARIO										
	RIPARIAN				INSTREAM				TOTAL	
Year	% Kcals Recruited in Year	New Kcals in Year	# New Properties	Kcals Running	% Kcals Recruited in Year	New Kcals in Year	# New Properties	Kcals Running	Kcal Running	% of Total
Year 25	2%	82,787,299	6.6	3,932,396,683	3%	342,368,438	1.6	9,700,439,063	13,632,835,745	87.7%
Year 26	1%	41,393,649	3.3	3,973,790,332	3%	342,368,438	1.6	10,042,807,500	14,016,597,832	90.1%
Year 27	1%	41,393,649	3.3	4,015,183,981	3%	342,368,438	1.6	10,385,175,938	14,400,359,919	92.6%
Year 28	1%	41,393,649	3.3	4,056,577,631	3%	342,368,438	1.6	10,727,544,375	14,784,122,006	95.1%
Year 29	1%	41,393,649	3.3	4,097,971,280	3%	342,368,438	1.6	11,069,912,813	15,167,884,092	97.5%
Year 30	**1%**	**41,393,649**	**3.3**	**4,139,364,929**	**3%**	**342,368,438**	**1.6**	**11,412,281,250**	**15,551,646,179**	**100%**
TOTAL	100%		330	4,139,364,929	100%		53.4	11,412,281,250		

Figure 16: Hypothetical median recruitment scenario.

The prioritized kilocalorie per day totals from Table 7 were multiplied by annual recruitment percentages. That percentage yielded a total volume of kilocalories associated with that year. Taking median project site size and thermal benefit production (kilocalorie per acre) information from the tax lot data set , The Trust identified the number of properties that would (assuming all project sites are median sized and have median thermal benefit production potential) be necessary to achieve that annual kilocalorie total.

The information in Figure 16 can be presented in several useful formats, including thermal benefit recruitment percentage per year (Figure 17), properties per year (Figure 18), and overall kilocalorie totals (Figure 19).

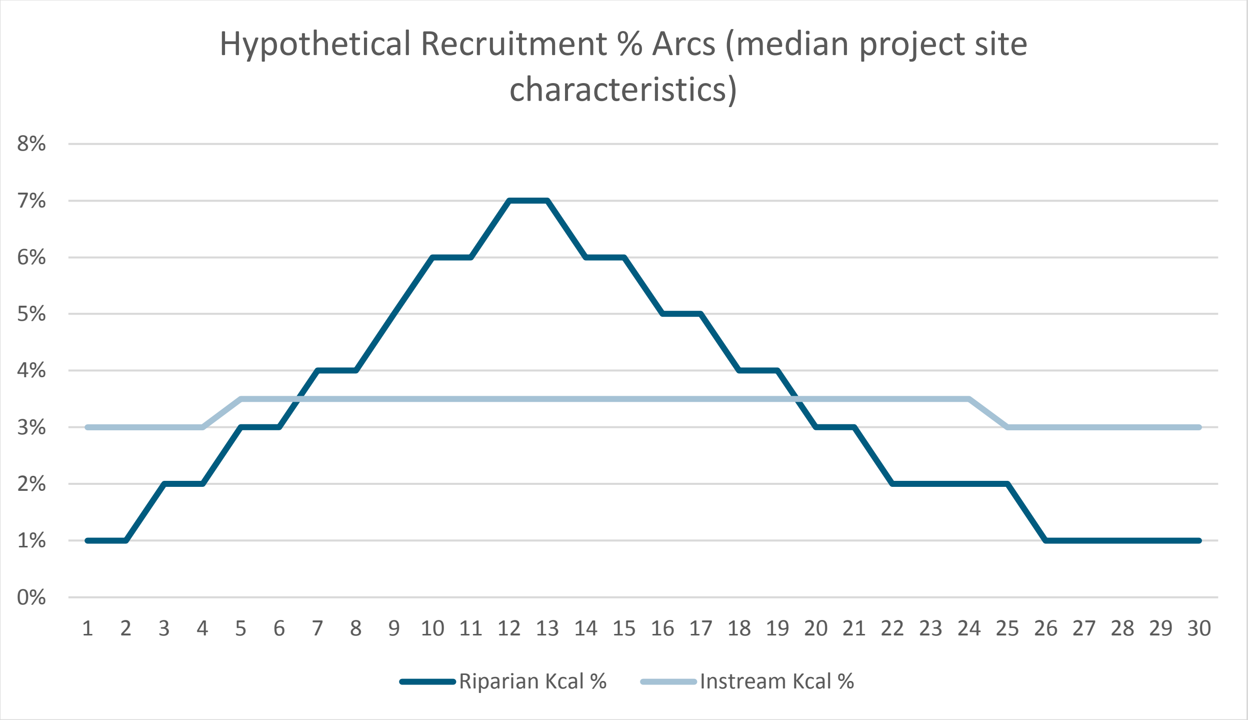

Figure 17: Hypothetical thermal benefit property recruitment percentage arcs associated with Figure 16.

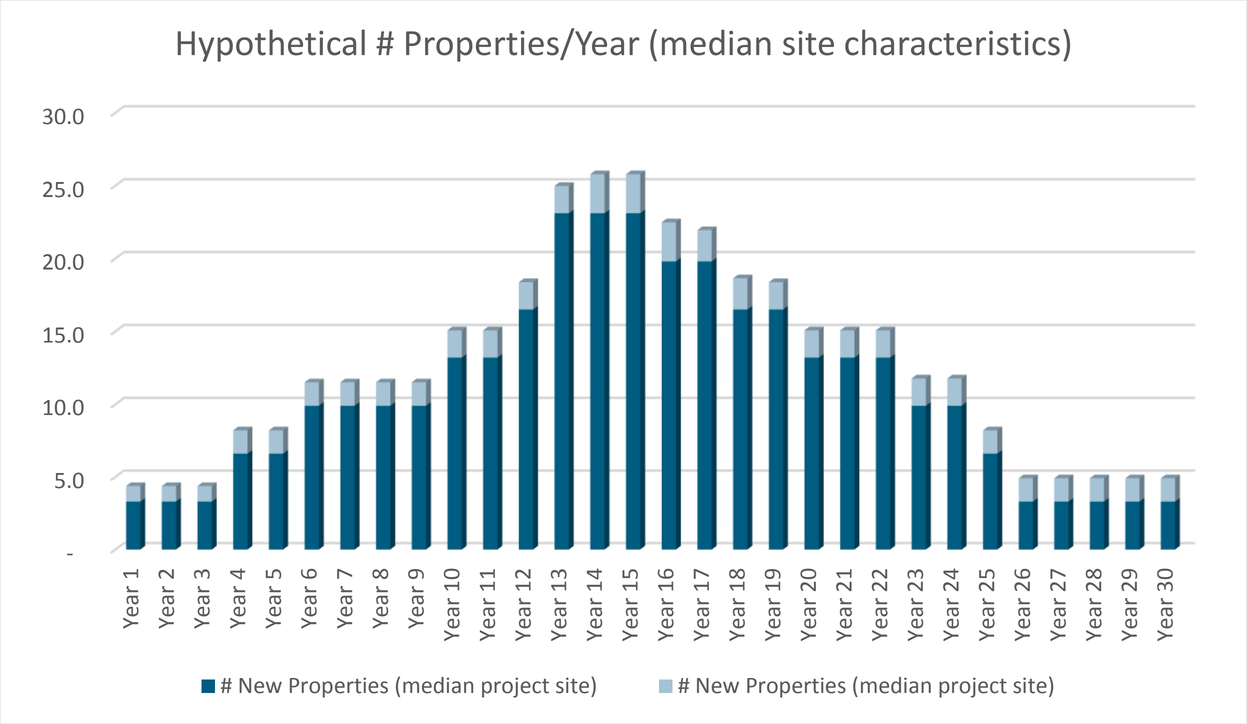

Figure 18: Hypothetical recruitment for properties per year, associated with Figure 16. The dark blue bars represent hypothetical recruitment for riparian projects; light blue bars represent the hypothetical recruitment for instream projects.

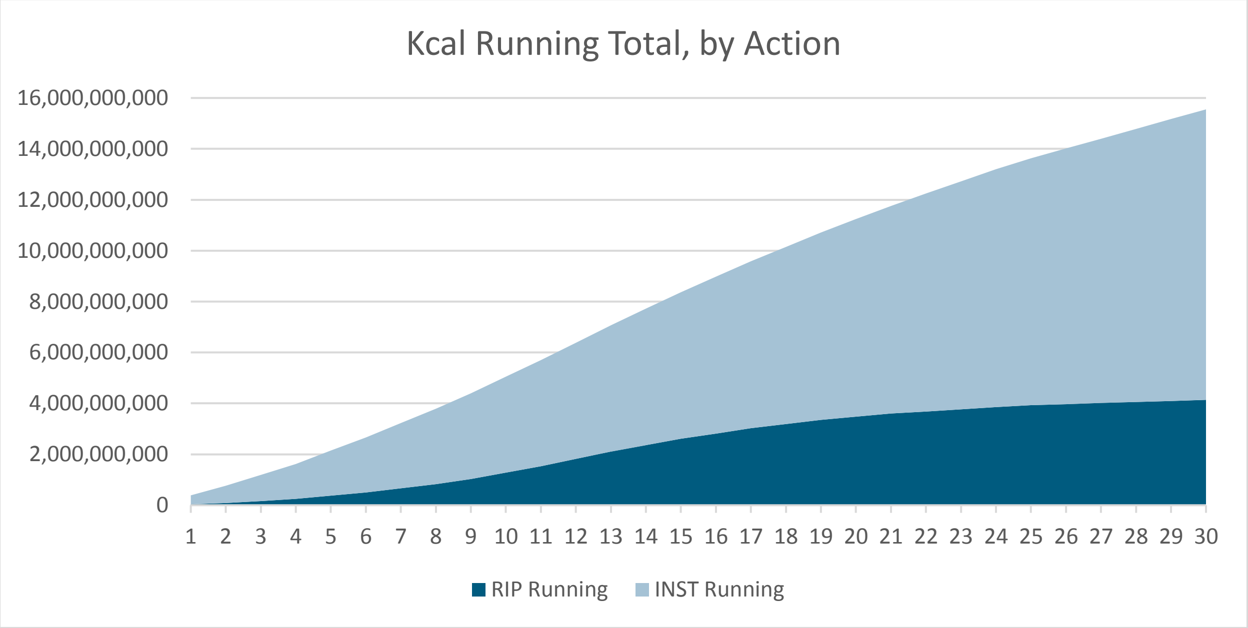

Figure 19: Hypothetical running thermal benefit totals, by action type, associated with Figure 16.

While the hypothetical thermal benefit recruitment percentage arc (Figure 17) and the hypothetical running total of thermal benefits (Figure 19) will not necessarily change based on individual property recruitment dynamics, the number of properties (Figure 18) necessary to achieve the thermal benefit per year estimates identified in Figure 16 will very likely change. For example, IPC can prioritize particular properties for recruitment based on the thermal benefit production modeled for project sites a particular tax lot, streamlining recruitment planning and leaving only landowner interest to chance. Using the tax lot-specific information developed for the feasibility assessment (see Table 5, Figure 15), IPC can target properties with the highest “thermal benefit production” (thermal benefits per acre). If IPC were successful in recruiting a program portfolio comprised almost entirely of properties with the highest efficiency project sites (as compared to the median characteristics used to identify the number of new properties needed each year in Figures 16 and 18), then IPC could reduce the necessary landowner recruitment success rate needed to meet their needed thermal benefits. In this targeted site selection scenario, instead of needing approximately 330 riparian properties and 53 instream properties (the total number of estimated properties identified in Figures 16 and 18 based on median project site characteristics), IPC would only need to recruit a total of 151 riparian properties and 38 instream properties (see Figure 20).

HYPOTHETICAL HIGH RECRUITMENT SCENARIO

	RIPARIAN				INSTREAM				TOTAL	
Year	% Kcals Recruited in Year	New Kcals in Year	# New Properties	Kcals Running	% Kcals Recruited in Year	New Kcals in Year	# New Properties	Kcals Running	Kcal Running	% of Total
Year 1	0.5%	22,164,552	2	22,164,552	2.5%	228,245,625	1	228,245,625	306,354,552	2.0%
Year 2	0.8%	33,845,977	2	56,010,529	2.5%	228,245,625	1	456,491,250	624,390,529	4.0%
Year 3	1.3%	52,971,887	2	108,982,416	6.6%	228,245,625	1	684,736,875	1,435,202,416	9.2%
Year 4	1.1%	45,941,252	3	154,923,668	11.2%	342,368,438	2	1,027,105,313	2,759,998,668	17.7%
Year 5	1.4%	58,958,195	4	213,881,862	9.3%	342,368,438	2	1,369,473,750	3,884,669,362	24.9%
Year 6	3.1%	127,695,603	4	341,577,466	8.3%	342,368,438	2	1,711,842,188	4,959,664,966	31.8%
Year 7	3.5%	144,194,655	6	485,772,120	7.2%	342,368,438	2	2,054,210,625	5,932,747,120	38.1%
Year 8	3.1%	126,487,301	4	612,259,421	6.8%	342,368,438	2	2,396,579,063	6,840,756,921	43.9%
Year 9	3.6%	148,185,441	4	760,444,863	6.2%	342,368,438	2	2,738,947,500	7,699,417,363	49.4%
Year 10	2.8%	114,547,496	4	874,992,359	4.8%	399,429,844	2	3,138,377,344	8,358,662,359	53.6%
Year 11	0.7%	28,471,319	2	903,463,678	4.8%	399,429,844	2	3,537,807,188	8,931,831,178	57.3%
Year 12	3.4%	142,521,778	7	1,045,985,457	4.3%	399,429,844	2	3,937,237,031	9,571,685,457	61.4%
Year 13	7.6%	312,794,292	12	1,358,779,748	3.7%	399,429,844	2	4,336,666,875	10,310,764,748	66.2%
Year 14	7.3%	303,160,434	7	1,661,940,183	3.7%	570,614,063	2	4,907,280,938	11,040,210,183	70.9%
Year 15	8.5%	351,497,065	9	2,013,437,247	3.7%	570,614,063	2	5,477,895,000	11,817,992,247	75.9%
Year 16	7.1%	292,800,972	7	2,306,238,220	1.9%	570,614,063	2	6,048,509,063	12,323,935,720	79.1%
Year 17	6.6%	274,427,127	9	2,580,665,346	3.5%	456,491,250	2	6,505,000,313	13,000,965,346	83.4%
Year 18	4.7%	192,910,102	6	2,773,575,449	3.1%	456,491,250	2	6,961,491,563	13,549,112,949	87.0%
Year 19	6.0%	250,434,008	8	3,024,009,457	2.9%	399,429,844	2	7,360,921,406	14,131,101,957	90.7%
Year 20	3.8%	155,448,370	7	3,179,457,827	2.9%	399,429,844	3	7,760,351,250	14,618,105,327	93.8%
Year 21	3.4%	140,653,489	7	3,320,111,315	0.0%	399,429,844	-	8,159,781,094	14,758,758,815	94.7%
Year 22	4.4%	183,536,729	9	3,503,648,045	0.0%	399,429,844	-	8,559,210,938	14,942,295,545	95.9%
Year 23	3.3%	135,534,530	6	3,639,182,574	0.0%	399,429,844	-	8,958,640,781	15,077,830,074	96.8%
Year 24	3.7%	153,676,048	6	3,792,858,622	0.0%	399,429,844	-	9,358,070,625	15,231,506,122	97.8%
Year 25	2.5%	104,633,007	6	3,897,491,630	0.0%	342,368,438	-	9,700,439,063	15,336,139,130	98.4%
Year 26	1.3%	55,905,407	3	3,953,397,037	0.0%	342,368,438	-	10,042,807,500	15,392,044,537	98.8%
Year 27	0.0%	-	-	3,953,397,037	0.0%	342,368,438	-	10,385,175,938	15,392,044,537	98.8%
Year 28	1.8%	74,664,228	1	4,028,061,265	0.0%	342,368,438	-	10,727,544,375	15,466,708,765	99.3%
Year 29	1.3%	51,950,965	3	4,080,012,230	0.0%	342,368,438	-	11,069,912,813	15,518,659,730	99.6%

HYPOTHETICAL HIGH RECRUITMENT SCENARIO										
	RIPARIAN				INSTREAM				TOTAL	
Year	% Kcals Recruited in Year	New Kcals in Year	# New Properties	Kcals Running	% Kcals Recruited in Year	New Kcals in Year	# New Properties	Kcals Running	Kcal Running	% of Total
Year 30	1.5%	61,931,755	1	4,141,943,985	0.0%	**342,368,438**	-	**11,412,281,250**	15,580,591,485	100%
TOTAL	100%		151	4,141,943,985	100%		38	11,412,281,250		100%

Figure 20: Hypothetical high property recruitment scenario.

Compared to the median uplift scenario illustrated in Figure 16, The Trust selected properties for this scenario based on the thermal benefit production potential of the project sites available on the property. If a property has higher thermal benefit production, it can produce more thermal benefits per unit of area. This figure illustrates the aggregate annual effect of successfully selecting and implementing high production properties.

The Trust does not suggest that the high thermal benefit production recruitment scenario represented by Figure 20 is reasonable to achieve in full, or that it be used as the basis for establishing thermal benefit compliance milestones. Rather, The Trust anticipates that actual recruitment will likely fall somewhere between the median scenario illustrated in Figure 16 and the high efficiency scenario illustrated in Figure 20. Nonetheless, this comparison illustrates how targeted recruitment according to property-level characteristics can help reduce the number of individual landowners that need to be recruited, allowing for targeted outreach and further improving program feasibility.

In The Trust's best professional judgment, the range of annual properties/year evaluated for implementation represented by Figures 16 and 18 is reasonable. For example, in Year 13 of these scenarios, which is the current implementation apex in both scenarios, 12–23 riparian properties and 1–3 instream properties are identified as need for successful program implementation. While the SRSP is a larger program than The Trust's current Medford water quality trading program—which currently results in implementation on 3–5 riparian revegetation properties each year—this number is reasonable when contextualized as a part of the 10–18 instream and riparian revegetation projects on the same number of properties and more than 160 instream flow leases that The Trust also implements each year.[19] In addition, IPC will be able to leverage the internal capacity of its Terrestrial, River Engineering, and Water Quality groups in order to support the implementation and scaling of the SRSP. Other entities have also developed successful watershed restoration programs. These programs include the systems needed to implement projects at the scale necessary for the SRSP. For example, Bonneville Power Administration (BPA) has over 26 different funding obligations for mitigation requirements and implements hundreds of projects across Oregon, Idaho, Washington and Montana.[20] Oregon Watershed Enhancement Board (OWEB) administers millions of dollars for restoration across the state. In 2012, 88 instream projects and 345 riparian projects were completed using OWEB funding.[21]

2.4.4 Thermal Benefit Implementation Compliance Milestones

The SRSP will be implemented over the term of the new FERC license for the HCC. Long-term implementation of the SRSP is consistent with regulator expectations for the TMDL (SR-HC TMDL, at 19–22). While kilocalorie benchmarks must be converted into needed properties to recruit (with median project site characteristics) in order to test program feasibility, properties and project sites vary in size and the production of thermal benefits, and so progress is best tracked during the program in terms of thermal benefit milestones.

To ensure that adequate progress is being made toward offsetting the cumulative thermal exceedance, The Trust recommends that the 401 certification include an ambitious, but achievable, thermal benefit

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[19] The Freshwater Trust documents the ecological benefits generated from its projects in an annual Uplift Report. Pages 10 and 11 speak to the number of projects completed in the last year. See the 2014 report here: http://www.thefreshwatertrust.org/wp-content/uploads/2015/09/2014_Uplift-Report_FINAL-web.pdf

[20] The Columbia Fish and Wildlife Program provides information on all BPA projects: http://www.cbfish.org/. The systems that BPA has developed to access information on mitigation projects could provide useful models for IPC.

[21] OWEB administers many grants, providing oversight and support to watershed councils and SWCD's across the state. See http://oe.oregonexplorer.info/RestorationTool/ and http://www.oregon.gov/OWEB/pages/sip.aspx and http://www.oregon.gov/OWEB/docs/oitt.html for more information.

implementation milestone schedule. While IPC will strive to recruit properties and implement project sites as quickly as possible, it will inevitably take time to scale up the supply and labor chain necessary to implement the SRSP—a watershed restoration program that covers a large geographic area. Accordingly, building thermal benefit milestones based on a median property implementation scenario (articulated in Figure 16–19), assumes appropriate scaling and progress, without setting impractical benchmarks. Based on the exercise articulated in Figures 16–19, the following thermal benefit compliance milestones are suggested:

Table 8: Example thermal benefit implementation compliance milestones.

Milestone Date	Milestone (thermal benefits)
15 years after FERC re-licensing complete	50% of total thermal benefits implemented
30 years after FERC re-licensing complete	100% of total thermal benefits implemented

In addition to these suggested thermal benefit implementation compliance milestones, one additional compliance will occur at the end of the operating license. At this point, IPC should document that the number of kilocalorie benefits modeled for SRSP restoration project sites is within some range of actual kilocalorie benefits being produced from those project sites (see Section 2.6.2).

2.5 Implementation

Full implementation of the SRSP will occur over the term of the FERC operating license (currently expected to be issued in 2020 or 2021). All projects included in the SRSP will need to be designed and implemented consistent with ecologically appropriate restoration quality standards, which are described generally in Section 2.5.1, and in more detail in Attachment 1 (draft restoration quality standards). In addition to being designed and implemented consistently with the restoration quality standards, restoration actions must also be shown to be "additional" in order for the thermal benefits from these actions to be certified and then registered and tracked on a public website (see Section 2.6) and used by IPC for compliance. Section 2.5.2 describes how regulatory additionality, financial additionality and project site-specific thermal benefit additionality can be demonstrated in the SRSP. The duration, or "life" of thermal benefits generated for the SRSP is also described in 2.5.3. To prepare for full implementation of the SRSP, and as an example of how these considerations will be addressed on-the-ground, implementation of research projects, such as the Bayha Island Research Project (an island enhancement project), are planned to be conducted prior to receipt of FERC license. The potential benefits associated with research projects, as well as a description of the Bayha Island project, are described in Section 2.5.4.

2.5.1 Restoration Quality Standards

In order to achieve the thermal benefits estimated by the suite of models described in Section 2.3, it will be essential to design and implement SRSP projects consistently with locally relevant, ecologically focused restoration quality standards. Clear guidance on project design and implementation promotes high project quality, integrity, and consistency over time and over the wide geographic area of the SRSP.

Equally important, consistent design and implementation allows for standardized thermal benefit model calibration and usage. Because the restoration quality standards are developed to achieve an independently-functioning ecosystem, design and implementation in accord with them improves the likelihood that the restoration actions will achieve the modeled future conditions used to calculate thermal benefits.

The Trust has worked with IPC to develop “draft” restoration quality standards for the instream and riparian restoration actions planned for the SRSP (described in detail in Attachment 1). The content of these draft restoration quality standards was informed by literature, experience, and interviews with professionals from watershed councils and agencies in each of the tributary basins. When possible, draft restoration quality standards draw from and supplement the USDA NRCS Conservation Practice Standards,[22] which are widely accepted as conservation practice standards across the country. Draft restoration quality standards will be applied in an ecologically appropriate manner at each project site, and the application of those standards will be consistently documented for all project sites. Restoration quality standards will contain the following elements:

> **Practice Description**: This section will describe the practice in general terms. Current approved restoration practices are discussed in detail in Section 2.2. The purpose of the description is to allow anyone interested in the program to understand the project type, its objectives, and implementation considerations.
>
> **Thermal Benefit Calculation Method**: Current thermal benefit calculation methodologies are discussed in detail in Section 2.3. The appropriate method for thermal benefit calculation will be applied depending on the restoration action selected. Key project-level inputs for thermal benefit calculation will be identified (e.g., project elevation, stream aspect, surface area) along with the assumptions that will be used in the thermal benefit calculation (e.g., height, density, node distance, number of samples).
>
> **Project Eligibility/Screening Criteria**: The goal of project screening is to confirm that the project site under consideration is appropriate for implementation of the proposed restoration action. The restoration quality standard provide broad screening criteria and outline any property, project site or land use characteristics that would make the restoration practice, property, or project site ineligible from IPC’s perspective, ineffective for the purposes of generating estimated thermal benefits, or that might make the action likely to fail.
>
> **Project Design:** Project design documents are meant to facilitate consistency across projects such that when the design and implementation components described in the restoration quality standards are followed, it is simple to estimate the thermal benefit value of those projects and understand how they contribute to meeting IPC’s cumulative thermal load exceedance. Project design documents afford project implementers the flexibility to tailor implementation to the needs

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[22] U.S. Dep’t of Agriculture, Natural Resources Conservation Service, Conservation Practices, http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/cp/ncps/?cid=nrcs143_026849 (accessed Apr. 30, 2015).

of an individual project site and document how the restoration standards were applied, while maintaining high quality and consistency in design and implementation. Practice design documents may need to be tailored to include additional information according to the restoration action type (riparian revegetation protocols will have different considerations than island enhancement, for example). At a minimum, all project design templates will include the following information at the project level:

- → Geographic location of the project(s)
- → Landowner information and approximate location
- → Length of legal protection agreement signed with landowner for project, and confirmation that the project protection agreement has been executed
- → Map of project area (with boundaries and thermal benefit areas)
- → Initial pre-project photo points, and methods for evaluating pre- and post-project site conditions
- → Outline of project goals
- → List of any anticipated risks to project success

The instream and riparian restoration quality standards in Attachment 1 are "draft" because they will need to be reviewed and approved as part of the 401 certification, and because they will likely be refined through the research project implementation phase. The restoration quality standards will be finalized upon initiation of the FERC operating license. An adaptive approach will be used to create regular version updates to the draft quality standards as data become available through implementation. Additionality

"Additionality" relates to the crediting of thermal benefits generated from a SRSP restoration action toward achievement of IPC's cumulative thermal load exceedance. The thermal and environmental benefits secured from a SRSP restoration action are additional when the action is not already required, and the benefit would not have been generated without the funds or resources provided by IPC. Additionality demonstrates that the program is not claiming credit for environmental improvements that would have occurred anyway in the absence of the SRSP.[23]

In the implementation of the SRSP, additionality will be considered in three ways. First, confirmation that the restoration action proposed for the project site is not already required by existing affirmative land management obligations. Second, ensuring that the thermal benefits from a restoration project site were not generated for another purpose, for example, through use of public funds already dedicated to nonpoint source restoration. Third, ensuring that any thermal benefit generated from pre-project conditions at a restoration project sites are not counted when calculating the thermal benefit from the site.

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[23] Of note, this is a separate inquiry from permitting, which will be properly undertaken by IPC for all restoration project sites.

2.5.2 Regulatory Baseline

In determining whether the thermal benefits generated from SRSP restoration actions are additional, the regulatory baseline applicable to the project site(s) where the restoration actions are implemented must be considered. “Regulatory baseline” in this context refers to affirmative land management obligations applicable to the project site at the time that the SRSP restoration actions are implemented that may be required by federal, state, tribal or local law, including any requirements derived from a TMDL. If any such affirmative land management obligations exist at the time the restoration action is implemented, compliance with those requirements must be documented to the DEQs before any thermal benefits from the implemented restoration actions can be counted toward the cumulative thermal load exceedance.

Below is an assessment of the regulatory baseline obligations, as of 2015, for the general area in which SRSP program actions are expected to take place. Upon implementation of the SRSP, this regulatory baseline assessment will be updated on a five-year basis that aligns with the SRSP adaptive management cycle (see Section 3). The results of this periodic assessment will constitute the regulatory baseline requirements associated with project sites implemented in the SRSP program area during the subsequent five-year period. For the purposes of determining the extent of thermal benefits credited towards compliance with the cumulative thermal load exceedance, once a SRSP project site has been implemented, the regulatory baseline analysis associated with that project site will remain in effect for as long as the project site continues to be supported and maintained in a manner consistent with the SRSP.

Neither instream habitat creation nor flow augmentation is affirmatively required in either Idaho or Oregon, so there are currently no regulatory baseline requirements associated with these restoration actions. The overlay of existing regulations on potential SRSP riparian revegetation project sites is more complex. The remainder of this section thus describes the state of overlay land use regulations that apply to riparian revegetation project sites as of 2015. No existing affirmative land management obligations have been identified for project sites on private or non-federally owned public properties in the SRSP program area that would reduce or otherwise affect the total thermal benefit calculated from project sites. As explained in more detail below, federally-owned federal land is not included here because there may be management or other conditions that require additional analysis.

Riparian revegetation implementation in the SRSP will likely be prioritized on private and non-federal public property, maximizing the benefits of restoration actions on project sites where there is not a current management mandate or obligation to restore instream or riparian habitat. Demonstrating additionality from SRSP projects implemented on public or federally-owned land involves additional considerations.[24]

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[24] Demonstrating additionality on publicly owned land involves the consideration of management actions, if any, which are already required by the federal or state management statute and plans governing that parcel. If any of those statutes or management plans already require active restoration of the riparian area where SRSP project sites would be implemented, it would be necessary to discount the thermal benefits generated from that project site so as to ensure that those benefits are

For private agricultural properties within the SRSP program area, no state, local or tribal obligations in Idaho currently affirmatively require riparian revegetation of proposed SRSP project sites. In high-priority, water quality limited waters in Idaho, "[o]nce the TMDL or equivalent process is completed, any new or increased discharge of causative pollutants will be allowed only if consistent with the approved TMDL. Nothing in this section shall be interpreted as requiring best management practices for agricultural operations which are not adopted on a voluntary basis." IDAPA 58.01.02.055.04 (2015). This same provision applies in medium and low priority waters. IDAPA 58.01.02.055.05 (2015). Nothing in IDAPA 58.01.02.110, .120, .130, .140, .150, or .160 establish any further requirements on nonpoint sources in the subbassins within the SRSP program area (17050117 - Lower Malheur; 17050119 - Willow Creek (in the Larger HUC3 Malheur); 17050118 - Bully Creek (also in the HUC3 Malheur); 17050110 - Lower Owyhee; 17050202 – Burnt; 17050203 – Powder; 17050115 - Middle Snake-Payette).

Best management practices (BMPs) under the jurisdiction of other Idaho agencies are discussed in IDAPA 58.01.02.350.03, but are likely not relevant in the areas where SRSP projects will be implemented.[25] In short, however, "so long as a nonpoint source activity is being conducted in accordance with applicable rules, regulations and best management practices as referenced in Subsection 350.03, or in the absence of referenced applicable best management practices, conducted in a manner that demonstrates a knowledgeable and reasonable effort to minimize resulting adverse water quality impacts, the activity will not be subject to conditions or legal action ***." IDAPA 58.01.02.350.02(a) (2015).

Depending on a property's location within the SRSP program area, it may be subject to a county or city comprehensive plan, zoning ordinances, subdivision ordinances or other local code requirements. Baseline requirements at the county and city level may therefore vary depending on location, land use type, applicable overlay districts (if any) and the type of BMP employed to generate thermal benefits. None of the Idaho counties or cities in the SRSP program area currently affirmatively require riparian restoration work at SRSP project sites. These local conditions applicable to a site will be documented as part of project eligibility (see Attachment 1).

Similarly, on private agricultural property within the SRSP program area, no state, local or tribal obligations currently affirmatively require riparian revegetation in Oregon. At the state level, the SRSP program area overlaps with four Oregon agricultural management plan (AgWQMP) areas: Owyhee (OAR 603-095-2700), Malheur (OAR 603-095-0900), Burnt (OAR 603-095-3200), and Powder/Brownlee (OAR 603-095-3600). In the Owyhee, for example, "no person may contribute to conditions that preclude establishment and development of adequate riparian vegetation for streambank stability and shading, consistent with site capability." OAR 603-095-2740(3). The other AgWQMP area rules establish similar requirements: Malheur (OAR 603-095-0940(5)(a)); Burnt (OAR 603-095-3240); Powder-Brownlee (OAR 603-095-3640(3)(a)). While these AgWQMP area rules protect against activities that will degrade

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not "double-counted." Such an assessment can prove difficult or subjective when a statute establishes a narrative, multi-use mandate, and thermal benefits from a site are measured in quantified units.

[25] For example, forestry operations must follow multiple practices when harvesting trees near streams, and are required to follow several practices regarding road building and maintenance near streams. *See* IDAPA 20.02.01.030.07(e); IDAPA 20.02.01.040 (2015).

riparian vegetation in SRSP project sites, they do not establish any affirmative restoration obligations on those project sites. Rather, these passive, non-disturbance regulations only require that land be left alone so that vegetation can be established, and are not affirmative riparian restoration obligations.

Depending on a property's location within the SRSP program area, it may be subject to a county or city comprehensive plan, zoning ordinances, subdivision ordinances or other local code requirements. Baseline requirements at the county and city level may therefore vary depending on location, land use type, applicable overlay districts (if any) and the type of BMP employed to generate thermal benefits. Similar to Idaho, Oregon county and city regulations in the SRSP program currently do not affirmatively require riparian restoration work. These local conditions applicable to a site will be documented as part of project eligibility (see Attachment 1).

Like the applicable state and local regulations, the SR-HC TMDL does not create any affirmative obligations to undertake riparian restoration actions on SRSP project sites. The SR-HC TMDL endorses "trades" between nonpoint sources, including those "between a watershed-based agricultural BMP implementation project and the Idaho Power Company." (SR-HC TMDL, at 25-26). In a trading context, regulatory baseline obligations may be derived from TMDL load allocations.[26] In the SR-HC TMDL, affirmative obligations to restore instream or on-land habitat would be derived from implementation plans issued by "designated management agencies," or DMAs (SR-HC TMDL, at 502-512). As noted in the overarching TMDL Water Quality Management Plan (WQMP) for the SR-HC TMDL, those DMAs relevant to riparian revegetation on private lands in the SRSP program area include IPC,[27] the State of Oregon (Departments of Agriculture, Environmental Quality and Forestry), and several cities and counties. Relevant to riparian restoration, the TMDL assumes that Oregon will rely on the AgWQMP area rules and local land use regulations to implement the TMDL (SR-HC TMDL, at 508-511). The SR-HC TMDL "implementation plans" created by these DMAs incorporate existing regulatory mechanisms—none of which require or impose any affirmative implementation requirements for nonpoint sources. Because none of these DMA implementation plans establish affirmative restoration obligations, IPC's "DMA implementation plan" is the 401 certification derived from its SR-HC TMDL load allocation. This is consistent with the SR-HC TMDL's expectations for IPC: "Specific compliance parameters for meeting [IPC's] load allocation will be defined as part of the 401 Certification process." (SR-HC TMDL, at 469).

Project sites within the SRSP program area must comply with the current laws and regulations, and affirmative obligations arising under a TMDL, described in the above paragraphs – but none of those laws, regulations or affirmative obligations require the implementation of the restoration actions proposed in the SRSP. The most conservative interpretation of the current laws, regulations, and regulatory requirements, outlined above, that are applicable to the project sites on which potential SRSP restoration actions are located would require the owner of a project site to cease any activity that is actively degrading the adjacent waterway prior to the crediting of any thermal benefits for IPC's

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[26] For a nonpoint source seller in a watershed under a TMDL, the source's baseline "would be derived from the nonpoint source's [load allocation]." U.S. EPA, Water Quality Trading Toolkit for Permit Writers, 30–31, EPA 833-R-07-004 (Aug. 2007, updated June 2009), *available at* http://www.epa.gov/npdes/pubs/wqtradingtoolkit.pdf.

[27] In identifying responsible participants, the TMDL states that IPC's implementation obligation is to "comply with conditions of Section 401 WQ Certification." (SR-HC TMDL, at 504).

restoration of the project site. Because there are no currently existing affirmative obligations to restore instream or riparian habitat imposed upon nonpoint sources in the SRSP program area, all thermal benefit values calculated for SRSP project sites may be credited toward IPC's cumulative thermal load exceedance.

The baseline obligations applicable to a project site are locked in when that restoration project has been completed and initially verified as consistent with design and implementation restoration quality standards (see Section 2.6.3). The current regulatory requirements may evolve over time if more nonpoint source controls applicable to project sites are promulgated by DMAs, as such, the regulatory baseline determination associated with new sites will need to be reassessed in each five-year regulatory baseline review cycle. Similarly, the obligations stemming from SR-HC TMDL implementation plans may evolve over time. This is consistent with the multi-phase implementation strategy associated with the SR-HC TMDL.[28]

2.5.2.1 Financial Additionality

Thermal benefits used to meet IPC's cumulative thermal load exceedance should be generated from SRSP restoration actions funded by and implemented by, or on behalf of, IPC. Restoration actions that are currently funded by another program, agency, or organization are not considered financially "additional" because they are already occurring. Because these actions would have occurred in the absence of the SRSP, IPC could not track any of these benefits to count as offsets against its cumulative thermal load exceedance (see Section 2.6.4 for more information on registration). Federal, state or local cost-share funds[29] may be used to supplement SRSP restoration actions that are being funded by IPC (e.g., sediment control investments that protect downstream instream restoration actions). However, public conservation funds cannot be used to generate thermal benefits that would count toward meeting IPC's cumulative thermal load exceedance. In the event that public conservation funds are used to supplement a thermal benefit-generating restoration project, it will be IPC's responsibility to demonstrate that no public conservation funds were used to generate thermal benefits.[30]

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[28] "For nonpoint sources, ODEQ and IDEQ also expect that implementation plans be implemented as soon as practicable. ODEQ and IDEQ recognize, however, that it may take some period of time, from several years to several decades, to fully develop and implement effective management practices. ODEQ and IDEQ also recognize that it may take additional time after implementation has been accomplished before the management practices identified in the general Water Quality Management Plan or specific implementation plans become fully effective in reducing and controlling pollution. In addition, ODEQ and IDEQ recognize that technology for controlling nonpoint source pollution is, in many cases, in the development stages and will likely take one or more iterations to develop effective techniques. The adaptive management process for implementation provides the flexibility necessary to identify and evaluate management practices and, accordingly, modify implementation plans to reflect revised or new management practices. It is possible that after application of all reasonable best management practices, some TMDLs or their associated targets and surrogates cannot be achieved as originally established. Nevertheless, it is the expectation of both ODEQ and IDEQ that nonpoint sources make a good faith effort to achieving their respective load allocations in the shortest practicable time." SR-HC TMDL, at 23.

[29] These are funds targeted to support voluntary natural resource protection and/or restoration with a primary purpose of achieving a net ecological benefit through creating, restoring, enhancing, or preserving habitats. Some examples include Farm Bill Conservation Title cost share and easement programs, EPA section 319 grant funds, U.S. Fish and Wildlife Service Partners for Wildlife Program, and state wildlife grants.

[30] One way to make this demonstration is through "proportional accounting." Under this approach, the benefits generated from the project site are subdivided proportionately according to financial contribution. Only the portion completed through IPC funds would be eligible to generate thermal benefits toward offsetting the cumulative thermal load exceedance.

2.5.2.2 Measuring and Accounting for Thermal Benefit from Pre-Project Conditions

At the individual project site level, care will be taken to ensure that pre-existing thermal benefits are incorporated into the pre-project modeling scenario and not registered by IPC and used to meet its cumulative thermal load exceedance. For example, riparian project sites may include some mature trees prior to undertaking restoration work at the project site. The thermal benefits generated from pre-existing vegetation that is more than five meters tall will not be included when thermal benefits from revegetation projects are modeled. In contrast, where pre-existing vegetation is 1) less than five meters tall, and 2) that vegetation needs to be cleared and replanted because it is either A) noxious or not native, or B) is likely to be out-competed by surrounding non-native or noxious vegetation in that part of the project site, IPC will be able to register the thermal benefits generated from restoration actions within the cleared area. Similarly, where an instream island is enhanced, the surface area associated with the existing island will not be counted when calculating thermal benefits—only the increase in surface area attributable to the restoration project will be factored into thermal benefit calculations. If riparian vegetation is planted on instream island enhancements for the purposes of generating thermal benefits from shade, the above approach to existing vegetation will apply. These pre-project conditions will be documented at each project site prior to project implementation and will be included in the project design documents; thermal benefits attributable to the changed condition post-restoration action will be included in the project performance confirmation documents (see Section 2.6.3 and Section 2.6.4).

2.5.3 Characteristics of Thermal Benefits

The thermal benefits generated from SRSP restoration projects may be counted against IPC's cumulative thermal load exceedance once they have been implemented and verified to be consistent with the applicable restoration quality standards (see Section 2.5.1). IPC may count the thermal benefits from a single restoration project in multiple years so long as the restoration action is still functioning that year in accord with performance confirmation audits (see Subsection 2.6.3). The thermal benefits generated from SRSP restoration projects do not need to be discounted on a project site-by-project site basis to account for river and reservoir attenuation, conservatism, or margin of safety, as those factors have already been accounted for in calculating IPC's cumulative thermal load exceedance (see Section 7.1 of the 401 application). Restoration projects will be legally protected from conversion through long-term, renewable property access and protection agreements with participating landowners.

2.5.4 Research Project Implementation

Once fully implemented, the SRSP will likely cover twelve subbasins and include more than 100 properties. Because of the size and scope of the SRSP, research projects are an essential part of program development. Research projects will allow for the extensive collection of pre- and post-project data to inform thermal benefit quantification model development and validation of modeled assumptions. Implementation of research projects will also allow IPC to streamline supply chain and implementation processes for this landscape-scale restoration program, develop more efficient implementation and project site prioritization processes, provide the public with tangible examples of the benefits that can be achieved by the SRSP and get a head start on meeting the thermal benefit benchmarks established in

Section 7.1 of the 401 application. The data collected at research project sites may also provide the empirical evidence necessary to establish and test new methodologies for calculating additional types of thermal benefits that are not currently described in Section 2.3, and will provide the data necessary to update the draft restoration quality standards (Attachment 1). Continued research project implementation may be used to more thoroughly evaluate program feasibility and to inform thermal benefit milestones in advance of FERC licensing. Thermal benefits generated from research phase projects can later be counted against IPC's 401 cumulative thermal load exceedance so long as those projects were implemented consistently with the restoration quality standards in place at the time the project was implemented, and the projects are otherwise consistent with the SRSP ultimately approved by the DEQs in the 401 certification process,

2.5.4.1 Bayha Island Research Project

The Bayha Island Research Project is an instream restoration action that was implemented in 2016-2017 (Figure 21) at Bayha and Wright Islands in the mainstem of the Snake River. In addition to the thermal benefit and habitat objectives that apply to all projects in the SRSP, the primary purpose of restoration at this property is research. It has provided IPC with an opportunity to collect baseline data and as-built data on instream restoration to inform and improve the programmatic implementation of the SRSP relative to feasibility and performance.

The enhancement of Bayha and Wright Islands by 7.5 acres reduced wetted channel width and promoted faster flowing water at deeper depths around the islands. This in turn should both reduce habitat for macrophytes and support the processes and conditions supportive of native species, such as Snake River Physa and mountain whitefish. Total thermal benefits for the Bayha Island Research Project were estimated at 211,000,000 kcal/day (averaged from July-October); As-built calculations of thermal benefits include both surface area from the islands and shade from planted vegetation. The total thermal benefits calculated for Bayha Island Research Project post-implementation are 183,061,107 kcal/day (averaged July 1-October 29). The difference in thermal benefits between estimated and as-built is due to a reduced overall project size. The Bayha Island Research Project will include long-term monitoring and tracking to gauge the ecological and thermal benefits of the project, as would future research projects. Implementation of this research project had the added benefit of requiring full permitting and mobilization logistics in order to move forward. Planning and implementation on Bayha Island has already provided all stakeholders with valuable information related to timelines, equipment, and costs for full program implementation. Additionally, as a research project, this project is utilizing and testing the restoration quality standards, quantitative monitoring protocols, and performance objectives that will be used for the overall SRSP implementation. Based on the data gleaned from this project and others, the draft restoration quality standards, and long-term monitoring and maintenance plans can be refined after 401 certification is received, before full program implementation begins. Revisions will then be scheduled concurrent with the five-year SRSP adaptive management review (see Section 3).

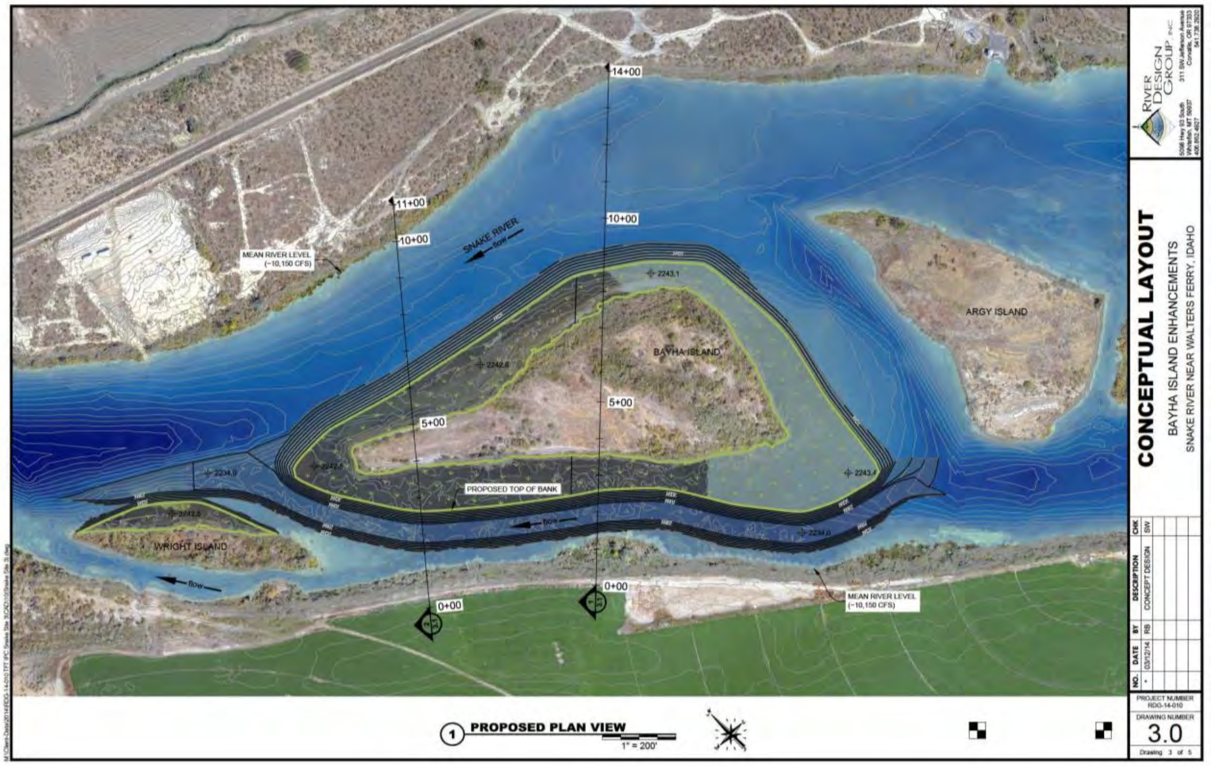

Figure 21: Conceptual design for Bayha Island Research Project, an island enhancement project that was completed as part of research phase implementation in 2017.

2.6 SRSP Stewardship and Tracking

This section describes the actions necessary for long-term stewardship of restoration actions which promotes restoration project trajectory toward achievement of modeled thermal benefits. In order to ensure that the SRSP is on the appropriate trajectory, and continues to be throughout the life of the program, the SRSP should include the following elements: 1) SRSP program year 15 and SRSP program year 30 thermal benefit implementation milestones based on expected recruitment success and feasibility (see Section 2.4); 2) project maintenance of these restoration projects to ensure that they become "established," and a three-tiered programmatic monitoring approach to document progress toward long-term goals (Sections 2.6.1 and 2.6.2, Attachment 1); 3) confirmation of successful project implementation and program performance over time (Section 2.6.3; Attachment 1); and 4) program tracking, with information made publicly available (Section 2.6.4).

2.6.1 Project Maintenance

Because the SRSP will be implemented to meet thermal objectives for 401 certification and FERC licensing, restoration projects must be as effective and durable as alternative technology solutions. Therefore ongoing maintenance of project sites is an integral part of the SRSP, and will occur throughout the life of the SRSP. Maintenance practices ensure that restoration actions for thermal benefits will continue to function for the full term of the 401 certification and FERC license. Specifically, project maintenance ensures that projects reach maturity, stay aligned with ecological performance objectives, and generate the expected thermal benefits. The draft restoration quality standards (Attachment 1) outline potential causes for concern that could trigger maintenance actions necessary to protect project integrity. Attachment 1 also describes how maintenance plans for project sites will be developed as part of the project design process.

2.6.2 Project and Program Monitoring

The thermal benefits modeled for SRSP restoration projects assume that those projects are maintained and successfully function into the future. As such, it is essential to monitor the progress of these projects towards achieving modeled future conditions for thermal benefits and ecological improvements over the duration of the SRSP. To confirm that the program remains on a trajectory toward success, monitoring for the SRSP will follow a three-tiered approach, including: 1) rapid qualitative monitoring on thermal benefit project sites, 2) remote effectiveness monitoring of the SRSP program area, and 3) quantitative confidence monitoring on a sample of project sites. These complementary approaches can be used to meet different monitoring objectives, and when combined will provide the necessary assurances that modeled kilocalorie/day thermal benefits are on track to be produced by the end of the SRSP.

The goal of rapid qualitative monitoring is to quickly ensure that all projects remain in place and are continuing to demonstrate progress toward modeled conditions for achievement of thermal benefits. Qualitative monitoring will be conducted on every project site from project implementation through “establishment,” which is expected to be five to ten years post-implementation for both riparian and instream projects (timeframes may fluctuate within this range depending on action, geography, climate, soil type, etc.). Once projects are established, qualitative monitoring will be used to confirm project trajectory and function over the life of the project (the license term), but the frequency of qualitative monitoring at a project site will be decreased after establishment. Qualitative monitoring will be completed by project managers, maintenance crews, or field technicians who have been trained to collect basic monitoring data using standardized protocols. This data collection will include repeat photo point monitoring at project sites and a rapid, standardized project site assessment “checklist” that is meant to both confirm that the project’s performance is consistent with the quantitative monitoring sample, and to identify maintenance concerns that need to be addressed at individual project sites. The narrative and visually-based questions on the checklist will address the same ecological performance objectives assessed in the quantitative monitoring sample. This checklist will be developed through research project implementation.

All implemented project sites will also be monitored periodically via remote sensing (i.e., LiDAR, satellite imagery, drone flights, etc.). This method of monitoring allows for efficient tracking of projects spread over the broad geographic breadth of the SRSP, and provides a set of digitized images that allows for effective comparison of thermal benefit estimate data against actual conditions (i.e., land area for instream island/bank augmentation, tree height and density for riparian revegetation projects). Remote imaging data will be collected for all project sites in the program at approximately five-year intervals. As on-the-ground qualitative monitoring decreases in frequency after planting establishment, remote sensing will help confirm that projects continue to endure and progress. These data will also help ensure that modeled thermal benefit performance appears consistent with actual project performance over time and can be used to confirm key empirical assumptions related to thermal benefit estimates. This information will also be used to compare produced thermal benefits against modeled thermal benefits at the end of the license term (see Section 2.6.5). As remote monitoring technology becomes more accurate, efficient, and affordable, methodologies will be adapted to support continued improvements in remote monitoring over the life of the SRSP.

In addition to qualitative monitoring and remote sensing, quantitative monitoring will occur on the ground at a geographically relevant sample of project sites. Quantitative confidence monitoring will be used to meet four goals: 1) generate empirical data about how project sites are progressing toward performance objectives known to represent ecological function (e.g., percent canopy cover, percent native woody understory cover for riparian revegetation projects; change in water velocity, change in channel width-to-depth ratios over time for instream augmentation projects); 2) validate thermal benefit modeling assumptions (e.g., the canopy density, tree heights, and change to riparian forest area parameters included in models); 3) serve as an internal quality control check by connecting empirical trends with qualitative monitoring tool questions and options; and 4) improve effectiveness of project implementation and maintenance over time based on the empirical evidence analyzed from these project sites.

To be most effective, quantitative monitoring project sites will be selected from geographic areas that are representative of the projects that have been implemented (i.e., if a large portion of projects are installed in a specific geographic area, a larger proportion of quantitatively monitored project sites may be targeted in that area as well). The total number of quantitative monitoring project sites needed will depend on the mix and type of restoration sites ultimately implemented as part of the SRSP. The quantitative monitoring project site sample size must be representative of the population of implemented projects.[31] This pool of projects will be assembled over time—until the total number of quantitatively monitored project sites in the pool is equal to the target percentage of the total expected site population—so that the effects of different management approaches can be analyzed and understood. Once a project site has been added to the quantitative monitoring pool, it will remain in that pool and will be monitored quantitatively for the remaining life of the SRSP. The monitoring frequency is expected to be high during the project site establishment phase and then reduced once projects have established and change more slowly.

Once collected, all monitoring data will be stored and maintained in a central database. Importantly, the data collected from these three levels of monitoring will be collated and compared so that rapid qualitative monitoring and remote monitoring outcomes can be correlated with relevant quantitative sample monitoring outcomes. This will generate confidence that projects that are monitored

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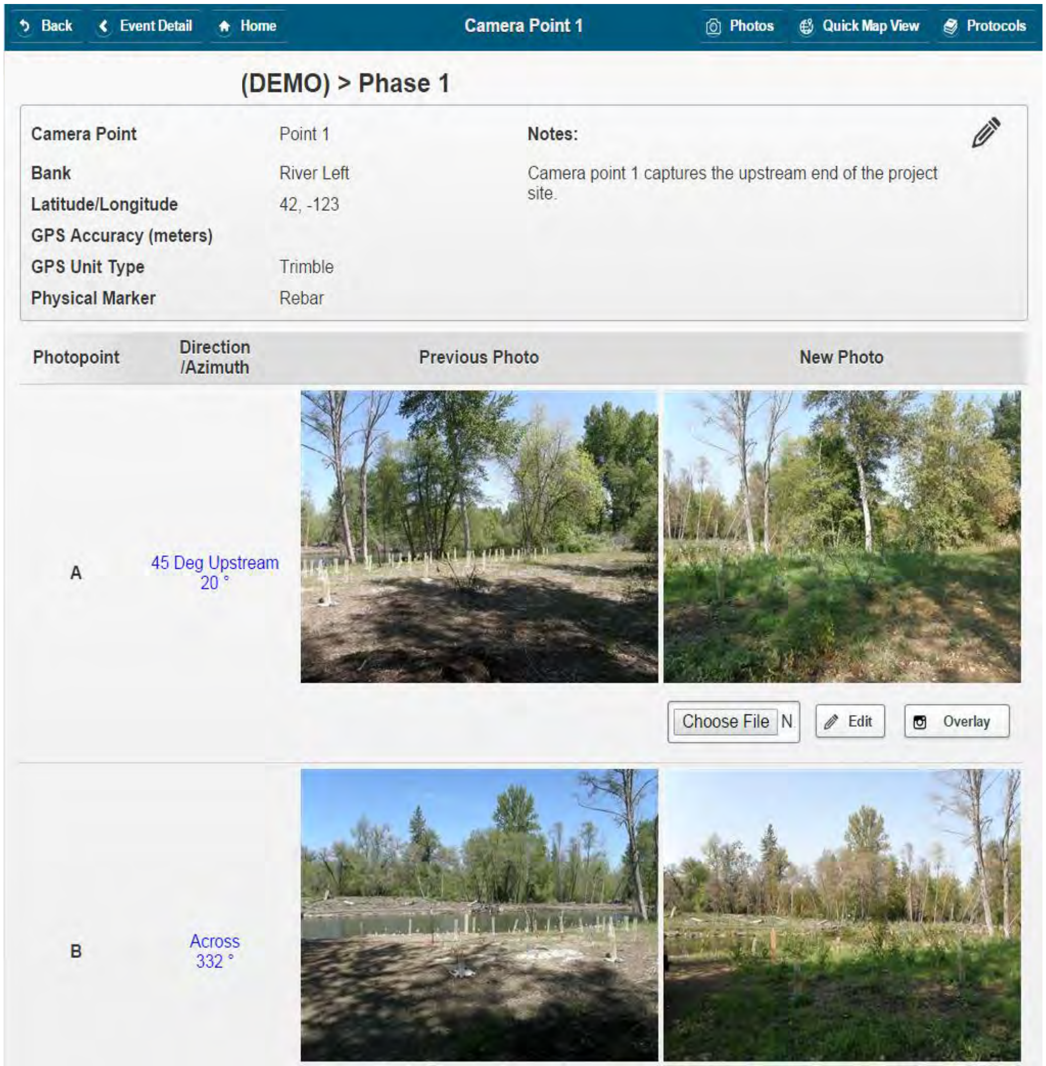
[31] The quantitative monitoring sample size will be a percentage of the total population of project sites likely to be implemented in the SRSP, based on the number of projects of each type anticipated in the SRSP implementation scenario used for feasibility evaluation, as well as considerations related to expected monitoring success, confidence level, and accuracy, The Trust anticipates that approximately 20-25% of the total population of likely implemented instream projects will need to become part of the quantitative monitoring pool by the end of SRSP implementation, and 5-10% of the total population of likely implemented riparian projects will need to become part of the quantitative monitoring pool by the end of SRSP implementation.

qualitatively are also on track to provide expected kilocalorie/day thermal benefits. Each year, IPC will a submit an SRSP summary report that identifies projects implemented to date, the monitoring efforts and results generated from the year, as well as the volume of thermal benefits implemented during the year. In addition, monitoring reports for each implemented project, and the results of the performance confirmations and ongoing audits, will be made available (see Section 2.6.3). Moreover, at adaptive management intervals (see Section 3), IPC will provide progress reports documenting that programmatic assumptions related to thermal benefit estimates are consistent with observations to date (see Section 2.6.3). All of this information will be available through IPC's online tracking and reporting system (see Section 2.6.4).

For each project, an appropriate monitoring plan will be developed. The nature of the monitoring plan will depend on whether the site is being studied qualitatively or quantitatively. Each plan should articulate the collection and analysis techniques that will be used. The Trust recommends streamlining data collection and analysis through the use of a web-based monitoring application. Figures 22 and 23 provide an example of photo points collected through The Trust's StreamBank™ Monitoring iPad application. Through the iPad application, the user can align and compare current photo points to previous photo points, and easily find previously captured monitoring information for the project. By using such an application, new monitoring technicians can consistently take identical photos each year, increasing the robustness of monitoring for the SRSP.

Figure 22: The Trust's StreamBank Monitoring photopoint screen.

This is provided as an example of a streamlined data collection approach that could help to scale the SRSP.



(DEMO) > Phase 1

Camera Point	Point 1
Bank	River Left
Latitude/Longitude	42, -123
GPS Accuracy (meters)	
GPS Unit Type	Trimble
Physical Marker	Rebar

Notes:
Camera point 1 captures the upstream end of the project site.

Photopoint	Direction /Azimuth	Previous Photo	New Photo
A	45 Deg Upstream 20 °		
B	Across 332 °		

Figure 23: An example of photo point monitoring.

Consistency in data collection over multiple years is facilitated by the ability to line up landscape features in previous photos. The data collected using the app is easily exported to reports and/or downloaded to a database for analysis.

Data collection techniques, including the use of technology, will be tested and refined via research projects and in the early phases of the SRSP, and the utility of each approach will continually be evaluated. Quantitative data will be used to refine ecological performance guidelines and goals, and to ensure that tools used in rapid qualitative approaches are aligned with the trends and key criteria identified through the quantitative monitoring sample pool. Research projects will also be used to adapt implementation and management approaches to maximize efficiency and value. It may be necessary to adapt components of the SRSP monitoring plan, including data collection techniques, throughout the life of the program (see Section 3).

2.6.3 Project Performance Confirmation and Ongoing Audits

In addition to the project monitoring described above, it will be important to have independent, external third-party confirmation that project sites are on progress to meet the desired objectives.

Third-party confirmation that thermal benefit-generating projects have been implemented as designed, are still in place after implementation, and are performing consistent with expectations will provide an added layer of confidence for regulators and the public. Independent project performance confirmation should occur throughout the program according to a hybrid audit procedure comprised of two key components: 1) third-party confirmation that every project has been implemented consistent with restoration quality standards (see Attachment 1); and 2) annual randomized project site audits of a percentage of projects by independent third party reviewers to confirm that projects are being maintained, monitored and tracked consistent with restoration quality standards such that they are likely to achieve the modeled thermal benefits at the program's conclusion (see Attachment 1). The project performance confirmation findings will be uploaded to IPC's program tracking tool (see Section 2.6.4).

Once project site implementation consistency with project design as described in the restoration quality standards has been confirmed and made publicly available, IPC will be able to count the thermal benefits generated toward its obligation by "registering" the thermal benefits (this is described in Section 2.6.4, but generally it means that project information will be posted to a public website for the SRSP) and tracking them against the cumulative thermal load exceedance. After passing initial confirmation, all project sites will be entered into an audit pool. Until the fifth year of the SRSP—when a sufficient number of projects will have been implemented and can serve as the basis of the audit pool—one instream and one riparian project site will be randomly audited on-site by a third party to confirm performance of those project sites. Each year after SRSP program year five, a representative sub-sample of instream and riparian project sites[32] will be randomly audited by a third party to confirm performance of those projects.

During these annual audit pool project site visits, the auditor will review: 1) the conditions of the project site as compared to the site design and implementation plan, and thermal benefit estimate inputs for that site; 2) confirm completeness of records for the property and project site; 3) confirm that there have been no changes on the project site and surrounding land use conditions that could materially affect the trajectory of the project; and 4) compare the project's condition against the qualitative and remote sensing data associated with that project site so as to assess the reliability of SRSP quality control.[33] The auditor will then determine whether the project site is or is not materially consistent with

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[32] The audit pool sample size must be representative of the population of implemented project sites. Based on the number of projects of each type anticipated in the SRSP implementation scenario used for feasibility evaluation, as well as considerations related to expected monitoring success, confidence level, and accuracy, The Trust anticipates that approximately 20-25% of instream project sites will need to be audited each year, and 5-10% of riparian project sites will need to be audited each year.

[33] According to the U.S. Government Accounting Office (GAO), the purposes of conducting an audit are to ensure the reliability of information, report deficiencies in internal control, provide an opinion on the effectiveness of internal control, and report any noncompliance with laws and regulations. *See* GAO Financial Audit Manual, Vol 1 §110.02 (2008), *available at* http://www.gao.gov/assets/80/77063.pdf. Because an assessment of an organization's totality of information is generally considered inefficient, it is common for auditors to develop a risk-based sampling plan that carefully selects a subset of information to examine. *See id.,* Glossary p.17; *see also* Int'l Stds. Org. (ISO), ISO 14064-3:2006: Greenhouse Gases – Part 3: specification with guidance for the validation and verification of greenhouse gas assertions §§ A.2.4.3, 2.4.6.1 (2006) ("it is generally inefficient to assess all GHG information collected by the organization or GHG project, therefore a risk-based approach should be used to determine the sampling plan for the collection of adequate evidence to support the expected level

records and deemed as still on track to generate modeled thermal benefits by the end of the program. In other words, the auditor will either "accept" or "reject" a visited project site, and then determine whether a sufficient proportion of the sampled project sites from that year conform.[34] So long as the number of nonconforming project sites is less than the "acceptance" or "materiality" threshold for the audit pool that year—set to 15% of the audit pool population after SRSP program year five[35] —then the

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of assurance…"). Within a given sampling plan, it is important for an auditor to determine which information is significant for the purposes of the audit, and which would not affect or inform the ultimate goal.

[34] "Acceptance sampling" is commonly used in quality control processes. It is an internationally recognized standard. *See* International Standards Organization (ISO), ISO 2859-2, Sampling procedures for inspection by attributes; American National Standards Institute (ANSI), ANSI/ASQ Z1.4.

[35] The GAO's Financial Audit Manual describes "material inconsistencies," also known as "fluctuations," as the difference between the recorded amount and the amount expected by the auditor, based on comparative information as well as the auditor's knowledge of the entity. *See* GAO Financial Audit Manual, Vol 1 §225.03(c) (2008) *available at* http://www.gao.gov/assets/80/77063.pdf. The Manual instructs that is within the auditor's discretion to establish certain parameters to identify whether the fluctuations are sufficiently significant to require further corroboration. These can be expressed either as a percentage or as the absolute size of the inconsistency. *Id*. The American Institute of CPAs (AICPA) allows for auditors to use their best professional judgement when assessing a sampling risk. AICPA Statement of Auditing Standards, § 350.12 *available at* http://www.aicpa.org/Research/Standards/AuditAttest/DownloadableDocuments/AU-00350.pdf.

Ecosystem service credit market audit systems draw heavily from greenhouse gas (GHG) trading protocols. Audit concepts come into play during project implementation confirmation and performance confirmation, where the concept of "materiality" or "acceptance" thresholds are crucial in order to determine the significance of any potential inconsistencies between the reporting about credit generating activity, and actual implementation or performance. Because ecosystem service programs vary so much, no uniform materiality thresholds have been established. For example, the ISO defined "materiality" in its GHG validation and verification standard as the: "concept that individual or the aggregation of errors, omissions and misrepresentations could affect the greenhouse gas assertion and could influence the intended users' decisions." ISO, ISO 14064-3:2006, §§ 2.29, 2.30 (2006). In terms of defining how an auditor can assess materiality, this ISO standard states: "In order to ensure consistency and avoid unanticipated discrimination, some GHG program[s] … assist this decision-making process by including materiality thresholds." *Id.* § A.2.3.8. The GAO Audit Manual uses an example to illustrate how such a materiality threshold may be structured: "[a]ll fluctuations in excess of $10 million and/or 15 percent of the expectation or other unusual fluctuation (such as debit amount in an account having normal credit balances) will be considered significant." GAO Financial Audit Manual, Vol 1 §225.03(c) (2008). Similarly, the California GHG cap and trade system defines material error (as the basis for initially invalidating an ARB offset credit) in the following way: "ARB may determine that an ARB offset credit is invalid for the following reasons: The Offset Project Data Report contains errors that overstate the amount of GHG reductions or GHG removal enhancements by more than [5%.]"California's Requirements of Offset Verification Services, 17 Cal. Code of Regs. § 95985(c)(1). In addition to these examples, the Willamette Partnership states that a developer's credit estimate must be within 15% of the value calculated by the verifier. Willamette Partnership Ecosystem Credit Accounting System, General Crediting Protocol Version 2.0, at 27 (2013), *available at* http://willamettepartnership.org/wp-content/uploads/2014/06/General-Crediting-Protocol-v2.0_2013-11-01_Final.pdf. This figure takes into account the "inherent uncertainty involved in field data collection and variation stemming from sampling and calculation differences." *Id.*

As part of an audit analysis, ISO requires that auditors develop a "sampling plan" that take into account the level of assurance agreed with the client, the verification scope and criteria, the amount or type of evidence necessary to achieve the agreed level of assurance, the methodologies for determining representative samples, as well as any potential risks of error. *See* ISO, ISO 14064-3:2006, § 4.4; ISO, ISO 2859-2, Sampling procedures for inspection by attributes. When developing a sampling plan, the verifier should consider the "the nature, scale and complexity of the validation or verification activity to be undertaken on the client's behalf, confidence in the responsible party's [credit] information and assertion, [the] completeness of the responsible party's GHG information and assertion, and the eligibility of the responsible party to participate in the GHG program[]." *Id*. § 4.4.1. And when undertaking verification activities, it is important to assess the source and magnitude of potential errors, omissions and misrepresentations. *Id.* "The categories of potential errors, omissions and misrepresentations assessed shall be the following: a) the inherent risk of a material discrepancy occurring; b) the risk that the controls of the organization or GHG project will not prevent or detect a material discrepancy; c) the risk that the validator or verifier will not detect any material discrepancy that has not been corrected by the controls of the organization or GHG project." *Id*. The steps to ensure that sampling risk in minimized echo those of the GAO Auditing Standards. US GAO Gov't Auditing Stds., § 6.11 (2011), *available at* program shall be deemed in compliance for that year for the purposes of third party review. If the auditing process identifies material nonconformance at more than 15% of audited project sites, then the inconsistencies must be remedied under the supervision of the DEQs.

2.6.4 Program Tracking and Public Documentation

Monitoring information, and the results of the performance confirmations and ongoing audits will be documented and uploaded to a publicly accessible website so that project site- and program-level success of this geographically diverse program can be tracked over time. This website will act as a registry and house project-specific information, including project design documents, photo points, and project performance information. There are several potential models for hosting this information, including use of a third-party registry, registration on agency website, or a registry/tracking tool hosted by IPC. Figure 24 provides an example of an online tracking system recommended by The Trust for use in the SRSP. This system tracks program goals or thermal benefits as they accrue, and allows viewers to easily compare the modeled thermal benefits with the achieved benefits generated by implemented projects over time. Program progress toward compliance goals can be tracked in other ways, as evidenced by other ecosystem service program tracking tools around the country.[36] While Figure 24 illustrates one possible way to track program progress, the actual platform is not as relevant so long as minimum criteria for such a system are met: 1) individual thermal benefits and transactions are accounted for and can be tracked, 2) program implementation progress can be tracked against thermal benefit milestones set by the 401 certification, and 3) sufficient information is provided related to individual project site trajectory (i.e., site monitoring reports). The exact contours and specifications of an online tracking system will be defined by regulators as part of 401 certification or FERC relicensing.

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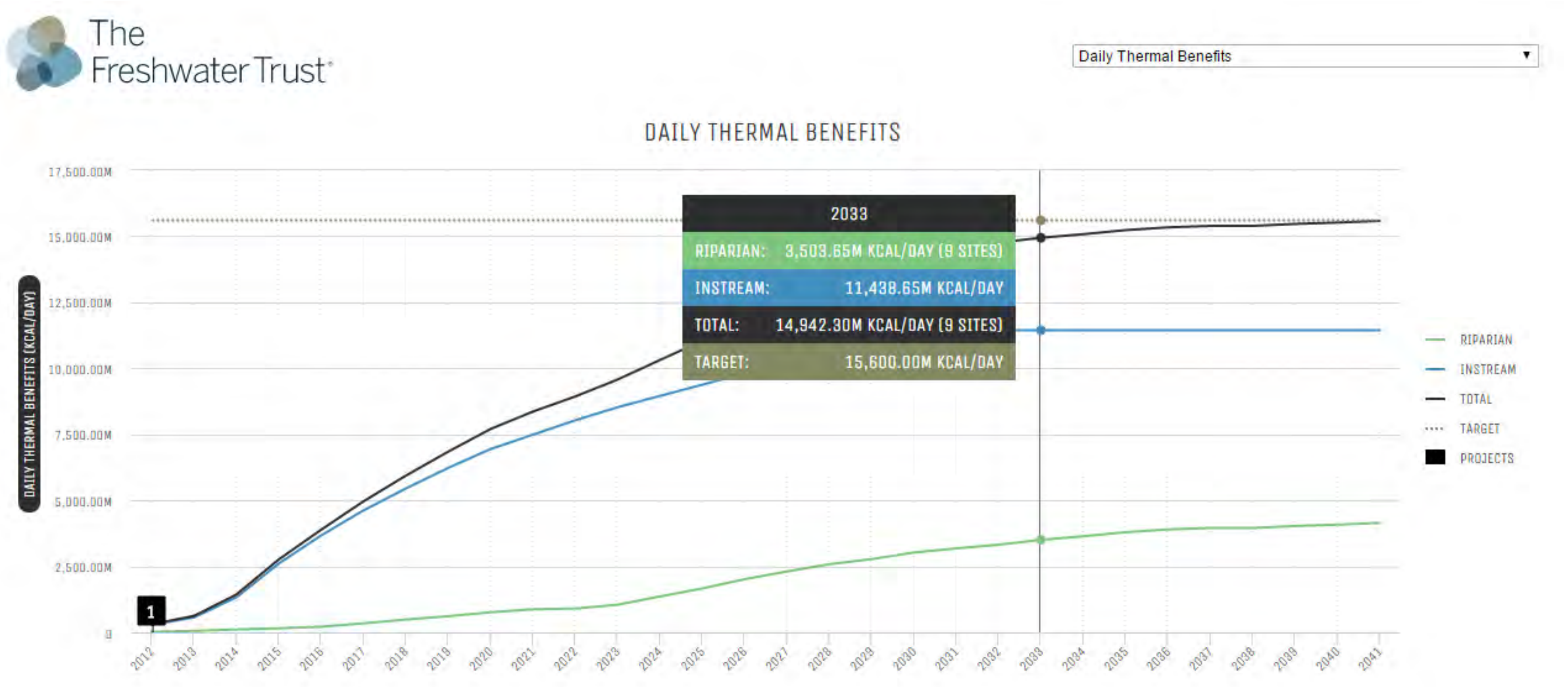
http://www.gao.gov/assets/590/587281.pdf. ISO recommends that, particularly in the GHG context, there be a percentage-based approach to materiality thresholds. *Id.* at § A.2.3.8.

Using the factors laid out in the sampling plan, an auditor or verification organization has the discretion to determine what, if any, threshold is appropriate to assess the audit risk of inconsistent information. IPC will use a 15% programmatic materiality, or acceptance, threshold for each annual audit. This programmatic approach aligns with ISO standards, which focus on acceptance sampling. ISO, ISO 14064-3:2006, §§ 2.29, 2.30; ISO 2859-2. This audit will rely on the auditor's best professional judgment. *See* AICPA Statement of Auditing Standards, § 350.12. In combination, the robust restoration quality standards for design, implementation, monitoring and performance tracking, the three-tier monitoring approach (see Section 2.6.2), and the transparent reporting and tracking mechanism, minimize the risk that a material discrepancy will occur, that IPC's internal controls will not prevent or detect the error, and that that the auditor will not discover any errors that IPC has not already discovered. *See* ISO 14064-3:2006, § 4.4.1. Moreover, in such a geographically dispersed program, there will be inherent uncertainty involved in field data collection and variation stemming from sampling and calculation differences. *See* Willamette Partnership, General Crediting Protocol Version 2.0, at 27. Because of these overlapping safeguards, and in recognition of the broad program area, a 15% materiality threshold is appropriate for the SRSP.

[36] Environmental credit trading programs have used several approaches to track program progress, MarkIt, an environmental credit registry, is one such portal for project information. The Electric Power Research Institute (EPRI) tracks the Ohio River Basin Nutrient Trading Program through Markit (https://mer.markit.com/br-reg/public/orb/index.jsp?s=cp), as does The City of Medford with its temperature compliance program run by The Trust (https://products.markit.com/br-reg/public/index.jsp?entity=holding&name=&standardId=&unitClass=&sort=account_name&dir=ASC&start=450). The California Air Resources Board (CARB) uses a password-protected market tracking system called Compliance Instrument Tracking System Service (CITSS) to track and manage GHG credits (http://www.arb.ca.gov/cc/capandtrade/markettrackingsystem/markettrackingsystem.htm). SOx and NOx trades completed pursuant the federal Clean Air Act must be registered in an EPA-managed database that serializes credits. EPA, Air Markets Program Data, http://ampd.epa.gov/ampd/.



Daily Thermal Benefits

2033

RIPARIAN: 3,503.65M KCAL/DAY (9 SITES)
INSTREAM: 11,438.65M KCAL/DAY
TOTAL: 14,942.30M KCAL/DAY (9 SITES)
TARGET: 15,600.00M KCAL/DAY

Figure 24: Online tracking system for thermal benefits.

The thermal benefit goal or “target” is shown in light green dotted line at the top of the graph. Modeled thermal benefits from a scenario of proposed projects modeled to be implemented over time (in the example from 2012 through 2041) can be seen in total in the dark black line that gradually increases. The thermal benefits that will accrue from instream projects are modeled in blue; benefits from riparian projects are modeled in green. As projects are actually implemented, confirmed and registered thermal benefits will be shown in comparison to the modeled thermal benefits. The black “project” box allows users to quickly see the number of projects that were implemented in a given year. Project boxes will be clickable and link to a short summary of each project completed in a year. The call out box makes is easy to see the all of the program tracking statistics in a given year.

2.6.5 Thermal Benefit Production Compliance Milestone

In addition to the thermal benefit implementation compliance milestones described in Section 2.4.4 at the end of the next FERC license term, IPC will empirically confirm that the programmatic assumptions related to thermal benefit estimates are still valid, within some reasonable margin that will be identified later in the program. To do this, IPC will check total program achievement of implemented thermal benefits against modeled thermal benefits using remote sensing information at the program's conclusion, at the end of the license term. For the instream project sites, this will require confirmation that the overall thermal benefit-generating surface area is materially the same as original surface area upon which thermal benefit estimates were derived (i.e., avulsion and accretion can occur so long as the overall net surface area increase stays materially the same). For riparian revegetation project sites, this will require confirmation that the density and height characteristics of implemented project sites are, on average, are materially the same as original density and tree height assumptions upon which thermal benefit estimates were derived (i.e., individual project sites are likely to have density and height profiles that vary from modeled assumptions so long as on average, the overall program averages ends up consistent with initial modeled conditions). IPC will also report on programmatic thermal benefit production progress at adaptive management intervals (see Attachment 1).

2.7 Watershed Improvement

In addition to creating thermal benefits for the purposes of compliance, the cumulative effects of the SRSP are also expected to help: 1) restore natural ecological processes and dynamism to a section of the Snake River and its tributaries, 2) meet ecological objectives identified in the region (i.e., increase riparian shade, increase flow velocity, decrease temperature and aquatic macrophyte proliferation, voluntarily decrease sediment loading, and provide more cold-water and riparian habitat), and 3) disrupt the current cycle of environmental impairment in the Snake River. 401 compliance with the SRSP will be evaluated based on creation and retention of a sufficient volume of eligible, functioning and stewarded thermal benefits at key milestone points.

2.7.1 Grand View Sediment Reduction Program

Sediment caused by the erosion of Idaho's croplands is the greatest nonpoint source pollutant to Idaho's surface waters (Mahler et al. 2003). Erosion of fine sediments from cropland and deposition of these sediments in the Snake River is a root cause of degradation of the Snake River. Observations in the reach of the Snake River between CJ Strike and the town of Homedale show that agricultural return drains are a substantial source of sediment inputs to the Snake River. Drain data collected by IPC show spikes in sediment inputs in two distinct locations in the program area: downstream of CJ Strike Dam near river mile 480 and downstream of the town of Marsing near river mile 420 (Figure 25). Both of these areas are dominated by furrow-irrigated agriculture, a type of surface irrigation that is known to cause high amounts of topsoil erosion. Approximately 50% of agriculture in the Mid Snake-Succor Creek watershed is furrow-irrigated (ISCC and IASCD 2005).

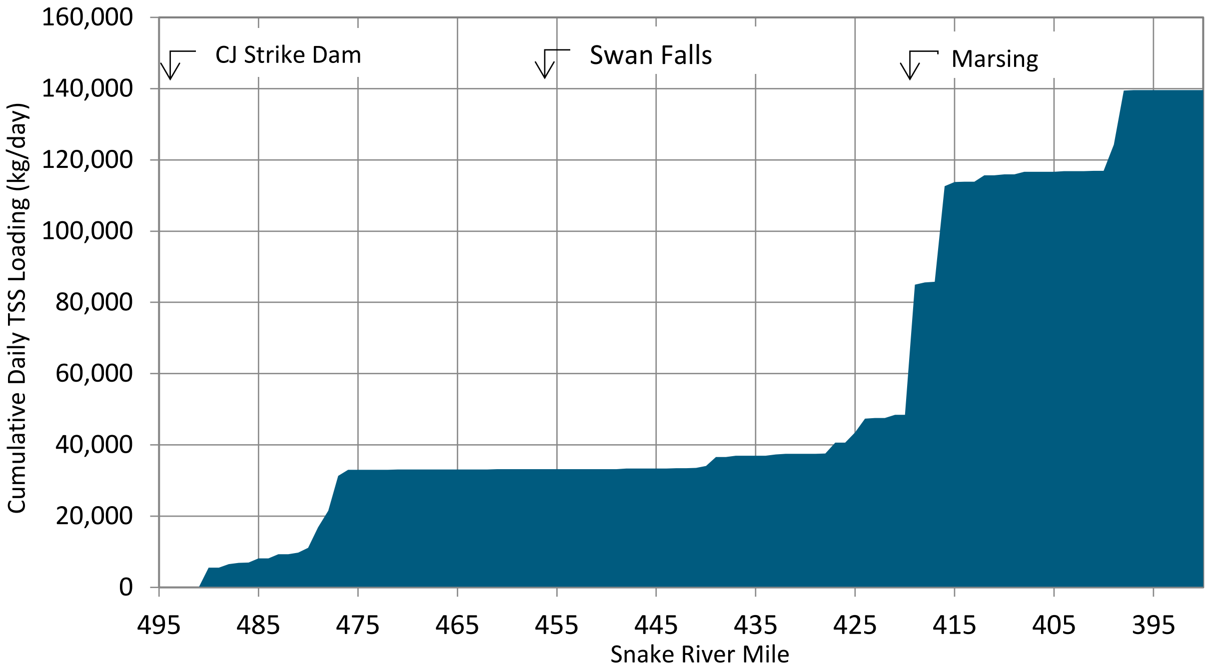


Figure 25: Cumulative Total Suspended Solids (TSS) Loading for Snake River Miles 495 to 390.

Large inputs of sediment are found just downstream of CJ Strike Dam near river mile 480, then again downstream of the town of Marsing near river mile 420. Data are from Idaho Power Company sampling in 1995 and 2013.

Sediment deposition in Snake River substrate prevents oxygen exchange between the water column and the interstitial substrate environment, provides a medium for macrophyte establishment, and reduces hyporheic exchange (Groves and Chandler 2005). Cropland erosion also results in phosphorus loading in the Snake River. Each ton of sediment eroding from Idaho's cropland carries associated phosphorus (Section 7.2 of the 401 application fully describes this ratio). Finally, channel aggradation in the Snake River is exacerbated by fine sediment runoff.

In order to create reasonable assurances for meeting dissolved oxygen requirements under the SR-HC TMDL, IPC is s working with voluntary landowners to upgrade irrigation systems to reduce agricultural runoff to the Snake River. These projects will have the additional benefit of helping to support the SRSP instream restoration work. As described in the 401 application Section 7.2.1.2.1, sediment reduction will be targeted between CJ Strike Dam and Swan Falls. Reductions in this river reach will benefit all SRSP instream restoration projects downstream by reducing sedimentation and supporting the longevity of instream project work. IPC will work to reduce sediment and phosphorus levels in agricultural drains discharging to the Snake River between CJ Strike Dam and Swan Falls Reservoir. While work is valuable to watershed improvements being proposed in the SRSP, but is not being proposed to generate thermal benefits. Since 2015, fourteen irrigation upgrade projects have been completed.

3 Adaptive Management of the SRSP

IPC is proposing to implement the SRSP in order to achieve 401 certification compliance and meet the cumulative thermal load exceedance for the HCC. IPC recognizes the importance of long-term maintenance and monitoring of projects in order to ensure overall SRSP, specific project success and ecological improvement in program areas. The three-tiered monitoring approach described in Section 2.6.2 will allow for programmatic tracking and evaluation of progress toward thermal benefit creation and achievement of programmatic goals. The multi-decadal timeframe of the anticipated 401 certification and FERC license necessitates the ability to adapt implementation, maintenance, monitoring, and performance tracking practices to reflect new knowledge and information as it emerges. As technologies, land management, production, and monitoring practices evolve, it is expected that more efficient approaches or better knowledge about sources and methods to achieve program goals will also develop.

3.1 Elements of Effective Adaptive Management in Practice

Adaptive management at the program scale is recommended as an essential part of IPC's SRSP proposal for thermal compliance. Implementation and evaluation of the SRSP will follow the adaptive management approach outlined in Figure 26.

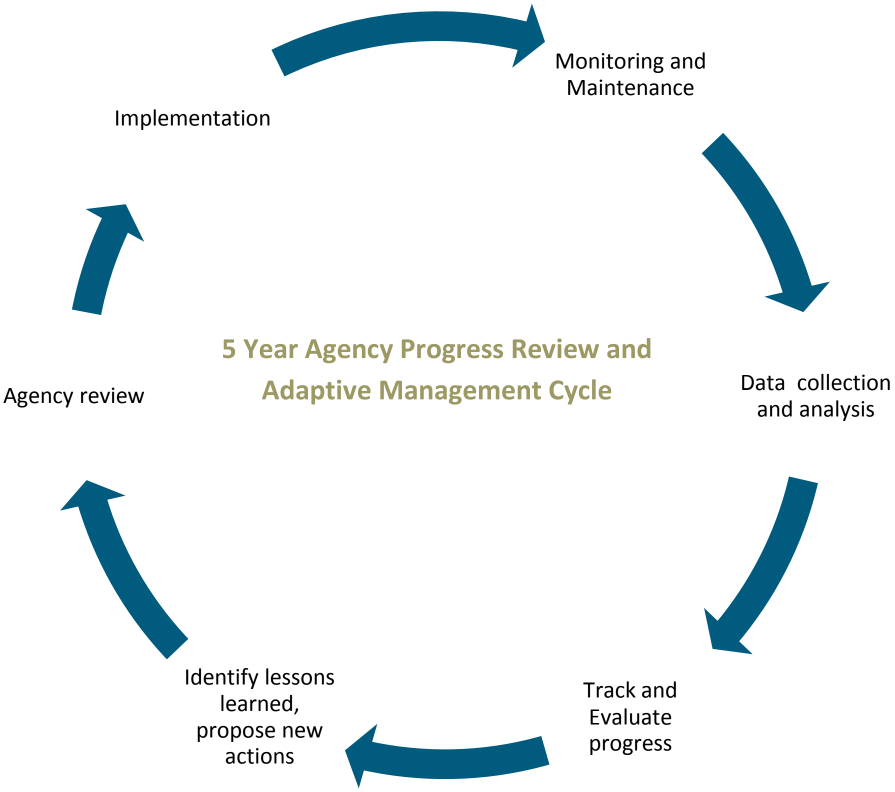


Figure 26: Adaptive management for program implementation.

For each adaptive management cycle, IPC and the DEQs should pursue an adaptive management approach that considers and incorporates: 1) pre-implementation data collection, which is essential in gauging the impacts of program implementation; and 2) monitoring and maintenance data. Data will be collected through the tracking approaches described in Section 2.6. Progress toward milestones outlined in the 401 application will be evaluated using the appropriate model to quantify thermal benefits. Monitoring data will be used to confirm the inputs used in modeled uplift estimates of thermal benefits. Every five years, program implementation and monitoring data should be evaluated and summarized in aggregate (to complement the project monitoring reports that have been uploaded to IPC's tracking website). At this time, new restoration actions, recommended changes to restoration quality standards, monitoring, and maintenance protocols, etc. may be considered, and discussed with the agencies. The adaptive management cycle should repeat for the next five years of the SRSP.

Adaptive management involves agency review of the SRSP every five years. A five-year review cycle provides a regular opportunity to review available data from the previous years of implementation, maintenance, and monitoring, and to incorporate new technologies and lessons learned through previous implementation cycles into restoration quality standards, as well as monitoring, maintenance, and performance tracking protocols. Periodic agency review also affords transparency and quality control. A review period of five years is recommended to allow enough time to properly evaluate: 1) progress toward overall programmatic goals, as well as 2) the effectiveness of maintenance approaches and monitoring protocols. Data on restoration projects, while limited, also suggests that there is the potential for substantial time lag in measuring the ecological effectiveness of watershed restoration, and so a five-year window provides more flexibility to appropriately collect and analyze these data.

Periodic agency review of implementation and performance progress will also allow for course correction with respect to the ongoing implementation milestones and obligations suggested in Section 2.4.4, should any be needed. For example, if the thermal benefit implementation milestones described in Section 2.4.4 are at risk or are not being met because a force majeure event occurs (i.e., prolonged drought, fire, pest), the agencies and IPC will be able to adjust these milestones accordingly, and identify the appropriate corrective action(s) (i.e., develop a new a strategy to meet thermal benefit milestones, choose to pursue a technological solution for thermal compliance, or some combination). This review cycle will also allow for updates to the regulatory baseline determinations associated with the SRSP.

3.2 Five-Year Report Elements

Consistent reporting for five year review cycles will allow for comparison of data between reports providing a reference and benchmark for IPC, the regulators, and the public. Some key elements include:

- Summary of data analysis, thermal benefit implementation progress, and program effectiveness during the five-year review period.
- Identification of any data gaps, program inefficiencies or challenges.
- Updates to restoration quality standards, including new eligible restoration actions, and proposals to quantify additional thermal benefits from riparian or instream projects and information on new models and any new proposed restoration actions.
- Estimates of current trajectory of thermal benefits to achieve modeled conditions.
- Updates to the regulatory baseline determination for the SRSP.

4 Conclusion

Through the implementation of a restoration program for thermal benefits, the SRSP represents a significant opportunity to not only improve riverine thermal regimes above, within and below the HCC, but also improve the currently impaired ecological processes in the Snake River and its tributaries. The riparian areas on the mainstem Snake River and along its tributaries fail to sufficiently retain sediments and phosphorus or to provide adequate shade. Moreover, the normative river processes of scour and deposition are nonfunctioning, and hyporheic flows are disrupted. Conditions in the Snake River, upstream from the HCC, reflect an altered ecological state—a state that lacks vertical complexity, contains high concentrations of sediment and phosphorus, has high temperatures, and is host to excessive macrophytes. In the tributaries of the Snake River, a history of flow and flood regulation and agricultural expansion necessitates riparian revegetation and flow augmentation to promote a functioning ecosystem. The proposed instream restoration projects, revegetation of riparian areas, and flow augmentation in mainstem tributaries described in the SRSP will help to break the impaired cycle and facilitate the restoration of dynamic processes to the reach (Figure 27).

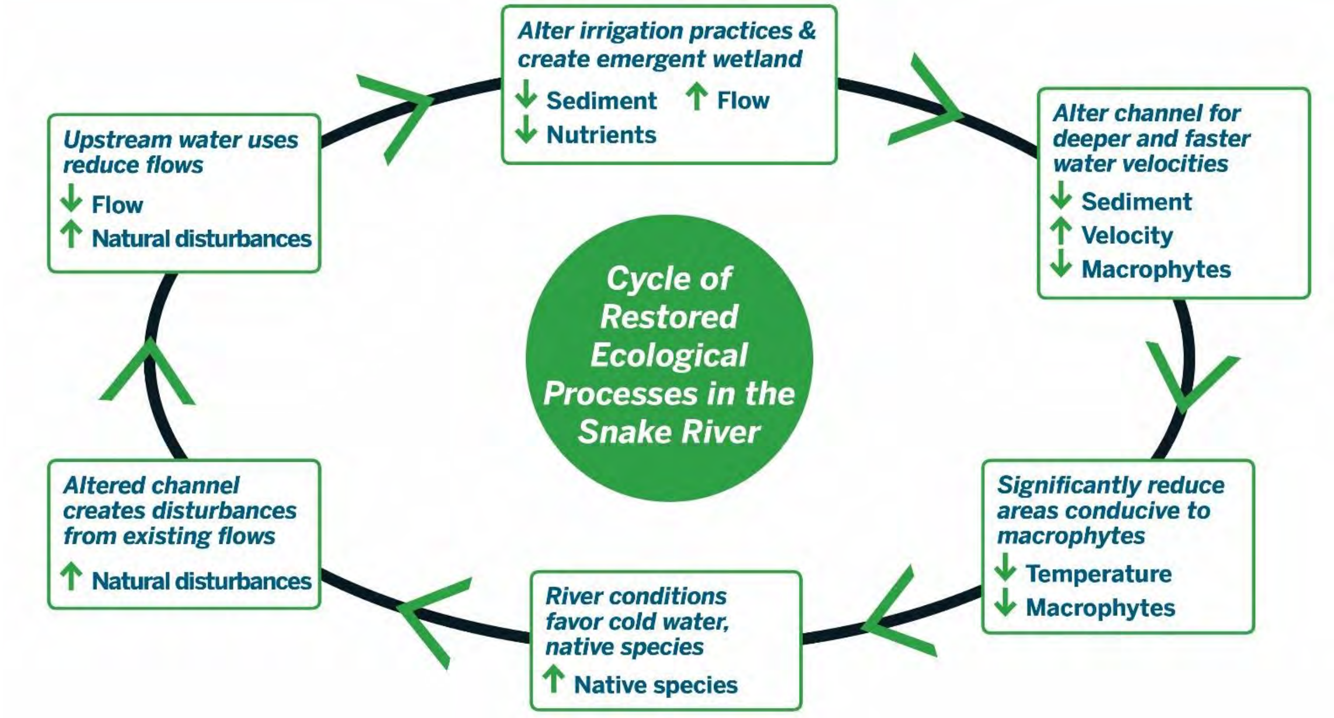


Figure 27: Cycle of Restored Ecological Processes in the Snake River.

The SRSP will be implemented according to restoration quality standards ensuring that projects will be maintained over time, and monitored and maintained as needed to achieve restoration goals. The draft restoration quality standards for program implementation in Attachment 1 will enable IPC to meet objectives for quality, transparency, and credibility. The thermal benefits of instream island enhancement, island creation, inset floodplains, and emergent wetland establishment combined with proposed riparian, and potentially flow, restoration of the Snake River and its tributaries are quantifiable according to a proven set of methodologies and show substantial benefit to the entire ecosystem. The kilocalories per day benefits from these actions can be calculated and compared to IPCs cumulative thermal exceedance at the outflow of the HCC. Maintenance and monitoring of these actions will occur post-implementation on an ongoing basis, assuring continued thermal and environmental benefits for the life of the HCC FERC license. Reporting and tracking of thermal benefits generated through restoration actions will provide transparency and accountability for IPC. By facilitating ecological disturbances and minimizing anthropogenic impacts in the Middle Snake River and tributaries, stream processes can be restored, encouraging a more ecologically resilient ecosystem.

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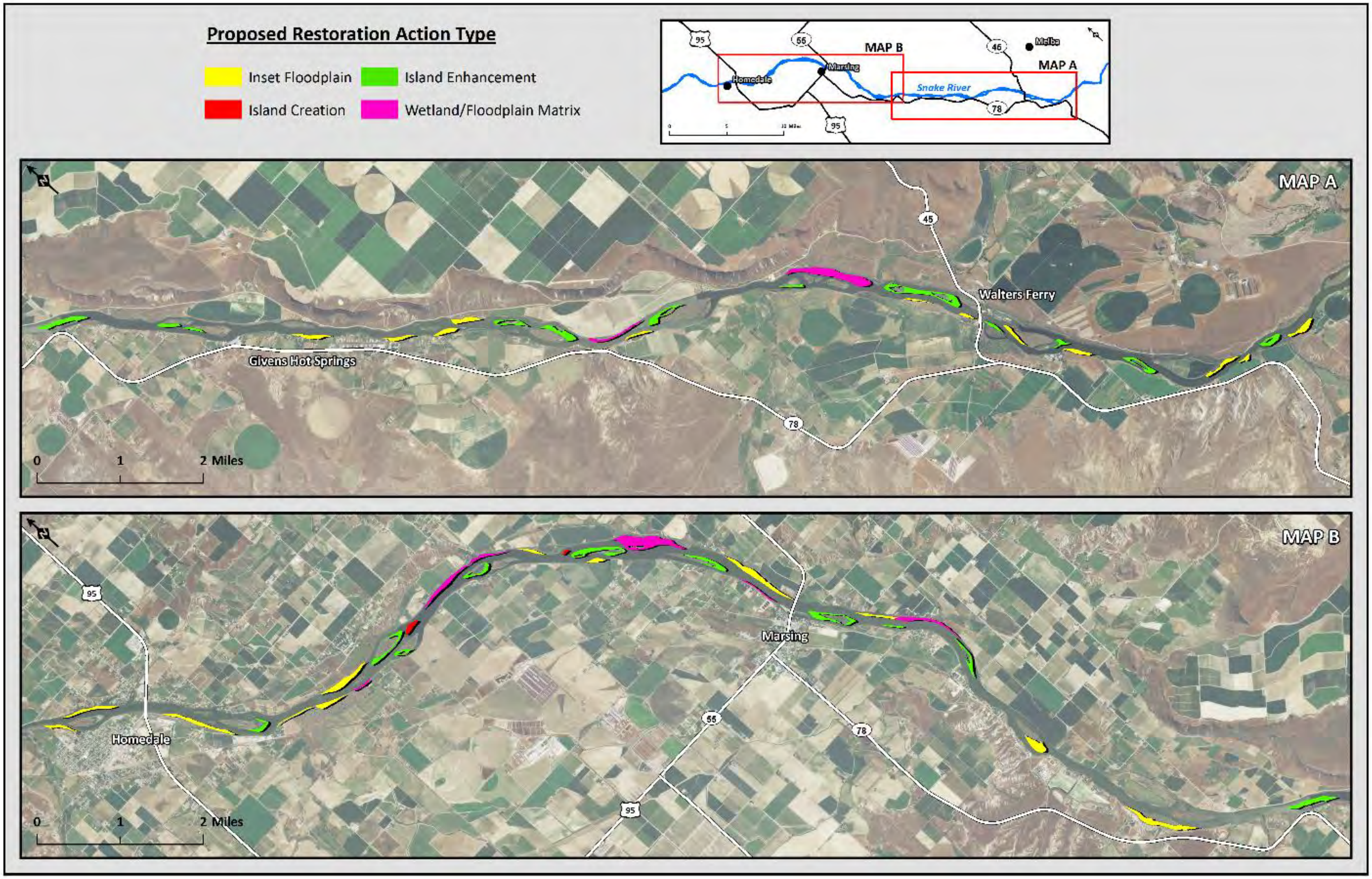

Figure 20: Full sized map of 55 projects and proposed project reach for instream restoration.

EXHIBIT 7.1-5, ATTACHMENT 1: DRAFT RESTORATION QUALITY STANDARDS

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Introduction

During the Snake River Stewardship Program (SRSP) research phase, Idaho Power Company (IPC) will confirm eligibility, design, implement, monitor, and maintain project sites, and report site performance consistent with the draft restoration quality standards outlined in this attachment. Restoration quality standards are developed to promote high quality projects likely to produce modeled thermal benefits with consistent design and implementation across the wide geographic area of the SRSP and allow for standardized thermal benefit model calibration and usage. They are also developed to promote an independently functioning ecosystem. Except where a minimum threshold or timeline is specifically noted, draft restoration quality standard restoration quality standards only require the completion of an action. For some draft restoration quality standards, IPC has developed internal guidelines for how standards may be most effectively met based on best available practices and expertise. This SRSP Program Manual provides guidance based on this experience, but the practice details are not incorporated directly into the draft quality standards presented here. These restoration quality standards will remain in draft form during the SRSP research phase, at which point they may be updated to reflect lessons learned during the research phase. After the initiation of IPC's renewed FERC license, the quality standards will hold steady for the remainder of the license term, though updates may occur through the 5-year adaptive management cycle detailed in section 3.1 of the SRSP.

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I. Instream Restoration Quality Standards

A. PROJECT SITE ELIGIBILITY

A number of steps must be taken to ensure that a project site is eligible for the SRSP. These required steps are noted in Table 1. These steps help to maintain transparency and consistency throughout the program. Additional guidelines related to fulfilling these eligibility requirements are described in IPC's SRSP Program Manual.

Table 1: Project eligibility requirements for instream project sites.

	Eligibility Standard	Rationale	Documentation Required for Initial Confirmation or Audit
A	Project is located within the Snake River Stewardship Program area.[1]	To ensure temperature benefits appropriately contribute to improved conditions in the Hells Canyon Complex (HCC), projects must be implemented within the designated program area.	• Map of SRSP program area with site location noted on map, and showing that site is not above a major impoundment on that waterbody (if above such an impoundment, will require DEQ approval, and likely a different attenuation ratio).
B	Project is consistent with regulatory baseline requirements, and compatible with current local land use requirements.	Thermal benefits from projects can be claimed if the action generating those benefits is not already required by federal, state, tribal or local sources of law. In addition, projects in the SRSP program area must be implemented consistent with any applicable county or city comprehensive plan, zoning ordinances, subdivision ordinances or other local code requirements to ensure full regulatory baseline fulfillment.	• Regulatory baseline analysis from SRSP section 2.5.2 applied to the project site (at the time of SRSP drafting, no regulatory baseline obligations apply to instream projects).
C	Project will produce thermal benefits through reduced thermal loading to the adjacent water course from reduced water surface area and/or increased evapotranspiration and percolation.	Reduced instream surface area and/or increased evapotranspiration and percolation. Projects currently have accepted calculation methodologies as described in the SRSP, and so project types are limited to these actions at this point in time. At the eligibility stage, it is important to confirm that a potential project site	• Documentation showing the potential to generate thermal benefits (e.g., existing river channel that can be filled in to minimize solar loading); and • Documentation showing that topographical shade (SRSP 2.4.2) does not

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[1] Thermal benefits must be generated within the SRSP area, which includes the Snake River from below Swan Falls Dam and upstream of the Hells Canyon Dam as well as its tributaries. Twelve tributaries are included in the SRSP: Boise River, Brownlee Reservoir creeks, Burnt River, Malheur River, Middle Snake-Payette River, Owyhee River, Payette River, Pine Creek, Powder River, Succor Creek, and Weiser River. Thermal benefits for riparian areas were assumed only for sections of the river that were below any reservoir or substantial impoundment on these rivers. If projects are to be installed above such a barrier, additional attenuation factors will be required to establish the thermal benefit value.

		will be able to generate thermal benefits (e.g., by ensuring that the site is not already exposed to topographically created shade).	reduce available thermal benefits to the extent that project is no longer viable.[2]
D	Planning in place to secure long-term project site access and protection, and project site management plan is being drafted to support desired future conditions.	Long-term access for maintenance and monitoring is essential for achieving project objectives.	• Draft landowner agreement; and • Draft project site management plan.
E	Participant landowner/manager is not knowingly causing harm to adjacent waterway through operations on that contiguous property.	If a landowner/manager is using property in a way that does not comply with other laws and regulations, it may pose a risk to documented thermal benefits and continued project site viability. If, for example, a state or local enforcement action is undertaken, it may result in a legal dispute, affect access to the land, and/or affect property ownership status. The goal of this requirement is to evaluate compliance with applicable laws and regulations, not to undertake an in-depth review of operations on the property.	• Current land use and identification of potential conflicts will be described in documentation of instream project site eligibility and suitability.
F	Contemplated project will result in an additional and improved state from previous management on the project site. Site should not have experienced intentional, unlawful degradation in the 5 years immediately preceding implementation of an SRSP project.	The purpose of this requirement is to avoid situations of deliberate degradation to generate thermal benefits and receive incentive payments at a project site, and promotes additionality as compared to historic practices.	• Review aerial imagery of project site within last 5 years to confirm that pre-existing ecosystem has not been deliberately destroyed in effort to have it restored under SRSP and receive payments. Document in instream eligibility and suitability analysis.

B. PROJECT SITE DESIGN

After evaluating the eligibility of an instream restoration project for the selected project site, project design can begin. The required components of a project design document are outlined in Table 2. Additional guidelines related to fulfilling these project design requirements are described in IPC's SRSP Program Manual.

Table 2: Project design quality standards for instream project sites.

	Project Site Design Standard	Rationale	Documentation Required

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[2] For example, a slope of greater than 30 degrees over the entire planting area would be a likely impediment to implementation, so this criterion should be used to exclude areas using remotely sensed data. Identifying areas with topographic shade issues is a more involved process. When the primary data source is aerial photography (which is typically flown during the late spring or summer under clear skies around mid-day), visible topographic shadows are a good indicator that a potential project should be excluded from riparian revegetation for thermal benefits. When time of day or year precludes this, steep rises (determined using Google Earth elevation visualization) in elevation immediately to the SW/S/SE of the stream are also viable indicators.

A	Clearly identifiable geographic location of the project site, accompanied by landowner contact information.	Must be documented to ensure project is in eligible area.	• Project site location and landowner contact information collected.
B	Project design map completed, showing proximity of project to waterbody, key attributes of project site, and clear delineations of project boundaries.	This information is necessary to delineate the thermal benefit generating area with enough specificity for project managers, auditors and agency staff to understand what initially occurred at a site.	• Map showing delineated project area, key attributes, proximity to waterway (not attached to lease); and • Legal protection agreement that identifies project boundaries.
C	Existing conditions are documented and pre-project data are collected.	Data on pre-project conditions is required to calculate pre-project thermal benefits, and future conditions must be modeled to prove that project is designed to provide additional benefits.	• Description of the reach in which the project is being implemented, the geomorphic context, river sediment sampling results, wetlands, fisheries, and conceptual restoration framework.
D	Description of how pre- and post-project site conditions are related to the model assumptions used to calculate thermal benefits at the site	Establishing pre-project conditions is required to calculate thermal benefits. Future conditions must be modeled to prove that project is designed to provide additional thermal benefits.	• Description of how changes expected to result from project restoration as designed will produce modeled thermal benefits (see Section I(D) and Table 9 of this document).
E	Project design documentation completed.	Imperative to set clear expectations about how the selected restoration action is going to be applied in practice at the project site, especially if projects may be implemented in different geographies, with help from different subcontractors, and may be overseen by different staff.	• Drawings of: project site layout, project plan view, project site access and staging, work area isolation, project site erosion control, grading plan, typical section detail, bank treatment details, project site design sections, project site reclamation plan; • Document design flows, design process, substrate sizing for habitat and channel stability; • Description of how change in channel conveyance from project implementation can be completed without adversely affecting local flood regime; and Demonstrate that excavation to design depths is achievable; • Description of appropriate vegetation requirements and specifications.
F	Project designs stamped by professional engineer licensed in Idaho.	A professional engineer with relevant subject matter expertise should be engaged during each project design phase to ensure that the contemplated project will not run into issues.	• Professionally stamped design documents.
G	Vegetation on project sites must be designed to maintain project newly added surface area and minimize erosion. Thermal benefits from shade	Once new surface area has been created through one of the four instream actions, vegetation of that area can help reduce erosion	• Planting plan that includes: plant quantity, species composition and planting layout;

	produced on new surface area may also be claimed by IPC (additional riparian restoration quality standards would apply).	and maintain the integrity of that surface area over time, especially during high flow events. Vegetation may also provide thermal benefits through shade (see Section II of this document if the latter).	• Irrigation plan, if applicable; • Specifications on additional project elements (e.g., fencing, off channel watering, weed treatment, etc.) as needed; and • Description of how vegetation design minimizes erosion and protects newly added surface area. If the vegetation is designed to generate thermal benefits, see Section II of this document for additional design requirements.
H	Describe potential risks associated with the project.	It is important to document the potential risks at a project site prior to implementation. Potential risks from instream projects include, but are not limited to: failure to maintain excavated channel depth due to deposition, loss of constructed features via scour and erosion, sediment deposition reducing habitat suitability for target species, erosion of adjacent bank surfaces, lowering of water surfaces at irrigation pumps, increase in waterfowl predation from terrestrial mammals and avian predators, future climate variability, changes to water management, adjacent land uses, and all risks associated with construction.	• Summary of potential risk factors that may affect project success; and • Description of how design has contemplated and minimized these potential risk factors.
I	Pre-project monitoring is completed, with photographic evidence to substantiate conditions.	Documentation of on-site project conditions prior to implementation is needed to establish assumptions used in pre-project thermal benefit modeling.	• Evidence that pre-project monitoring data has been collected, including photographs.

C. PROJECT SITE IMPLEMENTATION

After screening a project site and then designing and documenting it accordingly, project implementation can begin. The required aspects of implementation are outlined in Table 3. Additional guidelines related to fulfilling these project implementation requirements are described in IPC's SRSP Program Manual.

Table 3: Project implementation requirements.

	Project implementation	Rationale	Documentation Required
A	Legal protection agreement signed by both parties covering the full period of thermal benefits that will be claimed by IPC.	Demonstrates that the restoration project site is going to be legally protected from conversion for the duration of the period for which thermal benefits will be claimed, and that	• Signed landowner agreement (e.g. lease or easement); or Applicable agency permission to install a project for federal and state-managed lands (e.g.,

		IPC will have access to steward the site over that period.	easement from the Idaho Department of Lands).
B	All necessary permits and approvals have been obtained, and work is performed in accordance with those approvals.	Necessary to demonstrate approval to undertake the restoration project.	• List required permits, licenses and approvals obtained(e.g., Army Corps of Engineers authorization).
C	As-built project monitoring is completed.	Documentation of on-site project conditions after implementation is needed to establish assumptions used in post-project thermal benefit modeling.	• Post-implementation reports.
D	Future conditions have been estimated based on as-built project documents.	To calculate expected thermal benefits from a project site, need pre-project conditions and as-built conditions. This information is therefore essential for calculating thermal benefits and is necessary to prove that project was implemented in a way that generated additional benefits.	As built survey report that includes: • As-built surface model, • Modeled water surface elevations for various discharges, • Geospatial shape file used to calculate thermal benefits, • Aerial imagery showing water surface elevations at various discharges, and •
E	Vegetation on project sites implemented consistent with intended design.	Once new surface area has been created through one of the four instream actions, vegetation of that area can help reduce erosion and maintain the integrity of that surface area over time, especially during high flow events. Vegetation may also provide thermal benefit through shade.	• Description of how vegetation installed will help maintain project surface area; and • If vegetation installed with the intent of generating thermal benefits from shade, reference Section II(C) of this document.
F	Project implementation does not create significant adverse effects on other water quality parameters or locations.	This ensures that project actions do not have adverse effects on the waterbody or adjacent habitat or people.	• Adherence to applicable project work permits (e.g., instream work, conditional use permit, herbicide spray license, etc.); and • Documentation of instream project site eligibility and suitability.

D. THERMAL BENEFIT CALCULATION MODEL VERSION & PARAMETER REQUIREMENTS

As described in Section 2.3 of the SRSP, thermal benefits can currently be calculated from the reduced surface area of the water and energy lost from emergent wetlands. Thermal benefit units must be calculated using the approved quantification methodologies detailed in the SRSP. As described in Section 2.3 of the SRSP, Shade-a-lator or a wetland energy calculation can be used to quantify thermal benefits from instream actions in units of kilocalorie per day. All thermal benefit calculation methods compare the pre-project conditions to the expected post-implementation, as-built conditions. The thermal benefits associated with each condition are estimated. The difference between the two estimates represents the thermal benefit IPC may count toward its thermal benefit milestones.

Instream Channel Modification Thermal Benefits

Shade-a-lator incorporates the water surface area to calculate thermal loading, and so it can be used to calculate kilocalorie per day reductions from changes in the channel dimensions. Introducing channel complexity will often reduce the surface area of water that is exposed to the sun, thus reducing the amount of energy entering the aquatic system. To calculate the thermal benefits generated from such a project, IPC will use the pre-project footprint of an island or floodplain project and compare that against the land surface area added through the project. To calculate the thermal benefits generated from such a project, IPC will use the pre-project footprint of an island or floodplain project and compare that against the land surface area added through the project. Pre-project surface area extents are calculated using a surface and hydraulic model that was based on the 30-year mean discharge (CFS) for the July 1 – October 29 aggregate thermal benefit period. The output of these models (surface area waterlines) represents the 30 year average water elevation, calibrated to a specific reach of the Snake River.

Wetland Energy Budget

As described in Section 2.3.2 of the SRSP, for any wetland projects, IPC will use a wetland energy budget to calculate the thermal benefits generated.

Riparian Shade Thermal Benefits

If thermal benefits will be generated from riparian shade installed on top of new land surface area, refer to Section II of this document for restoration quality standards.

E. PROJECT SITE MONITORING AND MAINTENANCE

All projects will be monitored after implementation and throughout the duration of the SRSP. As discussed in Section 2.6.2 of the SRSP, monitoring will be performed according to a three-tiered approach. Quantitative or qualitative monitoring plans will be adapted for each project prior to implementation. These monitoring plans will detail the method that will be used to survey a particular project site and the frequency that the project site should be monitored. Site level monitoring will be complimented by remote sensing data on regular intervals. In response to monitoring and audit results, and so as to ensure that the site continues on the proper trajectory over time, maintenance will occur at project sites for the full duration of the SRSP.

Table 4: Project monitoring and maintenance requirements.

	Project Monitoring & Maintenance Standard	Rationale	Documentation Required
A	Monitoring plan developed for the particular restoration project site.	The goal of monitoring is to assess project performance to determine whether the site appears to be on track to achieve modeled thermal benefits. Because the SRSP will utilize three complementary monitoring approaches, it is important to specify which approach is being applied at a particular site and why.	• Monitoring plan.
B	Confirm overall thermal benefit-generating surface area is materially consistent with original constructed surface area.	To help ensure that instream project sites continue to generate the claimed thermal benefits, it is necessary to ensure through monitoring that the surface area of a site stays materially consistent with the initially developed surface area. Deposition and erosion is likely to occur within the system. Therefore, it will be important to assess all project sites holistically, as well as individually, to ensure that program as a whole remains consistent with initial modeled conditions	• Visual comparison of existing surface area versus originally constructed surface area (from as-built survey).
C	Over the life of the SRSP, ongoing maintenance will be completed as necessary to ensure that project sites are	The goal of maintenance is to promote the durability of newly constructed surface area and to reduce risks to achieving project objectives. Specific maintenance actions are at the discretion of project managers, but	• Complete maintenance logs, store digitally in central location so

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	in place and continue to function as designed.	projects should be maintained as needed in order to promote project longevity over the length of the SRSP.	can be accessed by project managers and auditors/ regulators, if needed

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II. Riparian Shade Restoration Quality Standards

A. PROJECT SITE ELIGIBILITY

A number of steps must be taken to ensure that a project site is eligible for the SRSP. These required steps are noted in Table 5. These steps help to maintain transparency and consistency throughout the program. Additional guidelines related to fulfilling these eligibility requirements are described in IPC's SRSP Program Manual.

Table 5: Project eligibility requirements for riparian project sites.

	Eligibility Standard	Rationale	Documentation Required for Initial Confirmation or Audit
A	Project is located within the Snake River Stewardship Program area.[3]	To ensure temperature benefits appropriately offset the temperature impacts of the HCC, projects must be implemented within the designated program area.	• Map of SRSP program area with site location noted on map, and showing that site not above a major impoundment on that waterbody (if above such an impoundment, will require DEQ approval, and likely a different attenuation ratio).
B	Project is located adjacent to natural waterbodies or permanent artificial drainage ditches.	By definition, riparian areas are those influenced by stream hydrology, and thermal benefits from riparian shade must therefore provide shade to a waterbody that will influence the SRSP program area.	• Project map demonstrating that the project is adjacent to a water course that fulfills these requirements.
C	Project is consistent with regulatory baseline requirements, and compatible with current local land use requirements.	Thermal benefits from projects can be claimed if the action generating those benefits is not already required by federal, state, tribal or local sources of law. In addition, projects in the SRSP program area must be implemented consistent with any applicable county or city comprehensive plan, zoning ordinances, subdivision ordinances or other local code requirements to ensure full regulatory baseline fulfillment.	• Regulatory baseline analysis (summarized in Table 5.1 of this document) applied to the specific project site.
D	Project will produce shade from riparian vegetation, creating thermal benefits through reduced thermal loading to the adjacent water course.	The objective of the SRSP is to address thermal loading to the Snake River and its tributaries by improving thermal conditions upstream of the HCC in a way that will address IPC's cumulative thermal load exceedance. Riparian projects implemented as part of the SRSP should	• Documentation showing the potential to generate thermal benefits (Section II(D) of this document describes assumptions to use for calculating actual site

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[3] Thermal benefits must be generated within the SRSP area, which includes the Snake River from below Swan Falls Dam and upstream of the Hells Canyon Dam as well as its tributaries. Twelve tributaries are included in the SRSP: Boise River, Brownlee Reservoir creeks, Burnt River, Malheur River, Middle Snake-Payette River, Owyhee River, Payette River, Pine Creek, Powder River, Succor Creek, and Weiser River. Thermal benefits for riparian areas were assumed only for sections of the river that were below any reservoir or substantial impoundment on these rivers. If projects are to be installed above such a barrier, additional attenuation factors will be required to establish the thermal benefit value.

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		meet the goals of the program, generating thermal benefits by reducing solar loading to a river's surface through the creation of shade. At the eligibility stage, it is important to confirm that a potential project site will be able to generate thermal benefits by confirming its aspect related to the sun, that shade cast from the site could hit the center line of the river, and ensuring that the site is not already exposed to topographically created shade.	thermal benefit values; this requirement is limited to demonstrating the potential to generate thermal benefits). • Documentation showing that topographical shade[4] (SRSP 2.4.2) does not reduce available thermal benefits to the extent that project is no longer viable.
E	Planning in place to secure long-term project site access and protection, and project site management plan is being drafted to support desired future conditions.	Long-term access for maintenance and monitoring is essential for achieving project objectives.	• Draft landowner agreement; and • Draft project site management plan.
F	Planting area does not appear subject to unreasonable, unmitigatable risks.	Land subject to un-mitigatable, excessive erosion is unlikely to persist long enough to provide expected shade benefits for the duration of the SRSP. Lands subject to un-mitigatable excessive browse are unlikely to support a riparian community tall enough to provide modeled shade benefits. Following the cessation of irrigation, land must have sufficient connectivity to the water table to provide plantings access to water so that they can continue to survive and grow to the heights and density presumed in thermal benefit modeling.	• Project manager review of site conditions during field visits and discussions with landowners; • Summary of potential risk factors to project success; and • Description of how site design has contemplated and minimized potential risk factors.
G	Contemplated project will result in an additional and improved state from previous management on the project site. Site should not have experienced intentional degradation in the 5 years immediately preceding implementation of an SRSP project.	The purpose of this requirement is to avoid situations of deliberate degradation to generate thermal benefits and receive incentive payments at a project site, and promotes additionality as compared to historic practices.	• Review of aerial imagery of project site within last 5 years to confirm that pre-existing ecosystem has not been deliberately destroyed in effort to have it restored under SRSP and receive payments. Document in eligibility/suitability analysis.

Regulatory Baseline for Riparian Shade Thermal Benefits

In the SRSP, baseline is defined as a "regulatory baseline" and addressed in Section 2.5.2. Projects are considered additional and able to generate thermal benefits for compliance only after the regulatory baseline requirements at a project site have been met. "Regulatory baseline" in the SRSP refers to affirmative land management obligations applicable to a riparian project site at the time that the restoration action is implemented that may be required by federal, state, tribal or local law, including

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[4] For example, a slope of greater than 30 degrees over the entire planting area would likely be an impediment to implementation, so this criterion should be used to exclude areas via remote sensing. Identifying areas with topographic shade issues is a more involved process. When the primary data source is aerial photography (which is typically flown during the late spring or summer under clear skies around mid-day), visible topographic shadows are a good indicator that a potential project should be excluded from riparian revegetation for thermal benefits. When time of day or year precludes this, steep rises (determined using Google Earth elevation visualization) in elevation immediately to the SW/S/SE of the stream are also viable indicators.

any requirements derived from a TMDL. As part of confirming that the thermal benefits produced by a SRSP project can be used to address IPC's obligation, IPC's auditor/verifier will need to confirm how/whether any potential baseline sources apply to the project at that point in time. Current sources are summarized in Table 5.1.

Table 5.1: Potential sources of regulatory baseline for riparian shade projects.

Potential Regulatory Baseline Sources	Baseline requirement
(1) RIPARIAN: Private / Non-Federally Owned (Oregon)	The discussion under (2) in this table is based on the Oregon water quality trading rule (OAR 340-039-0030).
(a) NPDES permit requirements	If IPC plans to purchase thermal benefits from an entity covered by a NPDES permit, it will need to review that entity's permit to ensure that the entity is not already obligated to generate those benefits under its permit. While IPC holds some NPDES permits, those obligations are separate and distinct from its 401 obligations.
(b) Rules issued by Oregon Department of Agriculture for an agricultural water quality management area under OAR chapter 603 division 095	The SRSP program area overlaps with four Oregon agricultural management plan (AgWQMP) areas: Owyhee (OAR 603-095-2700), Malheur (OAR 603-095-0900), Burnt (OAR 603-095-3200), and Powder/Brownlee (OAR 603-095-3600). In the Owyhee, for example, "no person may contribute to conditions that preclude establishment and development of adequate riparian vegetation for streambank stability and shading, consistent with site capability." OAR 603-095-2740(3). The other AgWQMP area rules establish similar requirements: Malheur (OAR 603-095-0940(5)(a)); Burnt (OAR 603-095- 3240); Powder-Brownlee (OAR 603-095-3640(3)(a)). While these AgWQMP area rules protect against activities that will degrade riparian vegetation in SRSP project sites, they do not establish any affirmative restoration obligations on those project sites. Rather, these passive, non-disturbance regulations only require that land be left alone so that vegetation can be established, and are not affirmative riparian restoration obligations.
(c) Rules issued by Oregon Board of Forestry under OAR chapter 629 divisions 610-680	Will be considered if/when forestry-zoned sites are considered for implementation.
(d) Requirements of a federal land management plan, or an agreement between a federal agency and the state	These will be considered on a case-by-case basis. Unlikely to apply unless recruited site is federally or stated owned. If this situation arises, go to step #5 of this table.
(e) Requirements established in a Clean Water Act Section 401 water quality certification	N/A, as IPC will hold a 401 Certification establishing its obligations (see detailed explanation in Section 2.5.2 of the SRSP). If IPC plans to purchase thermal benefits from an entity covered by a separate 401 Certification, it will need to review that entity's 401 to ensure that the entity is not already obligated to generate those benefits under its certificate.
(f) Local ordinances	See step #4 below.
(g)Tribal laws, rules, or permits	Unlikely to apply, but confirm on site-by-site basis.
(h) Other applicable rules affecting nonpoint source requirements	Unlikely to apply, but confirm on site-by-site basis.
(i) Projects completed as part of compensatory mitigation, or projects required under a permit or approval issued pursuant to [CWA] section 404, or a supplemental environmental project used to settle a civil penalty imposed under OAR chapter 340 division 012 or the [CWA]	IPC will be acting pursuant to its 401 Certification obligations, not a SEP or settlement. If a potential project site is already hosting a CWA 404 or SEP project, IPC will have the burden to demonstrate the proportion of the CWA 401 thermal benefit site that is additional.

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(j) Regulatory requirements a designated management agency establishes to comply with a DEQ-issued TMDL, water quality management plan or another water pollution control plan adopted by rule or issued by order under ORS 468B.015 or 468B.110.	The Snake River-Hells Canyon TMDL includes a water quality management plan designed by Oregon (pg. 489 of TMDL). The Oregon WQMP explicitly notes that point and nonpoint sources can consider effluent trading to help meet obligations. *Id.* at 498. The TMDL notes that ODA will develop an AgWQMP to support the TMDL. *Id.* at 529. No AgWQMP exists for the specific HC-SR reach, though AgWQMPs have been developed for upstream tributaries to the SR-HC reach. While AgWQMPs have been developed for Oregon subbasins covered by the SRSP, the "area plan is not regulatory or enforceable. Only the associated Area Rules are enforceable. (Oregon Revised Statute (ORS) 568.912(1))."[5] Of the Oregon subbasins within the SRSP program area, only the Malheur River Basin has an EPA-approved temperature TMDL (http://www.oregon.gov/deq/wq/tmdls/Pages/TMDLS-Basin-List.aspx), which means that only this basin has an associated water quality management plan that has been established to comply with a DEQ-issued TMDL. The Malheur River Basin temperature TMDL "requires designated management agencies to implement management strategies to restore or protect streamside vegetation…." At iv. While federal and state DMAs are required to develop their own plans for land they manage, only the Oregon Department of Agriculture agricultural water quality management plan (AgWQMP) covers locally- and privately-owned land where SRSP riparian projects would be installed. Malheur temperature TMDL, at 264, Tbl. 4.1 (summarizing DMAs and what is expected of each of the DMAs). "Historic vegetation is not required along streams, although the shade and function provided by historic vegetation *should be targeted*. As a general guideline, landowners are *encouraged* to maintain the widest possible band or buffer of native vegetation along the stream." ODA, Malheur River Basin AgWQMP, at 28 (2017), http://www.oregon.gov/ODA/shared/Documents/Publications/NaturalResources/MalheurAWQMAreaPlan.pdf (emphasis added). Section 2.5 of the AgWQMP describes the voluntary and regulatory measures that must be taken, but with respect to riparian area management, states that the only regulatory measures associated with the AgWQMP are the prohibitions listed in section 603-095-0940(4) and (5) (which are already addressed in this table, in section 2(b)). *Id.* at 37.
(2) **Private / Non-Federally Owned (Idaho)**	These potential regulatory baseline sources are discussed in detail in Section 2.5.2 of the SRSP.
(a) Priority basin regulations	In high-priority, water quality limited waters in Idaho, "[o]nce the TMDL or equivalent process is completed, any new or increased discharge of causative pollutants will be allowed only if consistent with the approved TMDL. Nothing in this section shall be interpreted as requiring best management practices for agricultural operations which are not adopted on a voluntary basis." IDAPA 58.01.02.055.04 (2015). This same provision applies in medium and low priority waters. IDAPA 58.01.02.055.05 (2015).
(b) Basin specific regulations	Nothing in IDAPA 58.01.02.110, .120, .130, .140, .150, or .160 establish any further requirements on nonpoint sources in the subbassins within the SRSP program area (17050117 - Lower Malheur; 17050119 - Willow Creek (in the Larger HUC3 Malheur); 17050118 - Bully Creek (also in the HUC3 Malheur); 17050110 - Lower Owyhee; 17050202 – Burnt; 17050203 – Powder; 17050115 - Middle Snake-Payette).

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[5] ODA, Powder-Brownlee Agricultural Water Quality Management Area Plan, at 3 (2016), http://www.oregon.gov/ODA/shared/Documents/Publications/NaturalResources/PowderBrownleeAWQMAreaPlan.pdf; ODA, Owyhee Agricultural Water Quality Management Area Plan, at 1 (2017), http://www.oregon.gov/ODA/shared/Documents/Publications/NaturalResources/OwyheeAWQMAreaPlan.pdf; ODA, Burnt River Agricultural Water Quality Management Area Plan, at 3 (2016), http://www.oregon.gov/ODA/shared/Documents/Publications/NaturalResources/BurntRiverAWQMAreaPlan.pdf.

(c) Nonpoint source regulations from other Idaho agencies	Forestry operations must follow multiple practices when harvesting trees near streams, and are required to follow several practices regarding road building and maintenance near streams. See IDAPA 20.02.01.030.07(e); IDAPA 20.02.01.040 (2015). If projects are installed on active forestry operations, these regulations will need to be consulted. Even if BMPs under the jurisdiction of other Idaho agencies could apply, "so long as a nonpoint source activity is being conducted in accordance with applicable rules, regulations and best management practices as referenced in Subsection 350.03, or in the absence of referenced applicable best management practices, conducted in a manner that demonstrates a knowledgeable and reasonable effort to minimize resulting adverse water quality impacts, the activity will not be subject to conditions or legal action ***." IDAPA 58.01.02.350.02(a) (2015).
(3) Local Community Regulatory Review (Both States)	County and City requirements, zoning ordinances, and other local codes must be evaluated for each site to ensure that the thermal benefit-generating action is not already required. Given the geographic breadth of the SRSP, an exhaustive list is not included in this table. However, as projects are installed, it will make sense to generate county- and city-specific sub-checklists to expedite review.
(4) Federally / State Owned Land (Both States)	Demonstrating additionality on publicly owned land involves the consideration of management actions, if any, which are already required by the federal or state management statute and plans governing that parcel. If any of those statutes or management plans already require active restoration of the riparian area where SRSP project sites would be implemented, it would be necessary to discount the thermal benefits generated from that project site to ensure that those benefits are not "double-counted." Such an assessment can prove difficult or subjective when a statute establishes a narrative, multi-use mandate, and thermal benefits from a site are measured in quantified units.

B. PROJECT SITE DESIGN

After evaluating the eligibility of a riparian shade restoration project for the selected project site, project design can begin. The required components of a project design document are outlined in Table 6. Additional guidelines related to fulfilling these project design requirements are described in IPC's SRSP Program Manual.

Table 6: Project design quality standards for riparian project sites.

	Project Site Design Standard	Rationale	Documentation Required
A	Clearly identifiable geographic location of the project site, accompanied by landowner contact information.	Must be documented to ensure project is in eligible area.	• Project site location and landowner contact information collected and available from IPC.
B	Project design map completed, showing proximity of project to waterbody, key attributes of project site, and clear delineations of project boundaries.	This information is necessary to delineate the thermal benefit generating area with enough specificity for project managers, auditors and agency staff to understand what initially occurred at a site.	• Map showing delineated project area, key attributes, proximity to waterway; and • Legal protection agreement that identifies project boundaries.
C	Pre-project monitoring is completed, with photographic evidence to substantiate conditions.	Documentation of on-site project conditions prior to implementation is needed to establish assumptions used in pre-project thermal benefit modeling, and to provide a baseline against which to measure progress over time.	• Must describe the status of existing vegetation at the site, and collect data, including photographic evidence, to document those conditions. If thermal benefit producing vegetation is installed on a newly constructed instream surface area consistent with Section I of this document, can use Table 3(C)-(D)

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			as-built instream documentation to satisfy this Table 6(C) pre-project documentation step.
C	Description of how pre- and post-project site conditions are related to the model assumptions used to calculate thermal benefits at the site.	Establishing pre-project conditions is required to calculate thermal benefits. Future conditions must be modeled to prove that project is designed to provide additional thermal benefits.	• Description of how changes expected to result from restoration as designed will produce modeled thermal benefits (see Section II(D) and Table 9 of this document).
D	Target vegetation structure and composition must be consistent with appropriate reference conditions.	Reference conditions developed from areas within the same geography and with environmental and natural disturbance characteristics similar to restoration site support description of appropriate desired future conditions and maximize the likelihood that project will achieve those conditions.	• Summary of reference conditions relied upon to inform site design.
E	Plant materials: • Local, native-derived plant material for woody species must be utilized. To the extent practicable, those plants should originate from sources in a similar ecoregion and at a similar elevation to project site. Woody plant material from within the same EPA level III ecoregion as the project site is highly preferred; woody plant material from within the same EPA level II ecoregion as the project site is acceptable. • To the extent practicable, , use local native-derived plant material for herbaceous species originating from sites in a similar ecoregion and at a similar elevation to project site. If native plant materials for herbaceous species are not available, non-native species may be used. • Transplanted shrubs may be used if materials come from outside the bankfull width, and if native plant material is abundant.	Plant materials must be selected to ensure local adaptability and maximize long-term project success.	• Description of plant materials origins and sourcing.
F	For riparian forest shade projects intended to produce	Standards support projects that are likely to achieve modeled thermal	• Planting plan that includes planting density, species

	thermal benefits through active restoration: Plant native trees in areas that are ecologically appropriate for their long term establishment. • Plant native trees at densities appropriate for the plant material type being used, at least 400 stems/acre. • Plant native shrubs at densities appropriate for the plant material type being used, at least 1,000 stems/acre. • Plant at least 5 native woody species, 2 of which will be trees, unless this number of species is already present on site and is expected to persist for the duration of the program.	benefits, while also allowing flexibility in design and implementation.	composition and planting layout; and • Description of how reference conditions were used to inform the planting plan.
G	For passive restoration sites, including conservation areas, thermal benefits will be the difference between baseline conditions and expected future conditions.	In some instances, passive restoration (e.g., exclosure fencing, browse protection, targeted interplanting, and/or weed treatment) may catalyze the reestablishment of a functional riparian area such that it produces thermal benefits.	• Documentation of restoration interventions utilized (e.g., weed treatment, fencing, active planting of ## density and type, etc.); and • [Methodologies for assessing how and when particular restoration interventions can qualify to generate thermal benefits will be developed during the SRSP Research Program].
H	Describe potential risks associated with the project.	It is important to document the potential risks at a project site prior to implementation. Potential risks from riparian projects include, but are not limited to: loss of constructed vegetation via scour and erosion, unfavorable soil conditions, water availability for plants, high animal browse, noxious weed encroachment, spray drift, livestock impacts, future climate variability, changes to water management, adjacent land uses, and all risks associated with construction.	• Summary of potential risk factors that may affect project success; • Description of how design has contemplated and minimized these potential risk factors; and • Description of how conditions that have contributed to poor riparian structure have been considered in project design so that the same conditions that led to degradation are mitigated.

C. PROJECT SITE IMPLEMENTATION

After screening a project site and then designing and documenting it accordingly, project implementation can begin. The required aspects of implementation are outlined in Table 7. Additional guidelines related to fulfilling these project implementation requirements are described in IPC's SRSP Program Manual.

Table 7: Project implementation requirements.

	Project implementation	Rationale	Documentation Required
A	Legal protection agreement signed by both parties covering the full period of thermal benefits that will be claimed by IPC.	Demonstrates that the restoration project site is going to be legally protected from conversion for the duration of the period for which thermal benefits will be claimed, and that IPC will have access to steward the site over that period.	• Signed landowner agreement (e.g., lease or easement); or • Applicable agency permission to install a project for federal and state-managed lands (e.g., easement from the Idaho Department of Lands).
B	All necessary permits and approvals have been obtained, with copies retained on-site.	Necessary to demonstrate approval to undertake the restoration project.	• Copies of final permits, licenses, and approvals (e.g., ESA permits, cultural resource survey and reporting).
C	Vegetation on project sites implemented consistent with the intended design.	The intended design of the project is meant to promote conditions that will generate thermal benefits as modeled. Additionally, because a project design considers ecologically relevant reference conditions and ecologically appropriate choices, it is important to confirm that the project has been implemented consistent with those considerations.	For active restoration sites, as-built survey report to include: • As-built project map that includes planting boundaries, as-built acreage, and site location; • As-built planting plan (plant quantities, species composition and planting layout); andand • Summary of project actions, including irrigation, fencing, off channel watering, etc. where needed. For any other approach that is not full active restoration, provide summary of interventions utilized (e.g., fencing perimeter, weed treatment, interplanting #s and species type, etc.).
D	Project implementation does not create significant adverse effects on other water quality parameters or locations.	This ensures that project actions do not have adverse effects on the waterbody or adjacent habitat or people.	• Adherence to applicable project work permits (e.g., water use licenses, conditional use permit, herbicide spray license, etc.); and • Documentation of riparian site eligibility and suitability.
E	As-built project monitoring is completed.	As-built information demonstrates how the restoration approach changed the site, and provides a new baseline against which to track changes over time.	• As built survey report that includes a modeled thermal benefit analysis comparing pre-project and future heights of vegetation; and • Post-implementation reports should include pre-

			project monitoring data for comparison, as needed.
F	Future conditions have been estimated based on as-built project documents.	To calculate thermal benefits from a project site, need pre-project conditions and as-built conditions. This information is therefore essential for calculating thermal benefits and is necessary to prove that project was implemented in a way that generated additional benefits.	• Articulation of how as-built conditions translate into future condition assumptions used to calculate thermal benefits.

D. THERMAL BENEFIT CALCULATION MODEL VERSION & PARAMETER REQUIREMENTS

Riparian vegetation blocks thermal load by preventing solar radiation from contributing heat to the waterbody. The estimated canopy density and height of the vegetation at full growth is used to estimate thermal blocking capacity. As described in Section 2.3 of the SRSP, thermal benefits from riparian revegetation can currently be estimated in units of kilocalories per day (kcal/day) based on the projected net increase of riparian canopy surface area following restoration. Benefit units must be calculated using Shade-a-lator, a module of HeatSource model. All thermal benefit calculation methods compare the pre-project conditions to the expected post-implementation conditions. The thermal benefits associated with each condition are estimated. The difference between the two estimates represents the expected thermal benefit generated from the project.

The SRSP will use Shade-a-lator to estimate thermal benefits from potential project sites within the SRSP program area. Shade-a-lator should be applied according to IPC's SRSP Program Manual.

The model parameters used in SRSP development are fully described in Section 2.4.2 of the SRSP. Individual Shade-a-Lator runs associated with pre-project and projected as-built thermal benefit values should be stored in the Model Parameter Log. The model parameter date is a range that accounts for the aggregate thermal benefits that will accrue during the cumulative thermal load exceedance, calculated as an average of the daily thermal benefits that accrue from the months of July-October.

Current and future condition vegetation height assumptions for sites in the SRSP are as follows:

- **Current Conditions**: The best available aerial imagery, collected during low flow conditions, is used to digitize bank lines and establish the pre-project footprint. "As is" vegetation heights based on data types such as LIDAR, aerial photography where LIDAR was unavailable or too outdated to use (alternative emerging technology may be evaluated and incorporated for use as appropriate). Where vegetation pre-existing the project is present, and it is currently less than the future mature height, it is presumed that this vegetation will grow to its mature height as a result of SRSP stewardship efforts at the site over time. On these portions of the site, the height variable for shade modeling is the difference between the vegetation's current condition height and the mature estimated height of the plant.
- **Future Conditions**: TFT used a combination of literature and interviews with riparian professionals in the SRSP area to identify two primary reference communities for riparian vegetation in the SRSP program area: 1) riparian vegetation dominated by hardwood species such as black and narrow leaf cottonwoods, and aspen and 2) riparian shrubs including willows, mountain alder, and hawthorn. The mature characteristics (height and canopy density) of these two vegetation communities differ. The mature heights of cottonwood-dominated riparian communities are reported in the U.S. Department of Agriculture's PLANTS database to be 100

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feet.[6] The Malheur River Basin temperature TMDL incorporated the PLANTS Database assumption for cottonwood height, and noted that when mature, these communities can be modeled with 80% canopy density.[7] Mature heights of willow species range from 15 to 45 feet depending on the species[8] and can be modeled with 70% canopy density.[9] The heights from the TMDL and USDA sources will be used for the purposes of projecting future conditions at these sites. Because multiple project-level characteristics will determine the composition of a plant community that can be supported at a project site—including depth to the water table, soil type, bank angle, and pests—to estimate the availability of thermal benefits from a specific riparian revegetation project, a modeler/verifier should refer to the as-built planting plan, with its notations as to which of the two vegetation classes is dominant in particular areas of the site.

E. PROJECT SITE MONITORING AND MAINTENANCE

All projects will be monitored after implementation and throughout the duration of the SRSP. As discussed in Section 2.6.2 of the SRSP, monitoring will be performed according to a three-tiered approach. Site-level monitoring will be complimented by remote sensing data on regular intervals. Monitoring plans will be adapted for each project prior to implementation. These monitoring plans will detail the method that will be used to survey a particular project site and the frequency that the project site should be monitored. In response to monitoring and audit results, and so as to ensure that the site continues on the proper trajectory over time, maintenance will occur at project sites for the full duration of the SRSP.

Table 8: Monitoring and Maintenance requirements.

	Project Monitoring & Maintenance Standard	Rationale	Documentation Required
A	Monitoring plan developed for the particular restoration project site.	The goal of monitoring is to assess project performance to determine whether the site appears to be on track to achieve modeled thermal benefits. Because the SRSP will utilize three complementary monitoring approaches, it is important to specify which approach is being applied at a particular site and why.	• Monitoring plan.
B	Confirm that vegetation at project site is making progress toward achieving modeled plant height profiles and likelihood of achieving thermal benefits.	To ensure that projects meet thermal benefit objectives at the conclusion of the program, project managers must evaluate site progress and take corrective actions if needed.	• Post-implementation monitoring reports.
C	Over the life of the SRSP, ongoing maintenance will be taken as necessary to ensure that the: 1) plant height profiles at the project site remain on track to achieve modeled thermal benefits; and that the	Maintenance activities may include: inter-planting, browse protection, weed control. Specific maintenance actions are at the discretion of project managers, but projects should be actively maintained as needed in order to promote project	• Complete maintenance logs

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[6] USDA, NRCS National Plant Data Team, The PLANTS Database (2015), http://plants.usda.gov.
[7] Oregon DEQ, Malheur River Basin Temperature TMDL, Appendix B, Table B-8 (2010).
[8] USDA, NRCS National Plant Data Team, The PLANTS Database (2015), http://plants.usda.gov.
[9] Oregon DEQ, Malheur River Basin Temperature TMDL, Appendix B, Table B-8 (2010).

	site is experiencing a positive trajectory with respect to 2) stream shade and canopy cover or closure, 3) abundance of native woody species, and 4) native woody species diversity.	health over the length of the SRSP. The goal of maintenance is to promote a healthy riparian area, limit noxious species colonization, and reduce risks to plantings.	

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III. Confirmation, Auditing, Tracking & Reporting

A. PROJECT IMPLEMENTATION CONFIRMATION AND ANNUAL AUDITS

Section 2.6.3 of the SRSP requires independent, external third-party confirmation that thermal benefit projects have been implemented consistent with designs, are in place post-implementation, and perform according to expectations. The SRSP includes a hybrid audit procedure comprised of two key elements: 1) every project will receive third-party confirmation that it has been implemented consistently with the restoration quality standards, and 2) on an annual basis, randomized site audits will be completed on a percentage of projects to confirm that they are being maintained, monitored, and tracked according to the Restoration Quality Standards and that they are likely to generate the modeled thermal benefits.

At the initial confirmation stage, auditors will review:

- Project eligibility to generate thermal benefits that can be counted toward IPC's obligation, including regulatory baseline analysis;
- Project has been designed and implemented consistent with SRSP restoration quality standards;
- The input/assumptions used to calculate thermal benefits, as compared to pre- and post-project conditions.
- Completeness of records for the project site.

Table 9: Initial confirmation quality standards and document requirements.

	Initial Confirmation Standards	Documentation Required
A	Eligibility, design & implementation documentation	• Eligibility Documentation: o Internal documentation of site eligibility and suitability (to show consistency with internal controls); o All documentation listed in Eligibility table (table 1 of this document); o Regulatory baseline analysis for site (table 1.1 of this document); o All documentation listed in Site Design table (table 2 of this document); and o All documentation listed in Implementation table (table 3 of this document).
B	Thermal benefit calculation & back-up documentation (if used Shade-a-lator) for all days during the July 1-October 29 aggregate thermal benefit time period	• Pre-project thermal benefit calculation data, including pre-project photo points, and site data supporting establishment of pre-project condition assumptions used in Shade-a-lator (e.g., stream centerline and site water lines, site elevation, vegetation characteristics); • As-built thermal benefit calculation data, including as-built restoration area, vegetation distribution and zones, etc.; and • Thermal modeling report: A) current conditions maps. B) Future anticipated conditions map. C) Shade-a-lator parameter log.
C	Thermal benefit calculation & back-up documentation (if used wetland energy budget)	• Sufficient documentation to prove calculations and assumptions described in Section 2.3.2 of the SRSP.
D	Stewardship & Monitoring documentation	• In the first year of auditing, following construction, auditor will be able to review the site monitoring plan. The nature of the monitoring plan will depend on whether the site is being studied qualitatively or quantitatively (see SRSP section 2.6.2). In later years of the project, monitoring reports will be audited for completeness of data and consistency of the site with the initial site confirmation.

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Once a project passes initial project confirmation, it will be entered into an audit pool. Until the fifth year of the SRSP—when a sufficient number of project sites will have been implemented and can serve as the basis of the audit pool—one instream and one riparian project site per year will be randomly visited, or audited, by a third party to confirm performance of those project sites. Each year after SRSP program year five, a representative sample of project sites will be audited to confirm performance of those project sites.

During annual project audits (sites selected by the auditor), the auditor will review: 1) the conditions of the project site as compared to the site design and implementation plan, and thermal benefit estimate inputs for that site; 2) confirm completeness of records for the property and project site; 3) confirm that there have been no substantial changes in project site and surrounding land use conditions that could materially affect the trajectory of the project; and 4) compare the project's condition against the qualitative and remote sensing data associated with that project site so as to assess the reliability of SRSP quality control. The auditor will then determine whether the project site is or is not "materially consistent" (defined in SRSP) with records and deemed as still on track to generate modeled thermal benefits by the end of the program. In other words, the auditor will either "accept" or "reject" a visited project site, and then determine whether a sufficient proportion of the sampled project sites from that year conform. So long as the number of nonconforming project sites is less than the "acceptance" or "materiality" threshold for the audit pool that year—set to 15% of the audit pool population after SRSP program year five—then the program shall be deemed in compliance for that year. If the auditing process identifies material nonconformance at more than 15% of audited project sites, then the inconsistencies must be remedied under the supervision of the DEQs.

Table 10: Project auditing quality standards and document requirements.

	Project Auditing Standard	Documentation Required
A	Provide updates to auditor on status of site	The following documentation should be provided to the auditor: • Any revised eligibility documentation due to site or regulatory changes; • IPC-signed statement attesting to any material changes in eligibility status or changes in site condition that may materially affect the site's ability to produce the modeled thermal benefit volume by the end of the project life; • Previous monitoring reports, and most recent remote imagery covering the site (to assess the reliability of SRSP quality controls); and • Maintenance logs for the sites.

B. TRACKING AND REPORTING

Once project implementation has been confirmed, the project site can be used for thermal benefits unless and until it is demonstrated to be ineligible. Disbursement of thermal benefits must be completed through registry on a publicly accessible website.

Table 11: Quality standards for project and program tracking.

	Project and Program Tracking Standard	Detail
A	Thermal benefits installed for the SRSP program must be tracked over time.	Modeled thermal benefits associated with project implementation should be tracked and compared to overall program goals on an ongoing basis. Program milestones to install half of the required thermal benefits and all thermal benefits are set for SRSP program years 15 and 30 respectively (see SRSP Section 2.4.4).

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B	Tracking system must be publicly accessible.	Thermal benefits must be tracked in accordance with SRSP Section 2.6.4. Tracking should facilitate transparency in the SRSP. The regulators and members of the public will be able to easily access project related information, and determine whether the program is on track to meet defined compliance milestones.

C. THERMAL BENEFIT DISBURSEMENT

Table 12: Quality Standards for disbursement of thermal benefits.

	Benefit Disbursement Standard	Rationale
A	Thermal benefits will be issued after appropriate implementation has been confirmed by an independent party.	Confirmation by an independent third-party serves three functions: 1) Demonstrates that thermal benefits are real and additional, that they exist on the landscape and are functioning; 2) Provide a level of assurance that quality standards were used in evaluating project eligibility, during project design and implementation; and 3) In combination with registration, provides transparency to the regulators and the public.
B	Thermal benefit performance at project sites, based on annual audits.	Once implementation has been confirmed by the third party, the thermal benefits from project sites can continue to be used unless and until an audit of the project site shows a material lack of consistency with restoration quality standards. IPC will use a 15% programmatic materiality, or acceptance, threshold for each annual audit. This programmatic “acceptance sampling” approach aligns with industry standards. So long as the number of nonconforming project sites is less than the “acceptance” or “materiality” threshold for the audit pool that year—here set to 15% of the audit pool population after SRSP program year five—then the program shall be deemed in compliance for that year for the purposes of third party review. If the auditing process identifies material nonconformance at more than 15% of audited project sites, then the inconsistencies must be remedied under the supervision of the DEQs.
C	Confirmation of overall SRSP thermal benefits produced.	In addition to the thermal benefit implementation compliance milestones described in Section 2.4.4 of the SRSP, at the end of the next FERC license term, IPC will confirm that the programmatic assumptions related to thermal benefit estimates are still valid, within some reasonable margin that will be identified during the research phase.

Exhibit 7.1-6

Snake River Stewardship Program 2017 research program summary

Snake River Stewardship Program

2017 Research Program Summary

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Senior Biologist

February 2018

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EXECUTIVE SUMMARY

The proposed Snake River Stewardship Program (SRSP) notes that IPC will engage in a pre-compliance research phase during which methods, supply chain, and expertise will be established. As part of the voluntary research phase of the proposed SRSP, Idaho Power Company (IPC) has implemented one instream project and two tributary projects from 2016 through 2017. Modeled thermal benefits from the instream and tributary projects will be verified by a third-party audit in 2018. Once IPC receives section 401 water quality certifications, thermal benefits will be counted towards IPC's thermal offset requirements. During the research phase, IPC will continue to implement projects, test methodologies, refine appropriate quality standard targets and build the management structure to support a fully functional compliance program. Research projects and thermal benefits are summarized below and described in more detail in this document.

Project	Thermal Benefit
Bayha Island Research Project	183,061,106 kcal/day
Powder River River Mile 9.8	5,185,382 kcal/day
Powder River River Mile 44.8	13,649,843 kcal/day

1.0 INTRODUCTION

The purpose of this report is to provide the Idaho and Oregon Departments of Environmental Quality (DEQs) the following information on the Snake River Stewardship Program (SRSP):

- Description of projects implemented from 2016 through 2017;
- Generated thermal benefits;
- Project-specific conditions and monitoring results; and
- Third-party audit information.

Instream and riparian projects were implemented in the Snake River and Powder River in 2016 and 2017, respectively (Figures 1 - 3 and Tables 1 and 2).

2.0 SNAKE RIVER RIVER MILE 439.5 (BAYHA ISLAND RESEARCH PROJECT)

The Bayha Island Research Project is in the Snake River near Walters Ferry, Idaho (Figure 1). The project area includes Bayha Island, Wright Island, and a small area on the southern bank of the adjacent mainland. Both islands are within the U.S. Fish and Wildlife Service Deer Flat National Wildlife Refuge Snake River Islands Unit. The project was constructed as a pilot to test the feasibility and practicality of floodplain enhancement work proposed by IPC in its §401 water quality certification applications for the relicensing of the Hells Canyon Complex (HCC).

In 2016, IPC constricted and deepened the river channel in the Marsing Reach of the Snake River for the purposes of decreasing the channel width to depth ratio and reducing the water surface area exposed to solar radiation. The project was designed to produce physical features that would support native biological communities. The dredged material was used to increase the area of floodplains around the margins of Bayha and Wright Islands, and the adjacent mainland, by 7.4 acres. For stability, bulk fill was topped with locally mined gravel of various sizes deposited to as much as 2 or 3 feet in depth, and extending 10-15 feet inland from top of bank around the entire perimeter of the island. Gravel was topped by 2-4 inches of compost as well as topsoil sourced from the bottom of a sedimentation pond located on a property adjacent to the project area. Woody materials (small native logs and brush) were installed into swales and ridges to increase floodplain roughness. Floodplains were planted with a mix of locally native trees, shrubs, and herbaceous materials[1]. The goal of the planting component is to establish and maintain a native riparian forest.

Based on the November 2016 as-built survey, the Bayha Island Research Project has generated 183,061,106 kcal/day of thermal benefits.

2.1.1 Vegetation Conditions

One growing season after planting, management efforts at the site have ensured that the site is on track to meet all Year 5 performance targets in the draft quality standards and guidelines. The site now supports a diversity of native trees and shrubs that will continue to contribute to riparian ecological function and stream health into the future. The project experienced high flows in 2016/2017, and performed well in terms of stability of the newly created surface. Although wetland plants in sod mats and plugs appeared to have been largely lost during high water and grazing from geese, the materials in which they were embedded helped to stabilize the surface of the fill material. Native woody plantings were resilient to floods. Vigor of sandbar willow and black cottonwood was often noted to be excellent during monitoring, and sandbar willow was vegetatively recruiting (sprouting new stems from roots), often in abundance. Some deer and beaver browse was observed on plantings, but was generally minor and is not expected to substantially affect plant vigor across the site. Several species of native forbs were taking hold, including both species in seed mixes as well as natural recruitment; these and the many other native herbaceous plants at the site provide important contributions to beneficial ecological functions. Although several noxious weed species were present, frequent maintenance efforts have kept average cover low within the planting area. Maintenance efforts will need to be sustained to keep weeds under control, particularly for tamarisk. Some planted shrubs have already flowered and fruited, providing food resources for native pollinators and other wildlife. Over the course of the growing season, small mouth bass nests were observed within the newly constructed side channel, and monarch butterflies, snakes, mule deer, beaver, great white pelicans, Canada geese, California gulls, belted kingfisher, nesting killdeer, and many other birds were seen on the project site.

2.1.2 Project Performance

Twenty-six randomly established transects were surveyed September 25 to 28, 2017, to provide estimates of each metric for the planting area (Figure 4). Achieving progress toward performance objectives indicates that the site is on a positive trajectory towards become a higher-functioning riparian forest and is likely to achieve its modeled thermal benefits. Restoration project performance is also illustrated in the Photo Point Monitoring Report (Appendix A).

One growing season after planting, the site is on track to meet all Year 5 performance targets. Table 3 provides vegetation monitoring results in comparison to draft SRSP performance objectives (guidelines). Measurements of site average native woody stem density, shrub and woody vine cover, and canopy closure are provided in Table 4. While there is no performance objective based on native woody stem

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[1] Common names are used throughout the body of the document and common and scientific names are provided in Appendix F.

density, this metric is surveyed in early years to provide an indicator of planting establishment prior to plants producing substantial cover. Native woody plant height is provided in Table 5 to support comparison with future years, as an indicator of vigor. Within monitoring transects, nine native woody species were documented in the planting area (Table 6). Only the most common species are expected to be detected when measuring cover using the line intercept method (see monitoring procedures for more information).

Average percent cover of noxious woody and herbaceous species is provided in Table 7. In addition to the species measured in plots, the noxious species whitetop, yellow flag iris, Scotch thistle, and puncturevine were also observed on site, but were not captured in plots. Non-noxious but potentially problematic species present on site included kochia (estimated average cover 0.5%), Russian olive (estimated average cover <0.1), and threebract loosestrife (estimated average cover <0.1%). Additional weeds that could be problematic that were seen within or near the planting area, but not within plots, include tree of heaven, black locust, elm, threebract loosestrife, tumbleweed, and reed canarygrass. Control of problematic species is ongoing, with the intent that their presence does not prevent the successful establishment and propagation of native ecosystem characteristics and functions (see Maintenance Actions, below). Cover of other herb types is provided in Table 8.

2.1.3 Maintenance Actions

Maintenance actions conducted at the project site over the growing season are summarized in Table 9.

Most of the planting area was designed at elevations expected to be inundated at least every five years. From February to July 2017, the Snake River experienced high flows which inundated the entire planting area (Figure 5). Velocities were highest near the head and southern portions of Bayha Island, where substantial damage occurred to fencing and some plantings were damaged. The downstream margins of Bayha Island at which emergent wetland materials were installed was scoured and submerged for extended periods. While the sod mats remained in place and helped stabilize the bank, the wetland plant species did not appear to survive these conditions. Flood waters also deposited large amounts of sediment on some portions of the constructed floodplain in downstream areas.

A small follow-up planting was conducted in July 2017 focusing on areas not previously accessible due to high flows. Another small planting was conducted in early September 2017 to replace plants that did not survive the first growing season. All plants were watered in immediately after installation, regardless of irrigation treatment. Plantings occurred prior to monitoring.

All plants were watered in immediately after planting, regardless of whether they were in the irrigated or non-irrigated treatments (described below). Irrigation is generally expected to be applied for the first two growing seasons after planting, May through October, as adjusted by island inundation and plant water needs. All plants that were installed in 2016 in irrigation treatment areas were regularly watered with overhead sprinklers through the end of October. Irrigation materials were removed over the winter to prevent flood damage. Some areas were not irrigated to determine if there is a detectable difference in vigor and survival between irrigated and non-irrigated plants. Overhead irrigation was reinstalled in 2017 as early as planting areas could be accessed. High water inundated plants and delayed the need to start irrigation until the week of July 8, 2017. Because water tables were high throughout the spring, the delay in irrigation was not thought to contribute to drought stress. However, the region in which the project is located was abnormally dry during the summer of 2017 (US Drought Monitor, Western US, 8/22/2017 and 9/26/2017), which probably contributed to flagging vigor noted in some areas. Vigor of sandbar willow and black cottonwood was often noted to be excellent during qualitative monitoring visits.

Sandbar willow was naturally recruiting vegetatively (sprouting new stems from roots) within the planting area, often in abundance. Additionally, occasional seedlings of an unknown, unplanted cottonwood or popular species were noted within the planting area. After consulting technical plant keys and local experts, this species was tentatively identified as Fremont's cottonwood, a native tree. This identification will be confirmed as the plants mature. Seeded forbs appeared to be starting to take hold, including common yarrow, western mugwort, showy milkweed, Lewis flax, Canada goldenrod, and annual sunflower. Seeded grasses may also have been present, but weren't identified due to immaturity. Natural recruitment of native herbs often associated with wetlands was also occurring, including tule, nutsedge, cattail, curltop ladysthumb, and others. Curltop ladysthumb was particularly abundant; the seeds of this species provide important food for water fowl.

Based on monitoring data, site project manager observations, and other information, management actions planned for the upcoming year include irrigation and weed control. Irrigation reinstallation and operation similar to 2017 are expected to occur in 2018 while planted native species continue to establish and while the threat of noxious weed encroachment is still high. Both manual and chemical weed control are expected to occur in 2018.

2.1.4 Research

In addition to monitoring for overall project progress toward achieving performance objectives, monitoring was designed to collect data needed to answer adaptive management research questions. Several implementation and maintenance approaches were used on Bayha Island, including different plant materials and stock types, irrigation methods, and browse control. Lessons learned from successes here will inform the next projects and eventually, full implementation of the SRSP. These research questions are not required by the SRSP.

RESEARCH QUESTIONS

Plant Water Availability

Water is a primary requirement to sustain establishment and growth of plantings. While water is expected to be available to plants through ground-water, precipitation, and overland flow, management can most influence water availability through irrigation. Irrigation is expected to be one of the major factors impacting both the successful establishment of plants and project cost. This research question focused on the planting response in irrigated areas compared to areas that were not irrigated.

Research Question

- How is native woody plant establishment and vigor associated with irrigation, as compared to no irrigation? Is vigor of non-irrigated plants in certain hydrological zones sufficient to achieve draft performance objectives (guidelines) on desired timelines? How is irrigation associated with noxious weed cover, native herb cover, or other variables of interest?

Hypotheses

- Increases in stem density, cover, and height classes for native tree, shrub and woody vine species will be greater in irrigated areas than in non-irrigated areas.
- If SRSP draft performance objectives (guidelines) for riparian planting projects can be met in non-irrigated areas, timelines for achieving standards will be longer than for irrigated areas.

- Increases in cover of noxious weeds and native herbs will be greater in irrigated areas than in non-irrigated areas.

Natural Recruitment

Areas that can naturally recruit native vegetation from nearby propagule sources can result in reduced project costs by minimizing plant materials and installation expenses, and species can be allowed to self-determine placement and densities to best reflect existing conditions without human mediation. However, only small unplanted areas were designated for this treatment for exploratory purposes. It is unlikely that enough of the planting area will be within these treatments to allow high confidence in the quantitative results. Further, it is important to acknowledge that outcomes are highly site-specific and are difficult to generalize to other sites differing in availability of native propagule sources, substrate characteristics, and other determining factors.

Research Questions

- How do areas planted with woody materials compare with unplanted areas in terms of species establishment and vigor, materials cost, implementation cost, and irrigation cost?
- Over time, do areas with natural recruitment require additional plantings to meet SRSP standards?
- How does natural recruitment of native herbaceous species in unplanted areas compare to areas that are seeded or in which wetland materials are installed?

Hypotheses

- Per area, the cost of materials and plant installation will be greater for planted areas than for unplanted areas. However, unplanted areas will require at least some future planting to meet SRSP Restoration Quality Standards within the needed timeframe, and may be higher cost over time.
- Increases in stem density, cover, and height classes for woody species, and cover for native herbaceous species, will be greater for planted areas than for unplanted areas.
- Increases in cover of noxious weeds will be lower in planted areas than in unplanted areas.

Monitoring Design

In addition to tracking project performance and helping answer the adaptive management research questions described above, effectiveness monitoring of vegetation at the Bayha Island Research Project will also be used to fine-tune performance objectives used for future SRSP vegetation projects, and to refine methods used in data collection.

Research Questions

- Do SRSP draft quantitative performance objectives for riparian forest vegetation projects include metrics that are ecologically relevant and useful for adaptive management decision making? Are thresholds set at levels that are achievable on the timelines indicated? Do thresholds appear to be indicative of a project on a trajectory towards success?
- How many samples are needed to achieve 80% confidence that native woody species metric estimates are within +/- 20% of actual values?

Hypotheses

- SRSP draft quantitative performance objectives include metrics that are ecologically relevant and useful for adaptive management decision making. While thresholds and timelines are achievable for actively managed projects in which a certain level of resources is invested, thresholds are too high and/or timelines too abbreviated for passive restoration projects or projects with a lower level of resources invested.
- The standard sampling rate of seven transects per two acres of planting area used for The

Freshwater Trust's standard riparian revegetation projects will be higher than needed at the Bayha Island Research Project to achieve desired confidence and precision for native woody species metric estimates. Because the planting area was newly constructed, it was relatively homogeneous and lacked competing and/or ameliorating vegetation at the time of planting. These factors will likely contribute to lower variability across samples than is typically observed at many revegetation sites; therefore, fewer samples will be needed to attain data confidence and precision objectives at this and similar sites.

RESEARCH DESIGN SUMMARY

Research treatments were implemented only on the fill area placed adjacent to Bayha Island and not on Wright Island. Based on on-site observations during project installation in 2016 and 2017, Bayha Island was divided into two areas expected to each have somewhat differing environmental conditions that may influence research outcomes[2]:

- In Environment N, roughly the northern third of the island, instream flows have lower velocity according to modeling as well as on-site observations in winter 2016/17. Because of this, fine alluvial deposits are greater than in other parts of the island, and surface elevations tend to be higher.
- In Environment S, approximately the southern two-thirds of the island, conditions are drier. The upstream tip of the island is also subject to scour during high flows, resulting in surface substrates with more cobble.

Possible variability in conditions were addressed by replicating the irrigation treatment twice in each of the two environments, for a total of four replicates. Irrigation treatment units were randomly distributed within each environment. Stratifying the project area in this way is expected to minimize the systematic covariation of environment and disturbance conditions with a treatment, and thereby reduces differences among outcomes that are unrelated to treatment (i.e., confounding factors related to environment and disturbance). Treatment units were oriented on the gradient from the water to inland to maximize variability of environmental, disturbance, and planting design conditions within a treatment, and to minimize variability between treatments.

In contrast to irrigation treatment units, natural recruitment treatment units were not randomly distributed, but instead were selected opportunistically. Treatments were in areas that were partly under water during installment of woody plant materials. These areas were left partially unplanted to observe natural recruitment over time. All natural recruitment areas were irrigated.

Monitoring data collection followed methods designed to assess project performance targets. Following the standard sampling rate of seven transects per two acres of planting area, data were collected along 26 transects within the approximately 7.4-acre planting area, with 24 of these on Bayha Island and one transect each on Wright Island and the mainland. Within the spatial constraints of the research design described above, transect origin locations were randomly selected from all possible locations within treatment units, along the inland edge of the planting area. The 24 transects on Bayha Island were equally divided across the two environments, to ensure that environmental variability within the planting area is equally represented. Transects were also equally divided between irrigated areas and non-

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[2] Only small areas on Wright Island and the mainland were planted, and these areas were not assigned to any environment for locating transects. The planting area on Wright Island is the most cobbly portion of the project, and is perhaps more similar to Environment S. The planting area on the mainland appears to be most different than the others due to its higher elevations, good soils, and very wet substrates due to irrigation runoff from adjacent agricultural fields.

irrigated areas (12 transects in each irrigation type). Because there are four replicates of each treatment, each non-irrigated treatment unit was sampled with three transects. The remaining 12 transects were randomly distributed across irrigated areas, with six transects in each of the two island environments. Of the 12 transects in irrigated areas, three transects intersected natural recruitment treatments.

The numerals used to name transects were appended with unique identifiers to indicate the treatment type in which a transect was located, as follows. This allowed data from each transect to be attributed to a treatment so that outcomes could be compared.

- NI – non-irrigated
- U – unplanted (natural recruitment)
- no unique identifier – irrigated and planted control

For example, transect "6_NI" is in an area that is not irrigated, and transect "15_U" intersected an unplanted area. Transect "2" is irrigated and planted.

For the purposes of adaptive management research, the primary metrics of interest were:

- Native tree, shrub, and woody vine species stem density, cover, and height classes,
- Noxious weed cover, and
- Native herbaceous cover.

Along with quantitative measurements on plantings, narrative observations were also collected on browse and other factors expected to be associated with plant establishment and vigor. To fully inform project effectiveness and inform management decisions on the Bayha Island project and other projects, costs are being closely tracked and will be correlated with project outcomes.

RESEARCH RESULTS

Ideally, analysis would focus on the magnitude of change over time in each metric value (e.g., change in average native woody cover from Year 1 to Year 5), and would compare trends among treatment types. This approach considers the expectation that various parts of the island may have started out differing from each other at implementation (e.g., variations in species composition, planting density, etc.). Because only one growing season has passed to date, however, the results presented below compare the status of plantings among treatments. Each hypothesis listed above is addressed to the extent that data allow, along with a brief explanatory narrative derived from qualitative observations.

To compare treatments, the two-tailed independent sample t-test was chosen to test the probability that that the observed difference was greater than could be expected due to chance, at a significance level of $p<0.05$ (i.e., there is less than a 5% chance that a difference calculated to be significant is not a real difference between treatments). This parametric test is appropriate because samples were located randomly, sample distributions were reasonably normal, and sample variances were reasonably homogeneous (within a factor of 2-3 of each other) (Elzinga et.al. 2001). For each test, the null hypothesis (H_0) was that treatments were not different from one another. The null hypothesis is most likely to be rejected (i.e., plants within treatments are significantly different from one another) if the difference is large, the monitoring design is efficient (has adequate power), and a sufficient number of transects was monitored.

Native Woody Stem Density and Cover by Treatment

Hypothesis: Increases in stem density, cover, and height classes for native tree, shrub and woody vine species will be greater in irrigated areas than in non-irrigated areas.

Hypothesis: Increases in stem density, cover, and height classes for native woody species will be greater for planted areas than for unplanted areas.

Hypothesis: If SRSP draft performance objectives (guidelines) for riparian planting projects can be met in non-irrigated and unplanted areas, timelines for achieving standards will be longer than for irrigated, planted areas.

Average stem density of native woody species was very similar between irrigated (control) and non-irrigated areas, as was the variability in stem density within each of these treatments (Table 10 and Figure 6). Average cover of native woody species was slightly lower in non-irrigated areas (Table10 and Figure 6). We did not find evidence that differences in native woody stem density or cover between these treatments was statistically significant (p=0.46 and 0.31, respectively). Stem heights were not compared across treatments for this analysis.

Similar stem density across irrigation treatments indicates that plant survival has been comparable. Although the difference in cover is not any greater than may be attributable to chance alone, somewhat lower cover in non-irrigated areas may suggest that these plantings may have slightly lower vigor, as noted on occasion during data collection. Overall, however, results suggest that after one growing season, planting performance is similar whether or not plants are irrigated. Most of the planting area is low elevation and, presumably, water tables are high; plant roots may have grown enough to reach the water table in both treatments, and survival and growth may be responding more to subsurface water availability than to irrigation inputs. Sandbar willow was generally noted to be performing better than other species in non-irrigated areas; this species was by far the most abundant shrub and may be obscuring differences in performance of other species between treatments. Based on the absence of a significant different between native woody plants in irrigated and non-irrigated areas, there is no evidence to date that timelines for achieving performance objectives will be longer in non-irrigated areas.

Caution is warranted on making conclusions based on a single year of data, however. While conditions were abnormally dry by the time of monitoring in 2017 (US Drought Monitor, Western US, 8/22/2017 and 9/26/2017), prolonged high flows made water availability to plants somewhat better later into the summer than usual. Several years of data collected over a variety of water availability circumstances will be most useful.

Similar to irrigation treatments, there was no evidence that differences in native woody stem density or cover between planted controls and "unplanted" areas were statistically significant (p=0.47 and 0.25, respectively). However, as noted above, there were very few transects that happened to intersect with unplanted areas, and statistically significant differences will be hard to detect with such a small sample size. Further, only the part of the unplanted treatment area that was under water during plant installment events was not planted. The area left unplanted corresponded roughly to the bank hydrological zone, while the area corresponding to the overbank hydrozone was planted similar to the rest of the project. The unplanted treatment areas may be most fruitfully tracked using qualitative monitoring.

Noxious Weeds and Native Herb Cover

Hypothesis: Increases in cover of noxious weeds will be greater in irrigated areas than in non-irrigated areas, and in unplanted areas in comparison to planted areas.

Outcomes in comparing noxious weed cover in relation to treatment may be difficult to interpret. This is because a maintenance objective is to adequately control noxious weeds regardless of treatment. Treatments may have similar cover of noxious weeds, but instead have differed in terms of the effort expended to control weeds. Although noxious weed cover did not significantly differ among treatments, project managers noted that non-irrigated areas were more difficult to treat manually for weeds. In particular, fine, dry sediments prevented pulling up a whole tamarisk seedling without breaking the root.

Hypothesis: Increases in cover of native herbaceous species will be greater in planted, irrigated areas than in non-irrigated areas.

The cover of native herbs was not compared across treatments this year. This is because a particularly abundant ladysthumb species was mistakenly assumed to be non-native at the time of monitoring. This species was identified as the native herb curltop ladysthumb after many transects had already been monitored. Because of this, measurements of native herb cover are expected to be inaccurate, and analysis did not proceed further.

Monitoring Design

Hypothesis: The standard sampling rate of seven transects per two acres of planting area used for The Freshwater Trust's standard riparian revegetation projects will be higher than needed at the Bayha Island Research Project to achieve desired confidence and precision for native woody species metric estimates. Because the planting area was newly constructed, it was relatively homogeneous and lacked competing and/or ameliorating vegetation at the time of planting. These factors will likely contribute to lower variability across samples than is typically observed at many revegetation sites; therefore, fewer samples will be needed to attain data confidence and precision objectives at this and similar sites.

IPC's contractor has subcontracted with a statistical expert to complete a review of the quantitative vegetation monitoring procedure used to collect performance and research data at the Bayha Island Research Project. To date, the subcontractor has reviewed this procedure and has developed a statistical data model appropriate to the procedure and expected data characteristics, including model subcomponents for power and cost/benefit analysis. In the second part of this review, to be completed in 2018, the subcontractor will analyze the statistical power of existing data and sampling schemes. These results can provide an indication of the average sample size a study needs to observe a statistically significant result with a desired likelihood, and make recommendations to optimize sampling schemes given logistical constraints. Results also have implications for how research hypotheses addressed here are answered, because they will confirm whether enough samples were collected to adequately detect actual differences between treatments.

2.1.5 Channel Stability

To evaluate the progression of the channel bathymetry near Bayha Island, survey data was collected throughout the project phases of: pre-construction, immediately after construction and approximately one year after construction. The survey information was compiled and sampled at six key cross section locations for comparison (Appendix B). Available survey information of the project area is comprised of:

- Pre-construction survey: bathymetry via single-beam sonar and RTK GPS surveying was collected by IPC in March of 2016; this was combined with aerial LiDAR collected in 2012 by an Idaho Power contractor.
- As-built construction survey: Collected by Idaho Power's construction contractor via RTK GPS; combined with channel bathymetry via single-beam sonar collected by Idaho Power in November, 2016.
- Current Conditions: Single-beam and Multi-beam data collected in August/September, 2017 by Idaho Power and an Idaho Power contractor.

Profiles using the three data survey datasets, at specific cross sections around Bayha Island, are shown on pages 2-4 of Appendix B. Cross section locations were selected based on continuous data coverage from all three data sets. However, some of the profiles did not have continuous data coverage across the entire profile due to surveying constraints. Profiles were developed by gathering the elevation data from surfaces created using the survey data, at each specific cross section. Note that the elevation profiles are displayed using a 5x vertical exaggeration.

RESULTS

Profiles 1-3 show very minimal change to channel form. Profile 4 appears to show some very minimal material deposition between the As-built Conditions and the Current Conditions, along the toe of the bank (about sta. 25 on the x-axis along the profile). Profiles 1-4 demonstrate that, despite the high flow rates experienced during 2017, the constructed portion of the channel and island floodplain were minimally effected. This demonstrates that the design of the channel/floodplain dimensions and zone gravel sizing (gravel that was placed on the channel bottom and banks) were successful to withstand flow rates up to 35,000 cfs, with minimal impact to channel form.

The profiles upstream of Bayha Island, which are mainly outside the extents of construction, experienced noticeable changes. Profile 5 shows (Current Conditions line in red) material deposition on the river left side of the channel thalweg, with some minor erosion up against the river right bank. There are many factors that could contribute to this adjustment in channel form, but there is not enough data available to conclude on the exact cause. The last profile, profile 6, was shown as a reference to an area that was not inside the constructed area. The channel thalweg shifted to river left, with some minor erosion on river left and material deposition on river right. During the high flows experienced in 2017, a portion of the bank along Argy Island sloughed into the river channel, possibly causing the additional material seen on the river right portion of this profile. This material likely transferred some of the river's energy to the river left side of the channel, causing the erosion seen on river left and subsequent shift in the channel thalweg.

Because of the dynamic conditions around Bayha Island, especially upstream near profile 5 and 6, bathymetry data will continue to be collected to document the progress of the project and surrounding area.

2.1.6 Water Level

Water surface elevations near Bayha Island have been monitored starting in mid-June of 2015 through present. The data are scheduled to be collected through September of 2018, when the equipment will be removed. At the time of this analysis, data were only available through September of 2017 due to the frequency of equipment downloading. There are five locations upstream and downstream of the project area where water level loggers (PTs) have been installed and collecting continuous data. The instrumentation records a stage reading (water depth above the orifice) every 15 minutes, which is converted to a water surface elevation via a surveyed correction. The correction from stage to water surface elevation is re-evaluated every 6-8 weeks when the equipment is downloaded. Water level logger locations are shown on Page 2 of Appendix C.

ANALYSIS

To analyze the water surface elevation near Bayha Island, three of the five sites were selected. These sites are:

- PT44040RL: Upstream of Bayha Island, approximately ½ mile.
- PT43982RM: Located on Argy Island, slightly upstream of Bayha Island.
- PT43935RR: Located slightly downstream of Bayha Island.

The time series for each site was divided into pre and post-construction: the pre-construction time frame was established as July 1, 2015 through June 30, 2016 and the post-construction time frame was December 1, 2016 through August 31, 2017. These timeframes were selected because of available data and the period of island construction, which lasted from approximately July 1, 2016 through November 30, 2016.

The water surface elevation from each PT was combined with the Idaho Power “Snake River blw Swan Falls Dam” gage (13172454) to produce a stage-discharge relationship. Typically, field discharge measurements are collected to develop a rating curve (stage-discharge relationship) at a stream gage. However, field discharge measurements were not collected at each site, so the discharge data from the Swan Falls gage was used. The discharge data was visually aligned to the PT data and an average travel time from the gage to the PTs was calculated. The calculated travel time was approximately 5 hours (varying slightly between PT locations). The discharge data was then shifted by the travel time and combined with the PT data to produce the stage-discharge relationship used for the analysis. Note that the “stage” used in this relationship was the actual water surface elevation (vertical datum NAVD88), not the traditional “stage” described as the site-specific water depth.

To compare the pre- and post-construction water surface elevations, scatter plots of the stage-discharge relationship were created. These plots were created with hourly data, which was converted from 15-minute data by averaging over each hour. The scatter plots were created for the following season/months:

- Spring: March, April and May
- Summer: June, July and August

The spring months appear to follow a visible trendline. As the spring progresses into summer, the data starts to become very clumped and tends to diverge from the trendline. The data typically returns to the trendline relationship in later winter/ early spring. The trend can be attributed to the growth cycle of aquatic macrophytes during the summer months. The aquatic macrophyte cycle typically starts with establishment and growth in the summer, recession in the fall/winter and occasional removal by spring high flows. Therefore, the summer months are typically highly affected by aquatic macrophytes due to low summertime flows and high water temperatures promoting growth. The growth of the macrophytes cause a divergence from the typical stage-discharge relationship by causing the water surface elevation to increase throughout the growing season for the same flow rate. This causes the stage-discharge data to clump, giving multiple water surface elevations for the same flow rate throughout the growth season. The increase in water surface elevation is due to an increase in channel roughness as the macrophytes grow, which decreases the channel's conveyance. This relationship is an important consideration when evaluating the water surface elevations in the Snake River.

RESULTS

The scatter plots for the PT sites are located on pages 2 through 7 of Appendix C. For both the pre- and post-construction timeframes, the spring stage-discharge plots show very similar results. The plotted data for both timeframes follows the same general trend, even though the magnitude of discharges experienced between years varies significantly.

The summer month plots differ between the pre- and post-construction. For the pre-construction timeframe, there is a visible shift ranging from approximately ½ ft. to 1 ft. for the months of June to August. For the post-construction phase, this shift was considerably less, ranging from ¼ ft. to ½ ft. for the months of July to August. This shift, for both timeframes, is due to the establishment and growth of the macrophytes. It appeared that in 2017, the macrophytes did not start having a visible effect on the water surface elevation until August, rather than starting in July as in previous years.

The reduction in timing and magnitude of the shift caused by aquatic macrophytes, from pre-construction to post-construction, can be seen at all analyzed PT locations. This indicates the shift is due to the high spring discharges experienced during 2017, which either limited the growth or removed a substantial amount of the macrophytes in this reach. Because of the variability from year to year of the river conditions in the Snake River, such as experienced in 2017, water surface elevations will continue to be monitored and analyzed at the current PT locations.

3.0 TRIBUTARY PROJECTS

IPC implemented one tributary project in 2016 and one in 2017 adjacent to the Powder River in eastern Oregon.

3.1 Powder River River Mile 9.8

The Powder River River Mile 9.8 site is located on IPC's Daly Creek Habitat Management Area (HMA) near Richland, Oregon adjacent to the confluence of the Powder and Eagle Rivers (Figure 2). This site was implemented while still developing a majority of the design, monitoring, and reporting tools; implementation of this project was used to inform development of the tools. The site was implemented in accordance with the proposed restoration quality standards and guidelines; documentation will be submitted to the DEQs for thermal benefits.

IPC planted approximately 1.6 acres of riparian vegetation along the edge of the Powder River in October 2016 (Table 11). High flows combined with ice and channel forming events during the 2016/17 winter eliminated roughly half of the original planting area. Originally, 2,000 native trees and shrubs were planted primarily on the overbank zone using hoedads. The area was sprayed with herbicide prior to implementation to eliminate competing vegetation and then disked to reduce compaction within the planting area. Drip supply lines with built in emitters (12” spacing) are staked near each plant and all plants were watered shortly after planting. All original tree/shrub rows were protected with 6-foot fabric mulch that was tucked in on all sides to prevent wind damage. After high flow events during the winter 2016/17 season, the site ended up being roughly one acre in size with roughly 1,093 plants from the original planting and supplemental planting during the 2017 season.

One growing season after planting, the site is on track to meet all Year 5 performance targets. Table 12 provides vegetation monitoring results in comparison to draft SRSP performance objectives (guidelines). Quantitative monitoring was conducted on August 8, 2017. Measurements of site average native woody stem density, shrub and woody vine cover, and canopy closure are provided in Table 13. Native woody plant height is provided in Table 14 to support comparison with future years, as an indicator of vigor. Within monitoring transects, 12 native woody species were documented in the planting area (Table 14). Canada thistle and scotch thistle were each recorded at less than 1% cover (Table 15). Photo point monitoring is provided in Appendix D.

Maintenance at the site was conducted throughout the year and more intensively from June through early October. Maintenance activities included:

- Operation and maintenance of the irrigation system. Irrigation was conducted twice a week at a minimum; additional irrigation was conducted based on plant health and weather.
- Inspection and maintenance of browse control.
- Noxious weed control.
- Light pruning, deadheading, and general tree care for planted nursery stock.

Maintenance and monitoring will be conducted in 2018 and will be ongoing through the life of the license. Maintenance activities in 2018 will focus on irrigation and noxious weed control and browse protection if necessary. Qualitative monitoring will occur monthly during the growing season (approximately May – October).

3.2 Powder River River Mile 44.8

The Powder River RM 44.8 project site is in the Keating Valley in eastern Oregon. The approximately 3.1-acre site was planted from October 23 – October 27, 2017, and both sides of the river bank were planted (Figure 3 and Table 16). The site is expected to produce thermal benefits of 85,303,050 kcals/day if the site maintains a positive trajectory towards project objectives. A comparison of as-built conditions at the project site to Draft Restoration Quality Standards and Guidelines for riparian restoration projects is included in Table 17. Pre-project photo points are provided in Appendix E.

Maintenance and monitoring will be conducted in 2018 and will be ongoing through the life of the license. Maintenance activities in 2018 will focus on irrigation and noxious weed control and browse protection if necessary. Qualitative monitoring will occur monthly during the growing season (approximately May – October) and quantitative monitoring will be conducted in the summer.

4.0 THIRD-PARTY AUDIT

IPC is preparing a Request for Proposal to hire a third-party auditor to audit Bayha Island and the Powder and Weiser River tributary projects in 2018. The auditor will be responsible for confirming that the Bayha Island Research Project and tributary projects located in the Weiser and Powder River basins have been implemented as designed and are performing consistent with SRSP standards. The auditor will also prepare a lessons learned document on the audit process and make recommendations to improve the audit process. Results of the audit will be used to assist IPC with development of SRSP tools and documentation of thermal credits.

5.0 LITERATURE CITED

Elzinga, C.L., D.W.Salzer, J.W. Willoughby, and J.P. Gibbs. 2001. *Monitoring Plant and Animal Populations*. Blackwell Science, Inc. Malden, MA.

US Drought Monitor, Western US, 8/22/2017 and 9/26/2017; http://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?West; accessed 11/26/17.

Table 1
Instream Project Summary

Project Name	Project Type	Project Status	Project Size (acres)	As-built Thermal Benefits	Notes
Snake River RM 439.5	Floodplain creation	Constructed - 2016 Monitoring and Maintenance - 2017	7.4 acres	183,061,106 kcal/day	Third-party audit to verify thermal benefits will occur in 2018

Table 2
Tributary Project Summary

Project Name	Project Status	Project Size	Modeled Thermal Benefits (kcal/day)	As-built Thermal Benefits (kcal/day)	Notes
Powder River RM 9.8	Constructed - 2016 Monitoring and Maintenance - 2017	1 acre	NA	5,185,382	Third-party audit to verify thermal benefits will occur in 2018
Powder River RM 44.8	Constructed October 2017	3.1 acre	NA	13,649,843	Third-party audit to verify thermal benefits will occur in 2018

Table 3.
Bayha Island vegetation monitoring results compared to SRSP draft performance objectives (guidelines) for actively restored riparian forest restoration projects. Objectives are not required to be met, but are instead intended to facilitate interpretation of monitoring results so that program goals are achievable over the full term of the SRSP (expected to be 40 years).

METRIC	PERFORMANCE OBJECTIVE				SURVEY ESTIMATE	MEETS/ ON TRACK TO MEET CRITERIA[3]
	YEAR 5	YEAR 10	YEAR 15	YEAR 20		
% canopy closure or cover	To be developed and refined through data collected during research project implementation.				1% closure	N/A
Combined live, native shrub and woody vine cover	≥ 25% cover				9% cover	Not yet met
% cover of noxious[4] woody species	≤ 10% cover				2.4% cover	Met
% cover of noxious herbaceous species	≤ 20% cover				0.6% cover	Met

Table 4.
Bayha Island monitoring results of metrics related to native woody structure.

METRIC	2017			
	YEAR 1	80% CONFIDENCE INTERVAL	SE	CV
All native woody stems/acre (trees, shrubs, and woody vines)[a]	2,821	(2,277 – 3,365)	414	0.75
Native tree stems/acre[a]	224	(145 – 304)	60	1.37
Native shrub and woody vine % cover[a]	9	(7 – 12)	2	1.12
% canopy closure	1	(0.4 – 1)	0.23	1.81

[a] Plants <6 inches tall are not measured; many small, live plants may not be counted in early surveys. Early-year cover estimates are expected to be low as plantings are still establishing root systems, and have not grown substantial above-ground biomass.

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[3] As documented in the monitoring procedure, the objective is met if any part of the 80% confidence interval meets the objective.

[4] Noxious species are those indicated by the Idaho or Oregon Departments of Agriculture on their respective noxious weed lists.

Table 5.
Bayha Island height of native and non-native, non-noxious trees stems and shrub and woody vine cover, including planted and naturally recruited plants as well as those that pre-existed the project.

HEIGHT CATEGORY	YEAR 1 (2017)	
	TREE STEMS/ACRE	SHRUB AND WOODY VINE % COVER
6 in. – 3 ft.	137	2
3 ft. – 7 ft.	88	7
7 ft. – 10 ft.	0	0
10 ft. – 15 ft.	0	0
15 ft. – 25 ft.	0	0
> 25 ft.	0	0

Table 6.
Bayha Island native and non-native, non-noxious tree stem density and shrub and woody vine cover by species.

SPECIES	YEAR 1 (2017)	
	TREE STEMS/ACRE	SHRUB AND WOODY VINE % COVER
Unknown tree	6	N/A
water birch	2	N/A
redosier dogwood	N/A	<1
Fremont's cottonwood	15	N/A
black cottonwood	59	N/A
peachleaf willow	50	N/A
sandbar willow	N/A	9
pacific willow	94	N/A
arroyo willow	N/A	<1

yellow willow	N/A	<1
unknown willow	N/A	<1

Table 7.
Bayha Island average percent cover of noxious woody and herbaceous species. Noxious species are those indicated by the Idaho or Oregon Departments of Agriculture on their respective noxious weed lists.

SPECIES	2017			
	YEAR 1	80% CONFIDENCE INTERVAL	SE	CV
saltcedar	2.4	(1.7 – 3.0)	0.5	1.04
TOTAL NOXIOUS WOODY % COVER	2.4	(1.7 – 3.0)	0.5	1.04
Canada thistle	<0.1	(<0.1 – <0.1)	<0.1	3.61
perennial pepperweed	0.2	(<0.1 – 0.4)	0.1	3.37
purple loosestrife	0.3	(0.1 – 0.5)	0.1	2.11
TOTAL NOXIOUS HERBACEOUS % COVER	0.6	(0.3 – 1.0)	0.3	2.17

Table 8.
Bayha Island average percent cover of other herb cover types.

HERBACEOUS FUNCTIONAL GROUP	2017			
	YEAR 1	80% CONFIDENCE INTERVAL	SE	CV
Ground substrate[a]	45.8	(41.6 – 50.1)	3.2	0.36
Non-native, non-invasive herbs (incl. seeded spp., if any)[b]	30.4	(26.0 – 34.7)	3.3	0.56
Native herbs (incl. seeded spp., if any) [b]	3.2	(2.3 – 4.0)	0.6	1.01
Seeded native herbs	0.4	(0.2 – 0.6)	0.2	2.05
Seeded non-native herbs	n/a	n/a	n/a	n/a

[a] Ground substrate includes bare ground, cobble, wood, plant litter, non-vascular plants, mulch, and other surface types that could potentially be vegetated.

[b] Non-native, non-invasive herb cover mistakenly included the naturally recruited native herb *Persicaria lapathifolia* (curltop ladysthumb), which was assumed to be a non-native *Persicaria* species at the time of monitoring, but was identified with a technical key after data collection. Because this species was relatively abundant, much of the non-native, non-invasive cover recorded is probably native.

Table 9.
Bayha Island maintenance actions taken at the project site over the growing season.

MAINTENANCE ACTION	TIMING	ACTION SUMMARY
Irrigation	Jul. 8 through Oct. 26	16,200 gal/week from Jul. through Sep. 12,096 gal/week from Oct. 1-26. Watering occurred approx. three to four times per week, although not all parts of the planting area were watered every time. Plants typically were watered 2 times per week. Irrigation pump partially submerged and repaired, intake propeller blocked and repaired, numerous clogged nozzles cleared, pumps winterized.
Herbicide application	N/A	N/A
Mowing/mechanical treatment	Jul. 8 through Oct. 26	Hand pulling noxious weeds >640 hrs. (Hours tracked only for that part of the season after which maintenance digital app became available.)
Fertilizer	N/A	N/A
Mulch	N/A	N/A
Fencing/browse control	Jul. 8 through Oct. 26 Aug. 3 Oct. 10-12	Vole guards removed; deemed unnecessary due to observed lack of vole and other small rodent presence on the islands. Removal of damaged fencing, repair of fence on NE side of island, installation of small fence on SW side of island. Salvage of beaver cages affected by flood waters and re-install on fall plantings.
Interplanting/seeding	Jul. 8 through Oct. 13 Sep. 5-8	2,029 plants installed 10 lbs. of native seed spread, including both a wetland and upland seed mix
Other actions	Oct. 30-31 Nov. 29	Break down and demobilization of 6,000 lbs. of fencing and irrigation equipment. Monitoring trials implemented that will allow tracking of tamarisk seedling response to flood inundation frequencies and duration.

Table 10.
Bayha Island native woody stem density and cover by treatment. The control was irrigated and planted.

METRIC	CONTROL	NON-IRRIGATED	"UNPLANTED"
Avg. native woody stems/acre (Standard Error)	3490 (647)	3403 (640)	7569 (4613)
Avg. native woody % cover (Standard Error)	12 (4)	9 (3)	13 (9)
# samples (transects)	11	12	3

Table 11.
Plant species, quantities (before flood event), stock types and sizes, and planting plan for the Powder River RM 9.8 Project.

Scientific name	Common name	Stock type and size	Quantity
Zone overbank **1.6 Acres** *Relatively flat topography with pasture/riparian mix grasses*			
Tree Species			
Populus trichocarpa	Black cottonwood	9 cubic inch plug	169
Salix amygdaloides	Peachleaf willow	9 cubic inch plug	95
Alnus incana	Thin-leaf Alder	9 cubic inch plug	78
Betula nigra	River Birch	9 cubic inch plug	44
Acer glabrum	Rocky mtn. maple	9 cubic inch plug	60
TOTAL			**446**
Shrub Species			
Salix exigua	Coyote willow	9 cubic inch plug	360
Salix spp.	Assorted willow	9 cubic inch plug	225
Philadelphus spp.	Syringa	9 cubic inch plug	110
Prunus virginiana	Chokecherry	9 cubic inch plug	72
Amilanchier alnifolia	Serviceberry	9 cubic inch plug	17
Crataegus douglasii	Black Hawthorne	9 cubic inch plug	76
Cornus sericea	Redosier Dogwood	9 cubic inch plug	159
Ribes auruem	Golden Current	9 cubic inch plug	150

Rosa woodsii	Woods Rose	9 cubic inch plug	135
TOTAL			**1,304**

Table 12.
As-built conditions at Powder River RM 9.8 compared to Draft Restoration Quality Standards.

Metric	Draft Quality Standard	As-Built Condition	Meets Standard
Plant materials are selected to ensure local adaptability and maximize long-term ecosystem impact.	• Local, native-derived plant material will be utilized, unless unavailable or otherwise impossible. Plant material from within the same EPA level III ecoregion as the project site is highly preferred. • Locally harvested cuttings from appropriate native species may be used to supplement plantings. • Transplanted shrubs may be used to supplement plantings if native materials are abundant and they come from outside the bankfull width.	• All plants installed are native plants sourced from 11d, the same EPA level II ecoregion as the project site.	Yes
Project will result in increased stream shade and canopy cover.	Plant approximately 400-600 native trees/acre, unless passive restoration is expected to lead to same density at Year 5.	278 native trees were planted per acre for the approx. 1 acre remaining after high water event	Yes
Project will result in increased native woody species presence.	Plant approximately 1,000-1,200 native shrubs/acre, unless passive restoration is expected to lead to same density at Year 5.	815 native shrubs were planted per acre for the approx. 1 acre remaining after high water event	Yes
Project will result in increased native woody species diversity.[5]	Plant at least 5 native woody species, 2 of which will be trees.	4 tree (*Populus trichocarpa, Salix amygdaloides, Alnus incana, and Betula occidentalus*) and 9 shrub species (*Salix exigua, Salix* spp., *Acer glabrum, Prunus virginiana, Amilanchier alnifolia, Crataegus douglasii, Cornus sericea, Ribes*	Yes

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[5] Species composition, diversity and distribution will be informed by references site conditions from sites with characteristics similar to project site and within the same HUC-5 watershed. Naturally recruited and regenerated species are included in project design and implementation standard.

		auruem, Rosa woodsia) were planted.	
Target vegetation structure is guided by reference site conditions.	Reference site conditions have environmental characteristics similar to revegetation site and are located within the same HUC 5 watershed.	Target vegetation selection based on existing vegetation in the area and professional experience at Daly Creek.	Yes
Limiting factors that have resulted in loss of riparian function have been addressed.	Factors that have contributed to poor riparian structure, such as unfavorable soil conditions, spray drift, high browse pressure, and noxious weed encroachment are considered in project design.	Historic browse pressure from cattle, high soil compaction, and invasive weed presence.	Yes

Table 13.
Powder River RM 9.8 performance summary.

Metric	Average	SE	80% Confidence Interval	CV
Native woody stems/acre	1,035	206	646-1423	0.35
Native tree stems/acre	182	73	45-318	0.69
Native shrub and woody vine % cover	0.84	0.84	-0.74 – 2.42	1.73
% Canopy closure	9.52	9.36	-8.1 -27.14	1.7
Invasive herbaceous species % cover	0.67	0.44	-0.13 – 1.5	1.15
% Cover planted native trees: 6 in. to <3 ft.	1.67	1.67	-1.47 – 4.81	1.73

Table 14.
Powder River RM 9.8 woody stems per acre in height class and average stems per acre by species.

Species Name	6 in. - 3 ft.	3 ft. - 7 ft.	Avg stems/ acre
Unknown tree	18		18.15
mountain alder	73		72.6
Saskatoon serviceberry	36		36.3
water birch	18		18.15
redosier dogwood	127		127.05
black hawthorn	73	18	90.75
mock orange	18		18.15
black cottonwood	54	36	90.75
western chokecherry	73		72.6

rose - native	36		36.3
Wood's rose	91		90.75
sandbar willow	54	18	72.6
Willow sp.	254	36	290.4

Table 15.
Powder River RM 9.8 percent cover invasive and target species summary.

Name	Avg % cover	SE	CI: low	CI: high	CV
Canada thistle	0.17	0.17	-0.15	0.48	1.73
Scotch thistle	0.5	0.5	-0.44	1.44	1.73
% cover invasive herbaceous species	0.67	0.44	-0.16	1.5	1.15

Table 16.
Plant species, quantities, stock types and sizes for Powder River RM 44.8.

Scientific name	Common name	Stock type and size	Quantity
Tree Species			
Populus trichocarpa	Black cottonwood	9 cubic inch plug	450
Salix amygdaloides	Peachleaf willow	9 cubic inch plug	500
Alnus incana	Thin-leaf Alder	9 cubic inch plug	100
Alnus rhombifolia	White Alder	9 cubic inch plug	120
Betula occidentalus	River Birch	9 cubic inch plug	160
TOTAL			**1,330**
Shrub Species			
Salix exigua	Coyote willow	9 cubic inch plug	120
Salix spp.	Assorted willow	9 cubic inch plug	500
Acer glabrum	Rocky Mountain Maple	9 cubic inch plug	100
Prunus virginiana	Chokecherry	9 cubic inch plug	210
Amilanchier alnifolia	Serviceberry	9 cubic inch plug	100
Sambucus spp.	Elderberry	9 cubic inch plug	300
Cornus sericea	Redosier Dogwood	9 cubic inch plug	400
Ribes auruem	Golden Current	9 cubic inch plug	400
Rosa woodsii	Woods Rose	9 cubic inch plug	310
TOTAL			**2,440**

Table 17.
As-built conditions at Powder River RM 44.8 compared to Draft Restoration Quality Standards.

Metric	Draft Quality Standard	As-Built Condition	Meets Standard
Plant materials are selected to ensure local adaptability and maximize long-term ecosystem impact.	• Local, native-derived plant material will be utilized, unless unavailable or otherwise impossible. Plant material from within the same EPA level III ecoregion as the project site is highly preferred. • Locally harvested cuttings from appropriate native species may be used to supplement plantings. • Transplanted shrubs may be used to supplement plantings if native materials are abundant and they come from outside the bankfull width.	• All plants installed are native plants sourced from 11d, the same EPA level II ecoregion as the project site.	*Yes*
Project will result in increased stream shade and canopy cover.	Plant approximately 400-600 native trees/acre, unless passive restoration is expected to lead to same density at Year 5.	427 native trees were planted per acre	*Yes*
Project will result in increased native woody species presence.	Plant approximately 1,000-1,200 native shrubs/acre, unless passive restoration is expected to lead to same density at Year 5.	784 native shrubs were planted per acre	*Yes*
Project will result in increased native woody species diversity.[6]	Plant at least 5 native woody species, 2 of which will be trees.	5 tree (*Populus trichocarpa, Salix amygdaloides, Alnus incana, Alnus rhimbifolia,* and *Betula occidentalus*) and 8 shrub species (*Salix exigua, Acer glabrum, Prunus virginiana, Amilanchier alnifolia, Sambucus spp., Cornus sericea, Ribes auruem, Rosa woodsia*) were planted.	*Yes*
Target vegetation structure is guided by	Reference site conditions have environmental characteristics similar to	Reference site conditions were derived from reference site	Yes

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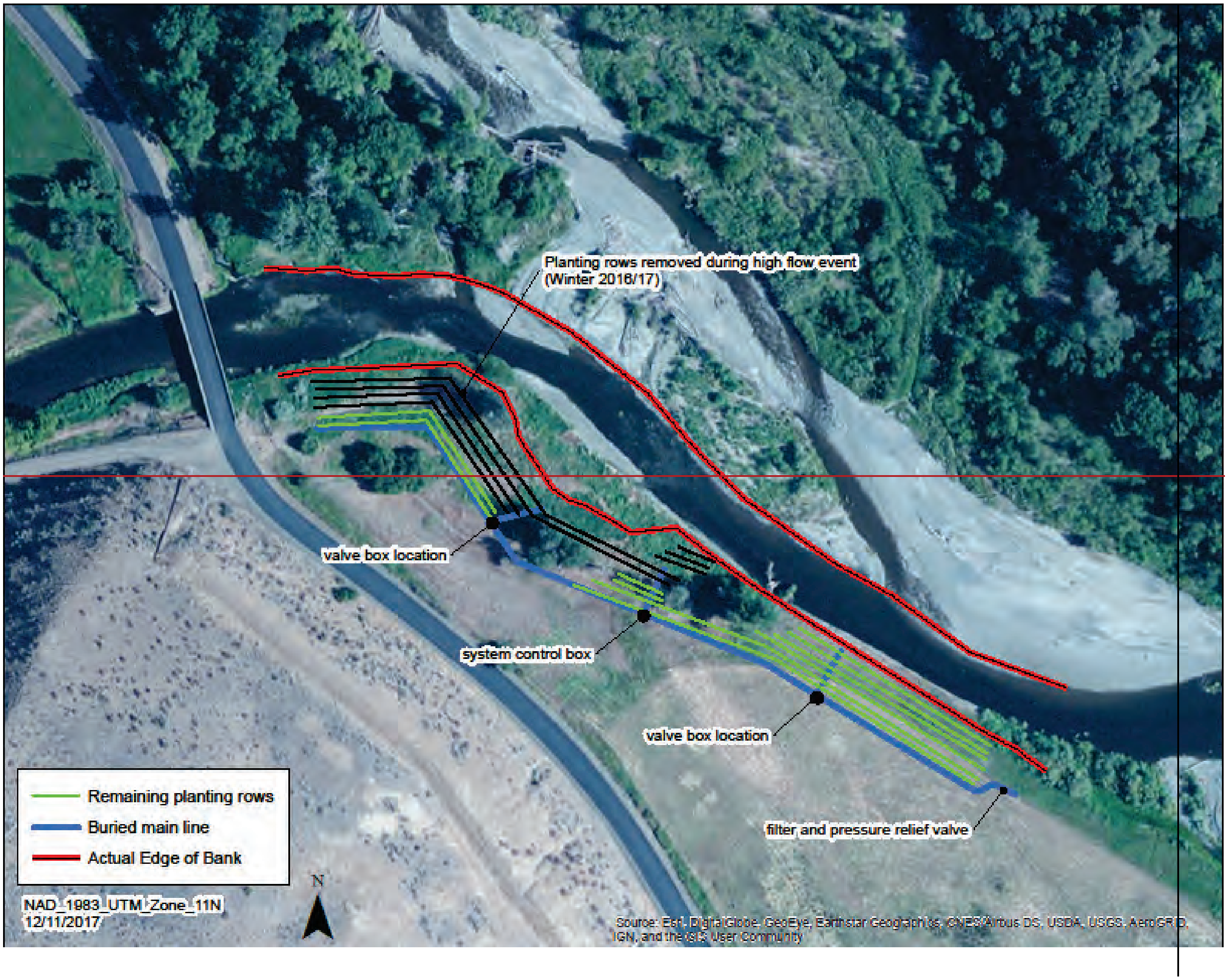
[6] Species composition, diversity and distribution will be informed by references site conditions from sites with characteristics similar to project site and within the same HUC-5 watershed. Naturally recruited and regenerated species are included in project design and implementation standard.

reference site conditions.	revegetation site and are located within the same HUC 5 watershed.	surveys conducted within the Powder River area.	
Limiting factors that have resulted in loss of riparian function have been addressed.	Factors that have contributed to poor riparian structure, such as unfavorable soil conditions, spray drift, high browse pressure, and noxious weed encroachment are considered in project design.	The site has historic browse pressure from cattle, high soil compaction, and invasive weed presence. Fencing, planting methods, and ongoing noxious weed control have, and will continue to, address limiting factors.	Yes

Figure 1
Bayha Island Research Project

Figure 2
Powder River RM 9.8 Plant Layout



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 3
Powder River RM 44.8 Plant Layout

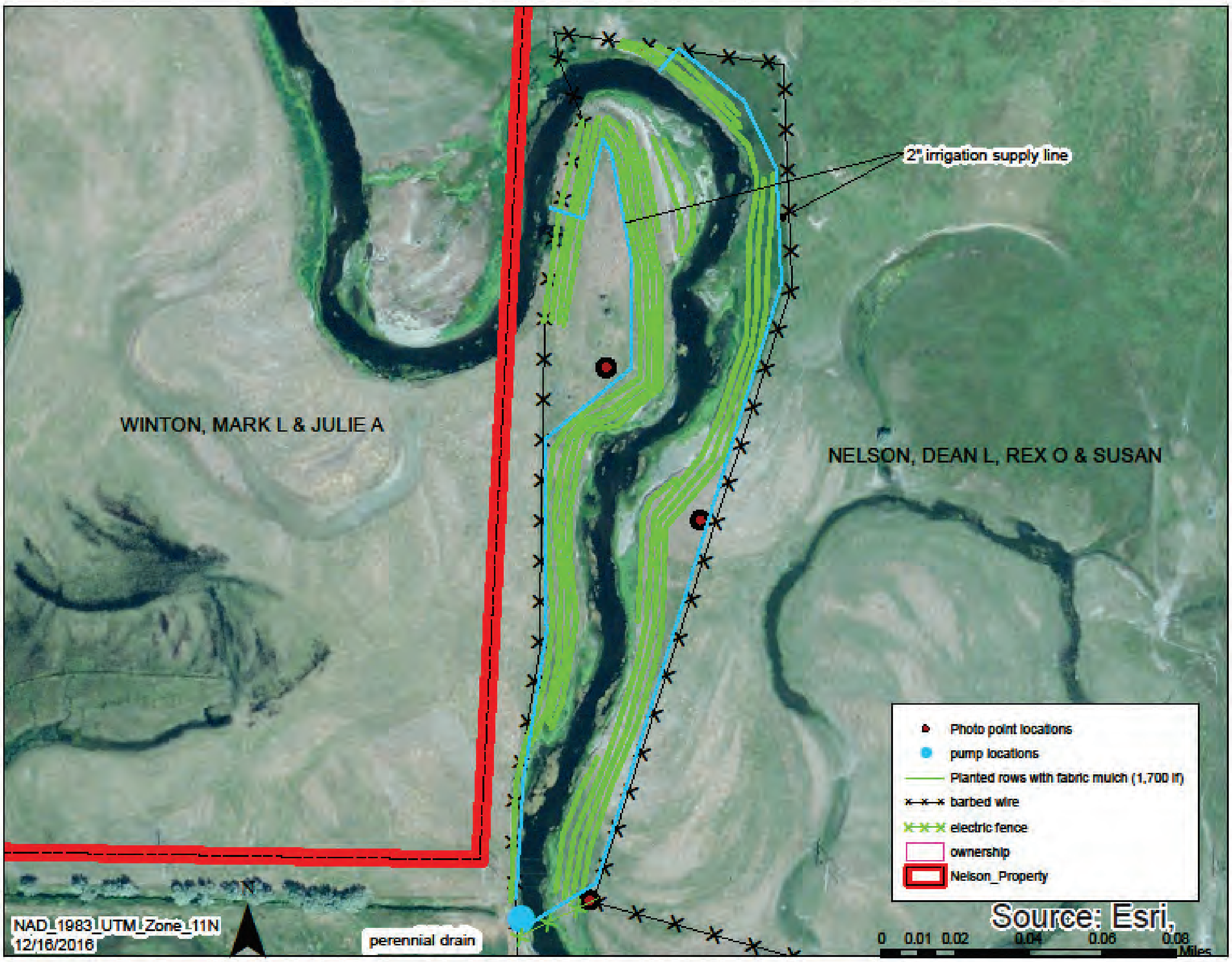


Figure 4
Bayha Island Research Project Vegetation Monitoring and Camera Point Locations

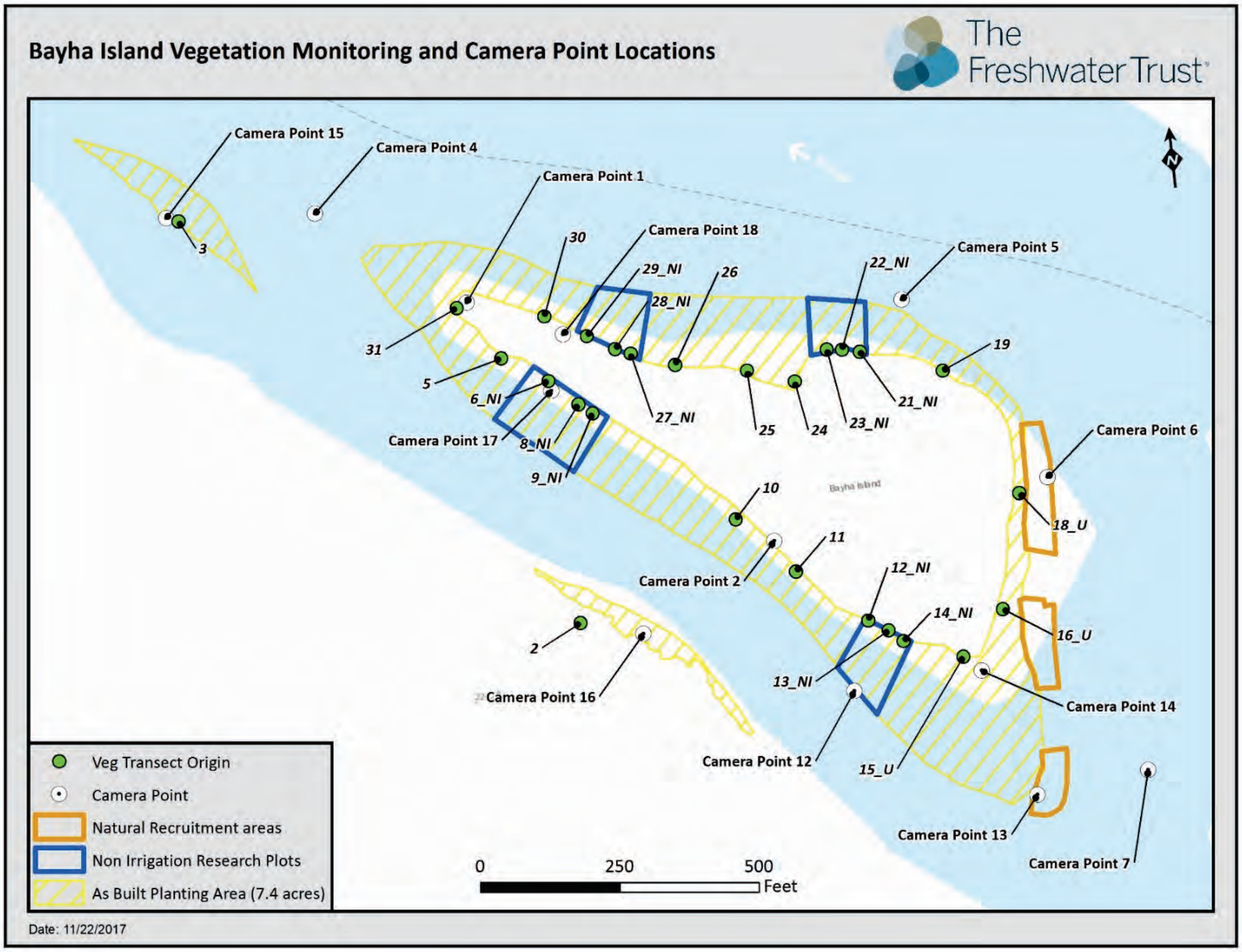


Figure 5
Flows, in cubic feet per second, for the first year of the Bayha Island Research Project

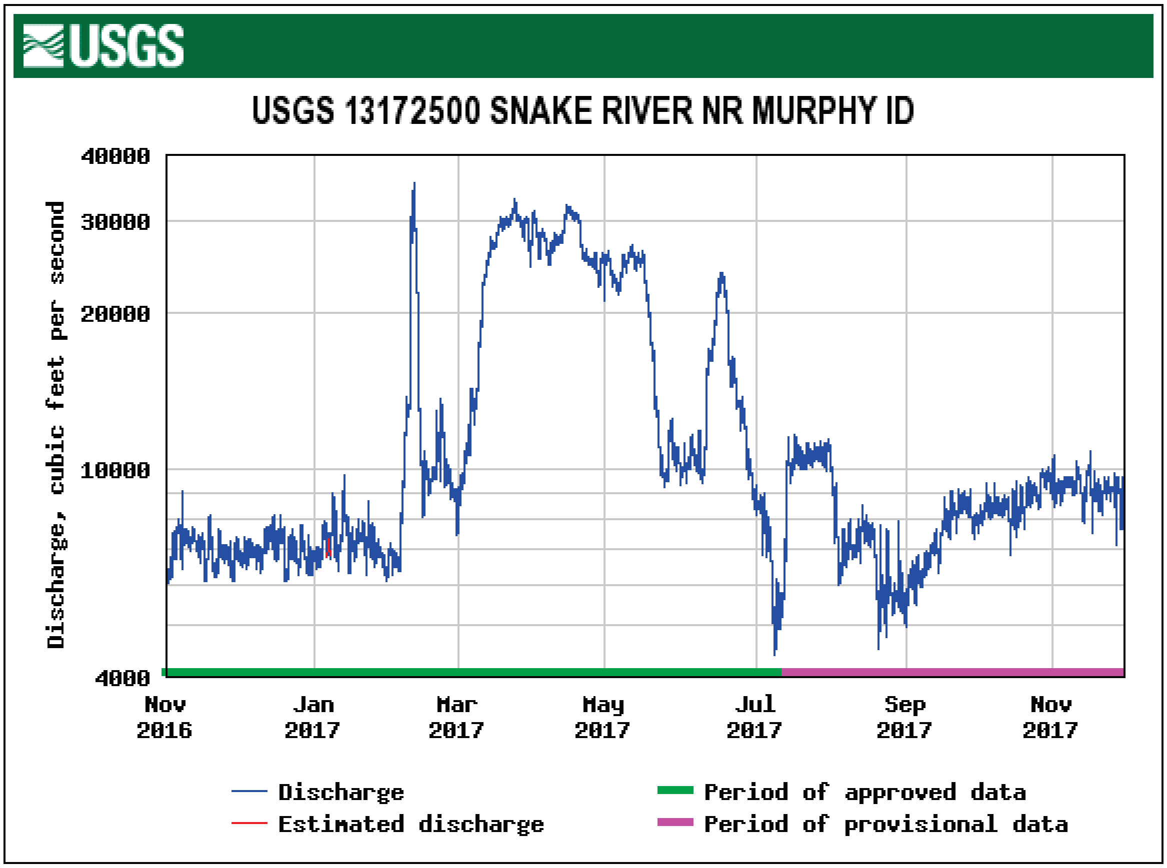
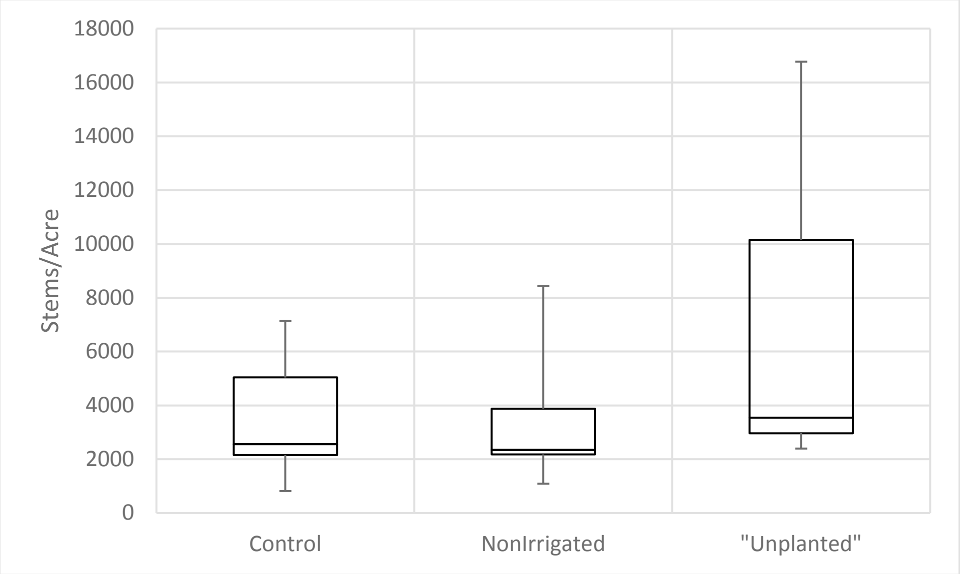


Figure 6
Box and whisker plots showing native woody stem density by treatment.



The control was irrigated and planted. Lower boxes represent the bottom 25% of measurements, upper boxes represent the top 25% of measurements, and horizontal bars represent the median value of each set of samples. Bars indicate minimum and maximum measurements.

Appendix A
Bayha Island Research Project Photo Point Monitoring Report.

Note that Photo Points 8-11 are not included in the report. They were collected from private property during the pre-construction survey and were deleted due to access constraints.

The Freshwater Trust®

This report has been generated by The Freshwater Trust's StreamBank Monitoring App.

Snake River RM 439.5 (Bayha Island Project)
Middle Snake-Boise
River: Snake River
Reach number/name: Reach 1
Implementation start date: 07/11/2016

Procedure Name: Photo Point
Photo Point monitoring purpose: Year 1
Number of camera points: 14
Surveyor(s): Hilary Cosentino, Katelyn Detweiler
Date surveyed: 09/25/2017

Photo Points

Camera Point 1 (43.37082°, -116.6285°) Bank : River Center

A - Nw or downstream 322° Year 1


09/27/2017 10:48 PM

Figure 1.

B - Left 218° Year 1


09/27/2017 10:48 PM

Figure 2.

C - Upstream 153° Y ear 1


09/27/2017 10:48 PM

Figure 3.

D - Across upstream 83° Y ear 1


09/27/2017 10:48 PM

Figure 4.

E - Across 7° Y ear 1

Figure 5.

Camera Point 2 (43.36948°, -1 16.62662°) Bank : River Left

A - Across 222° Y ear 1

Figure 6.

B - Up across 162° Y ear 1

Figure 7.

C - Across 56° Y ear 1

Figure 8.

D - Down 322° Year 1

Figure 9.

Camera Point 3 (43.36989°, -1 16.12724°) Bank : River Left

A - Down 290° Year 1

Figure 10.

B - Up 153° Year 1

Figure 11.

Camera Point 4 (43.37134°, -1 16.62945°) Bank : River Left

A - Across, looking at right bank 186° Year 1

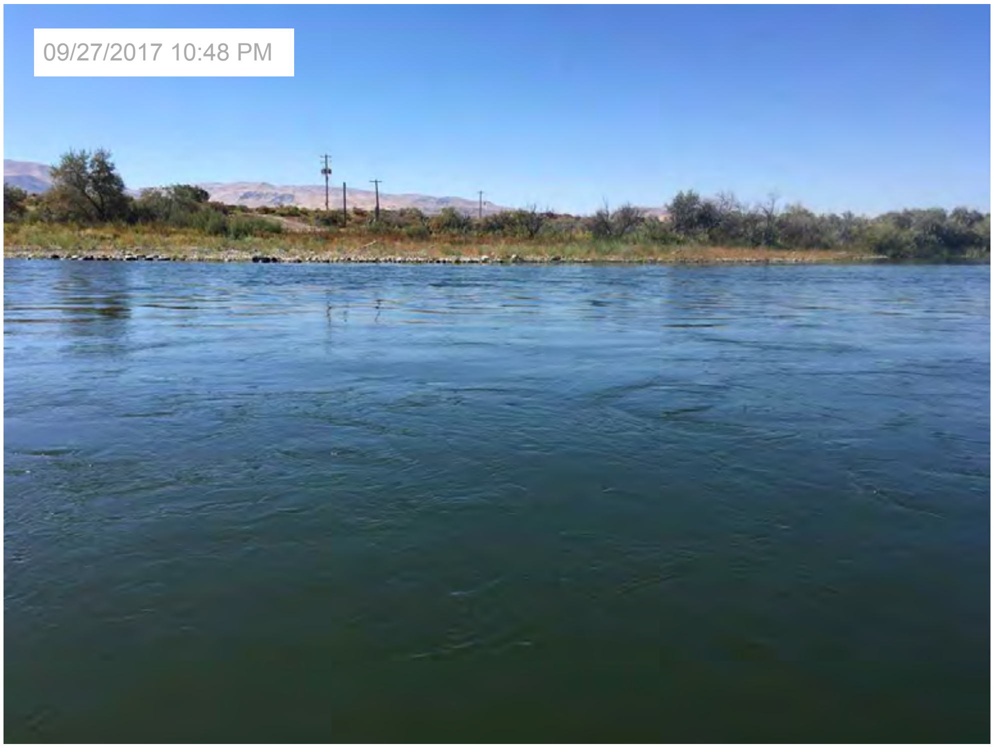


Figure 12.

B - Across and downstream 252° Y ear 1

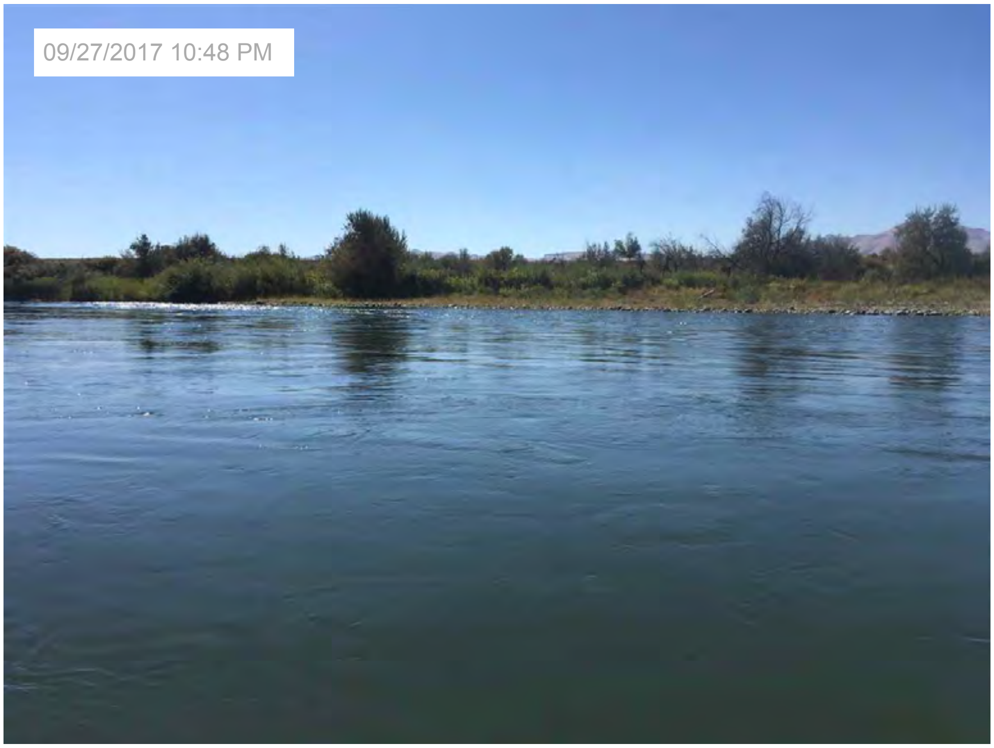


Figure 13.

Camera Point 5 (43.37059°, -1 16.62558°) Bank : River Right

A - Across inland 208° Y ear 1

Figure 14.

B - Down 264° Year 1

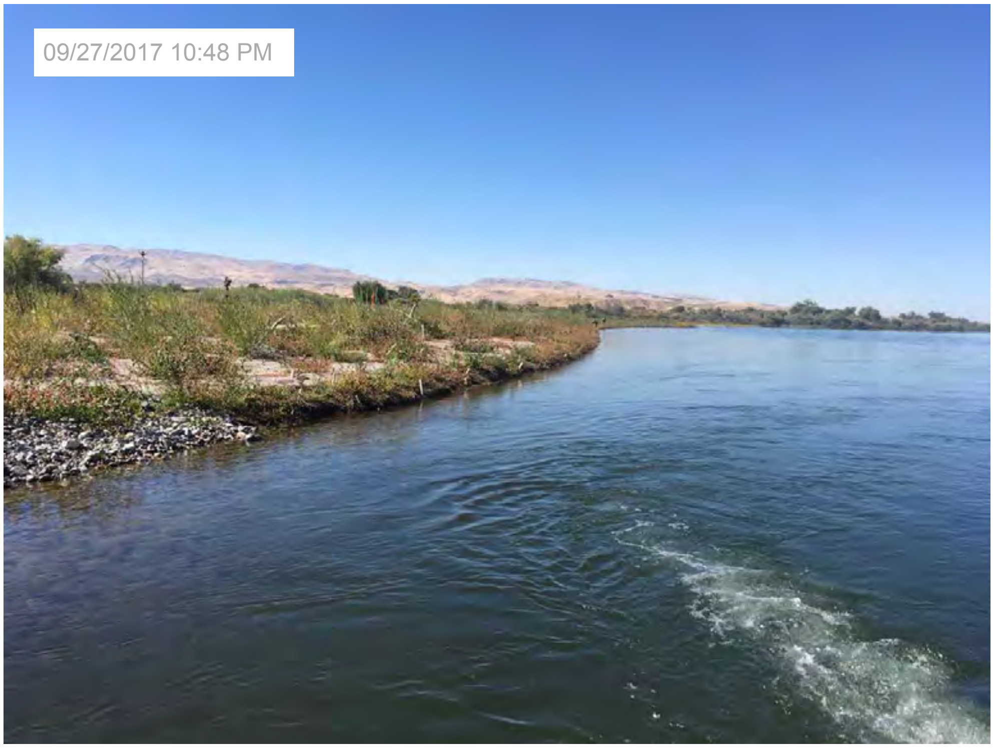


Figure 15.

C - Up 132° Year 1

Figure 16.

Camera Point 6 (43.36964°, -1 16.62474°) Bank : River Right

A - Up across 206° Y ear 1

Figure 17.

B - Down 336° Y ear 1

Figure 18.

Camera Point 7 (43.36815°, -1 16.62429°) Bank : River Center

A - Across 238° Y ear 1

Figure 19.

B - Across down 270° Y ear 1

Figure 20.

C - Down 300° Year 1

Figure 21.

D - Down 248° Year 1

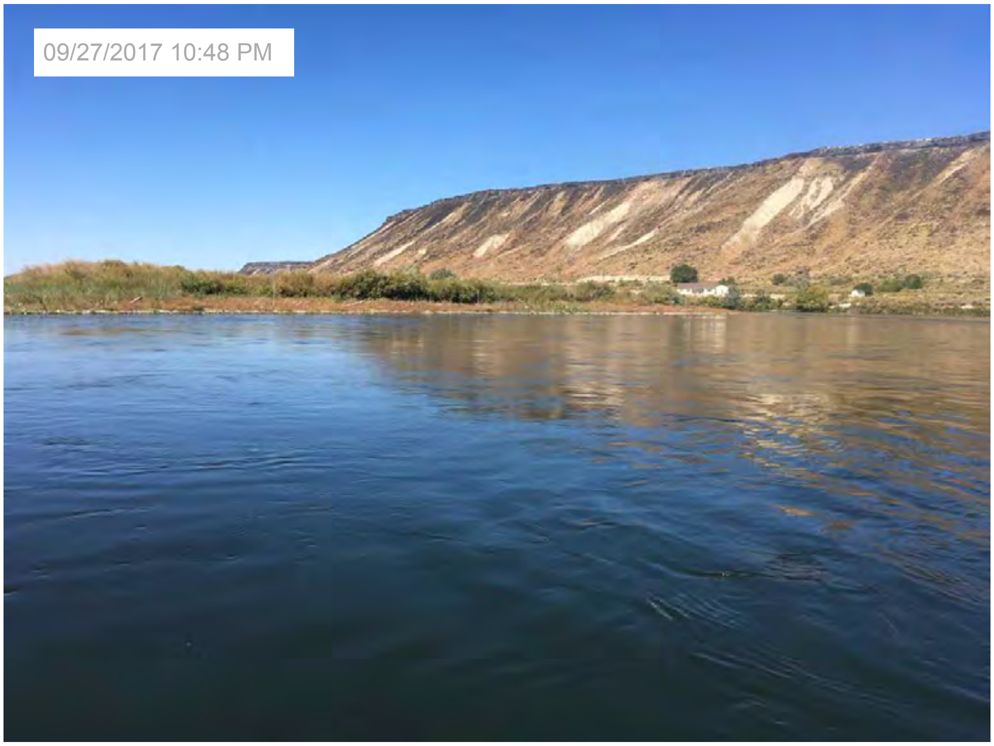


Figure 22.

Camera Point 12 (43.3687°, -1 16.6262°) Bank : River Right

A - Downstream Inland 351° Y ear 1

Figure 23.

B - Upstream Diagonal Inland 102° Y ear 1

Figure 24.

C - Downstream Across - Mainland 293° Y ear 1

Figure 25.

Camera Point 13 (43.36809°, -1 16.62505°) Bank : River Center

A - Downstream river left 304° Y ear 1

Figure 26.

B - Downstream inland 350° Y ear 1

Figure 27.

Camera Point 14 (43.36873°, -1 16.62533°) Bank : River Center

A - Across river right 54° Y ear 1

Figure 28.

B - Upstream diagonal 166° Year 1

Figure 29.

C - Downstream across 270° Year 1

Figure 30.

Camera Point 15 (43.3714°, -116.63045°) Bank : River Left

A - Downstream Across 8° Year 1

Figure 31.

B - Upstream Across 114° Year 1

Figure 32.

Camera Point 16 (43.3691°, -1 16.62757°) Bank : River Left

A - Across 45° Year 1

Figure 33.

B - Downstream 324° Year 1

Figure 34.

C - Upstream 103° Year 1

Figure 35.

Camera Point 17 (43.37034°, -1 16.628°) Bank : River Right

A - Upstream 144° Y ear 1

Figure 36.

B - Downstream 301° Y ear 1

Figure 37.

Camera Point 18 (43.37061°, -1 16.62788°) Bank : River Left

A - Downstream 328° Y ear 1

Figure 38.

B - Across 30° Y ear 1

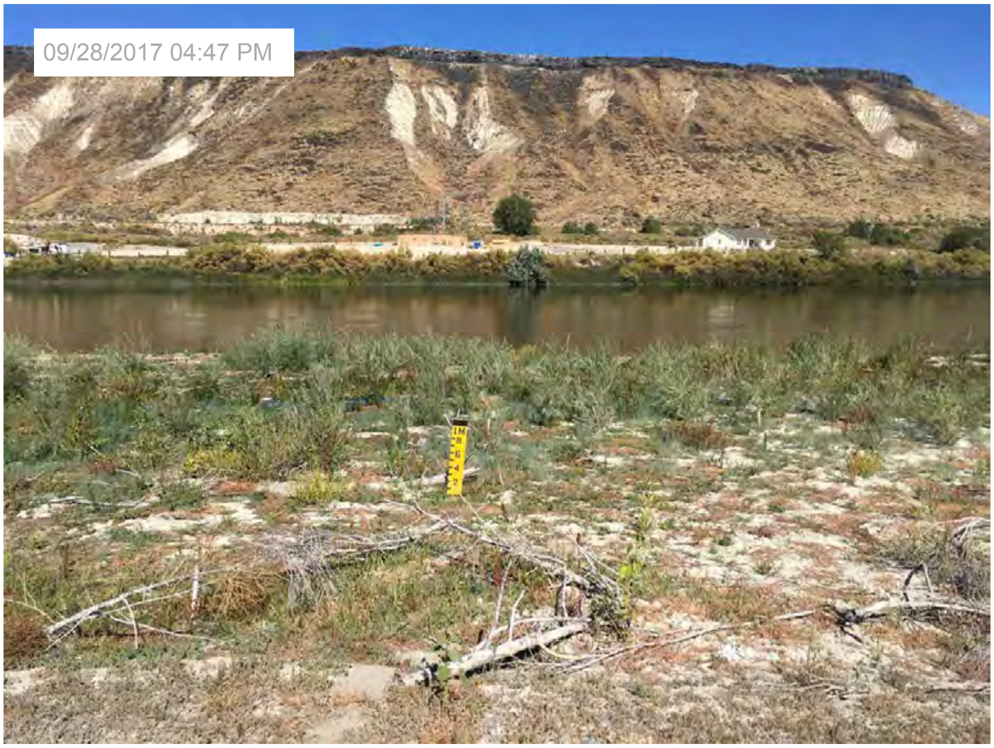


Figure 39.

C - Upstream 102° Y ear 1

Figure 40.

Appendix B

Bayha Island Research Project Channel Stability

Legend

🟨	Profile Extent for Pre-Existing and As-Built Conditions
🟥	Profile Extent for August/September 2017

Bayha Island
Profile Locations

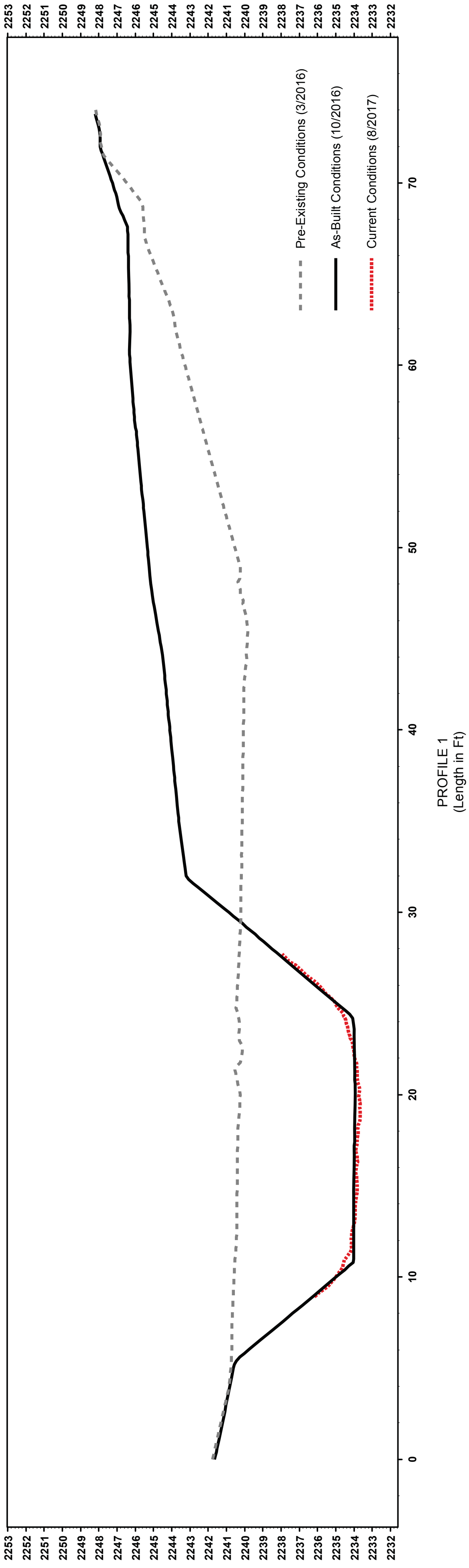
1 inch = 200 feet

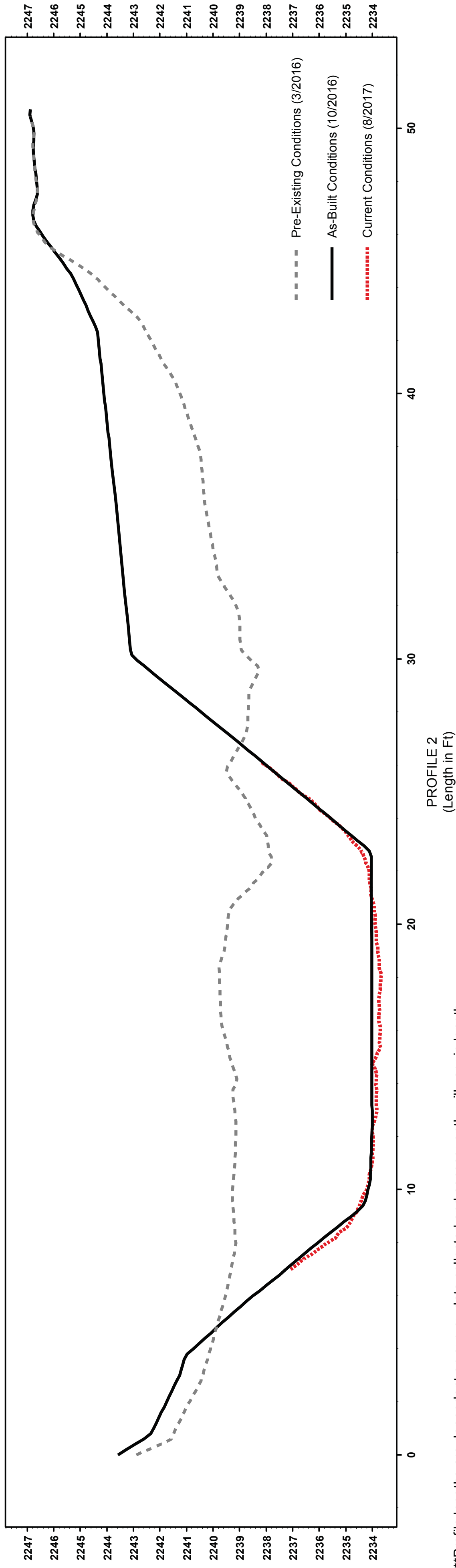
0 30 60 120 180 Feet

IDAHO POWER®
An IDACORP Company

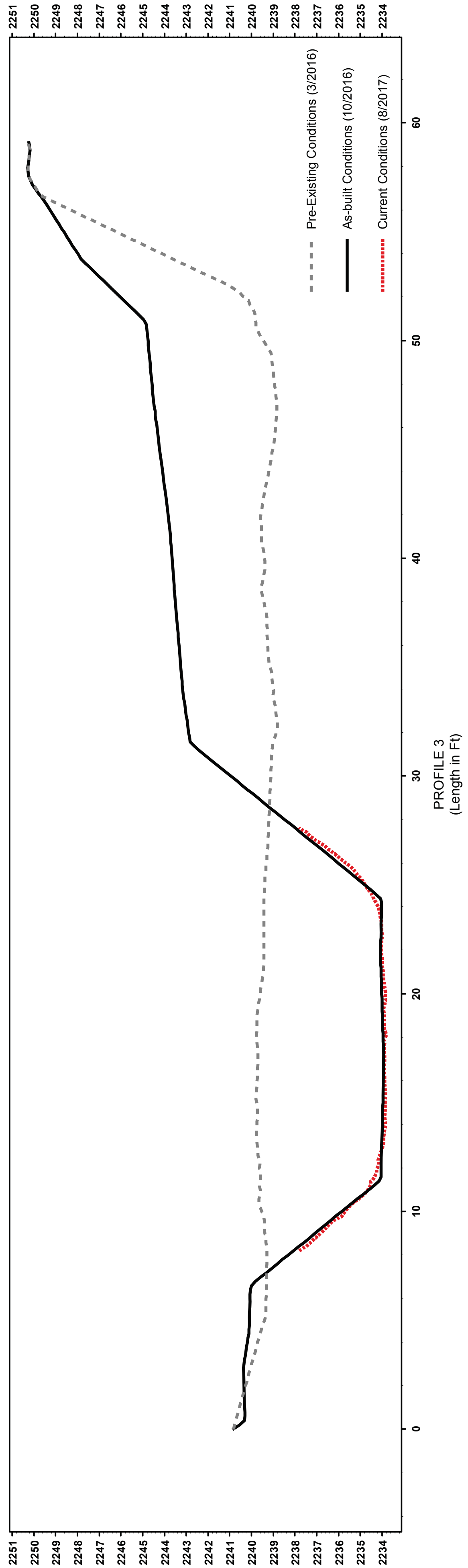
DECEMBER 2017

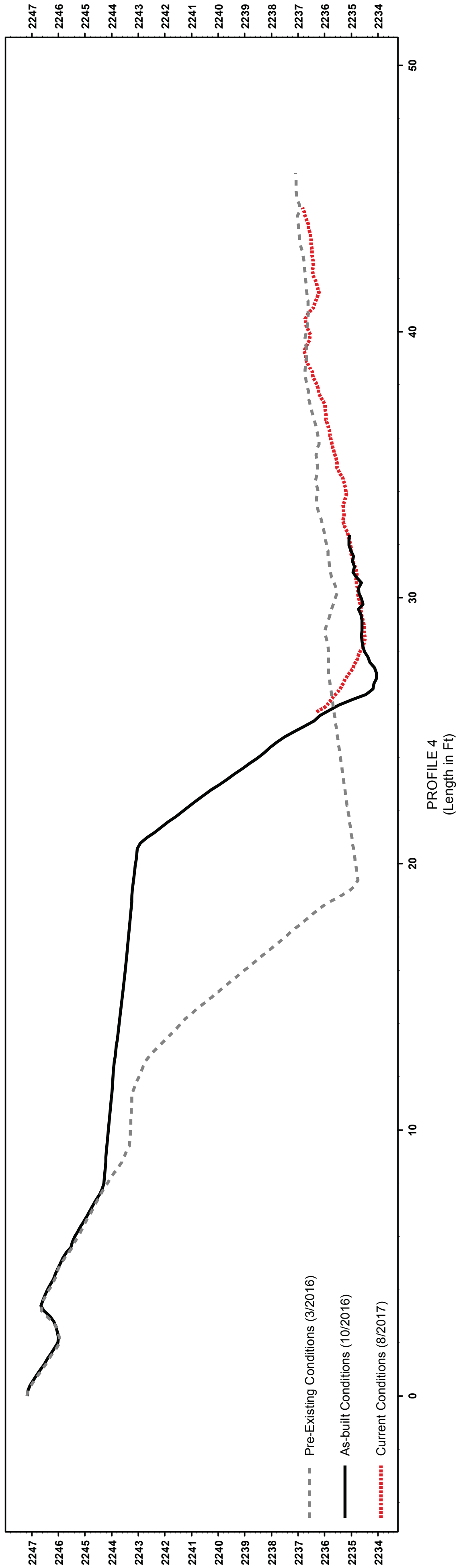
Document Path: \\fresno\Enviro_GIS\WaterManagement\MidSnake\SnakeRiverStewardship\Bayha\Misc_Projects\Cross_Sections\MXDs\Profile_Locations.mxd



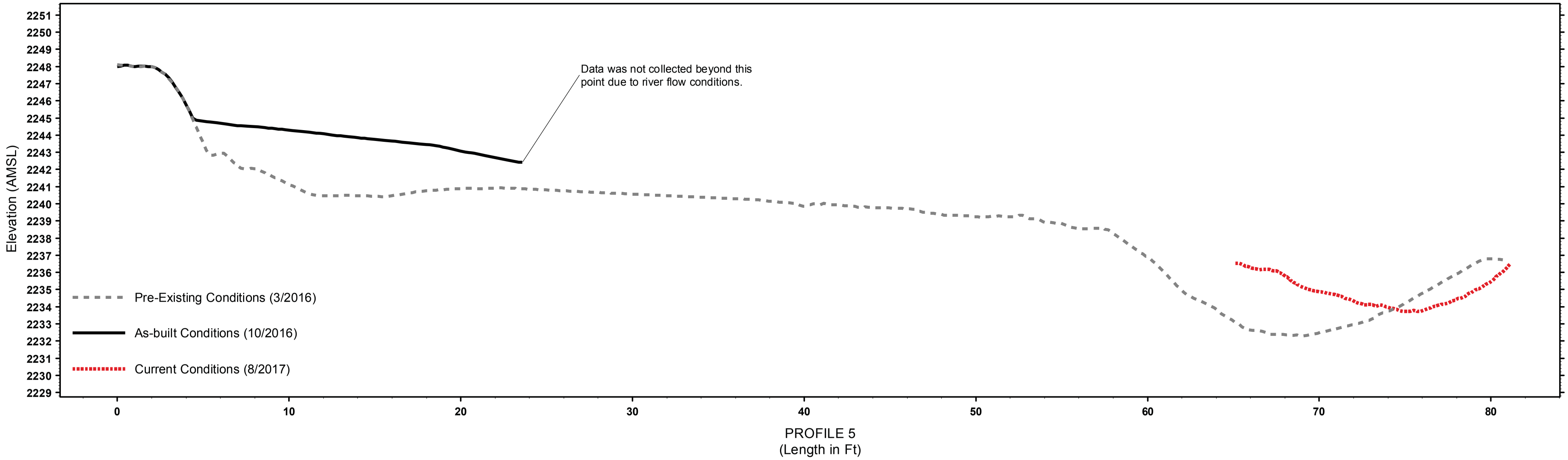


**Profile lengths are dependent on survey data collected and consequently will vary in length.

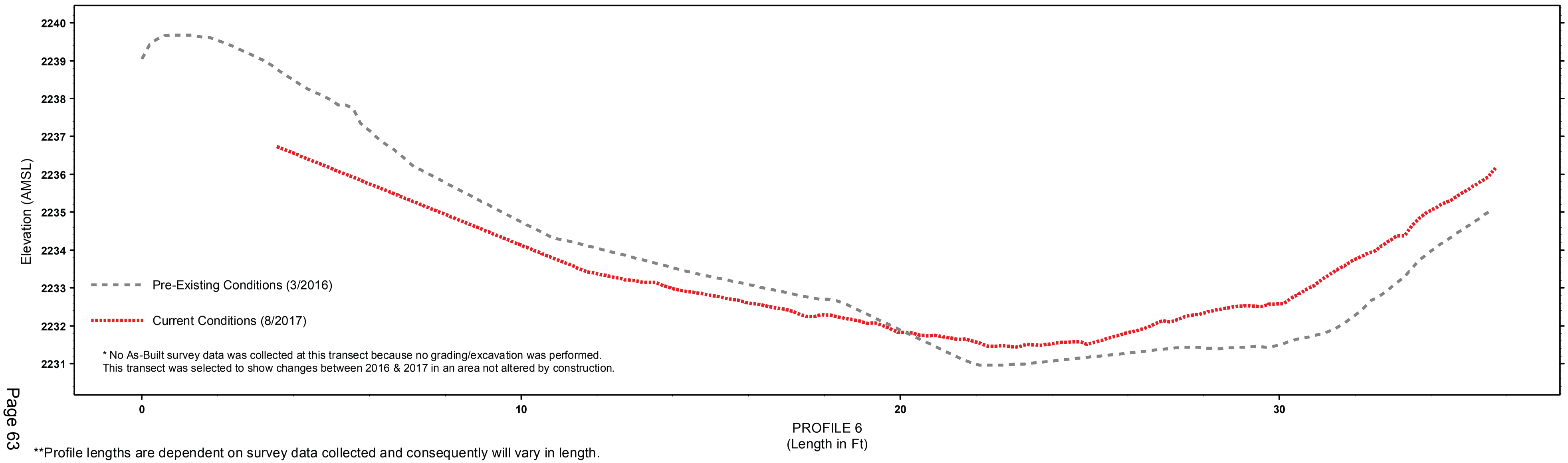




**Profile lengths are dependent on survey data collected and consequently will vary in length.



Data was not collected beyond this point due to river flow conditions.



* No As-Built survey data was collected at this transect because no grading/excavation was performed.
This transect was selected to show changes between 2016 & 2017 in an area not altered by construction.

**Profile lengths are dependent on survey data collected and consequently will vary in length.

Appendix C

Bayha Island Research Project Water Level

Legend

▲ Water Level Logger

* Base imagery consists of 2017 orthomosaic (IPCO) positioned over 2015 satellite imagery (Digital Globe).

**Water level logger locations shown are the approximate location of the instrumentation located on the river bank. Actual water surface measurements are performed in the river channel, adjacent to the location shown

Bayha Island
Water Level Loggers

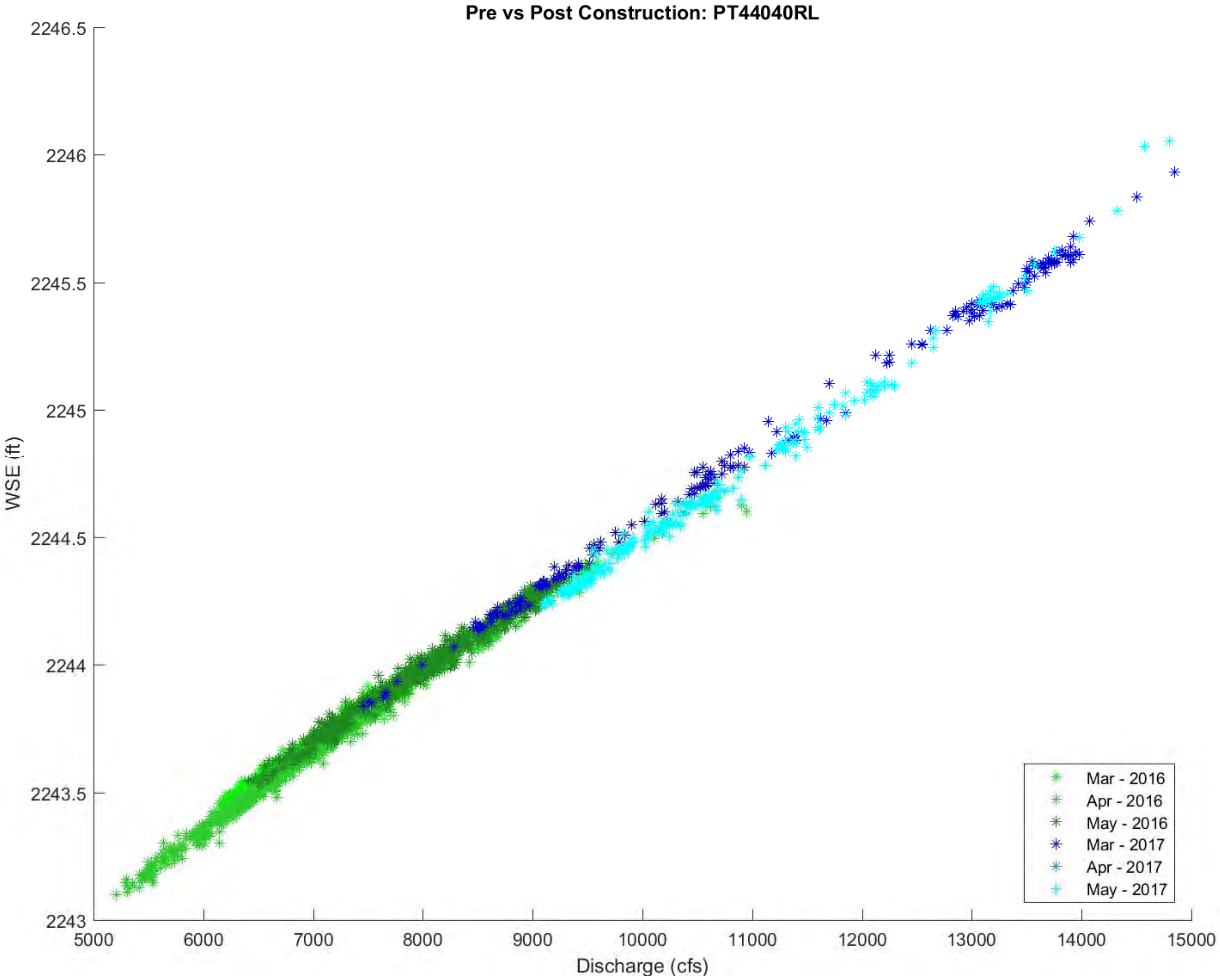
1 inch = 400 feet

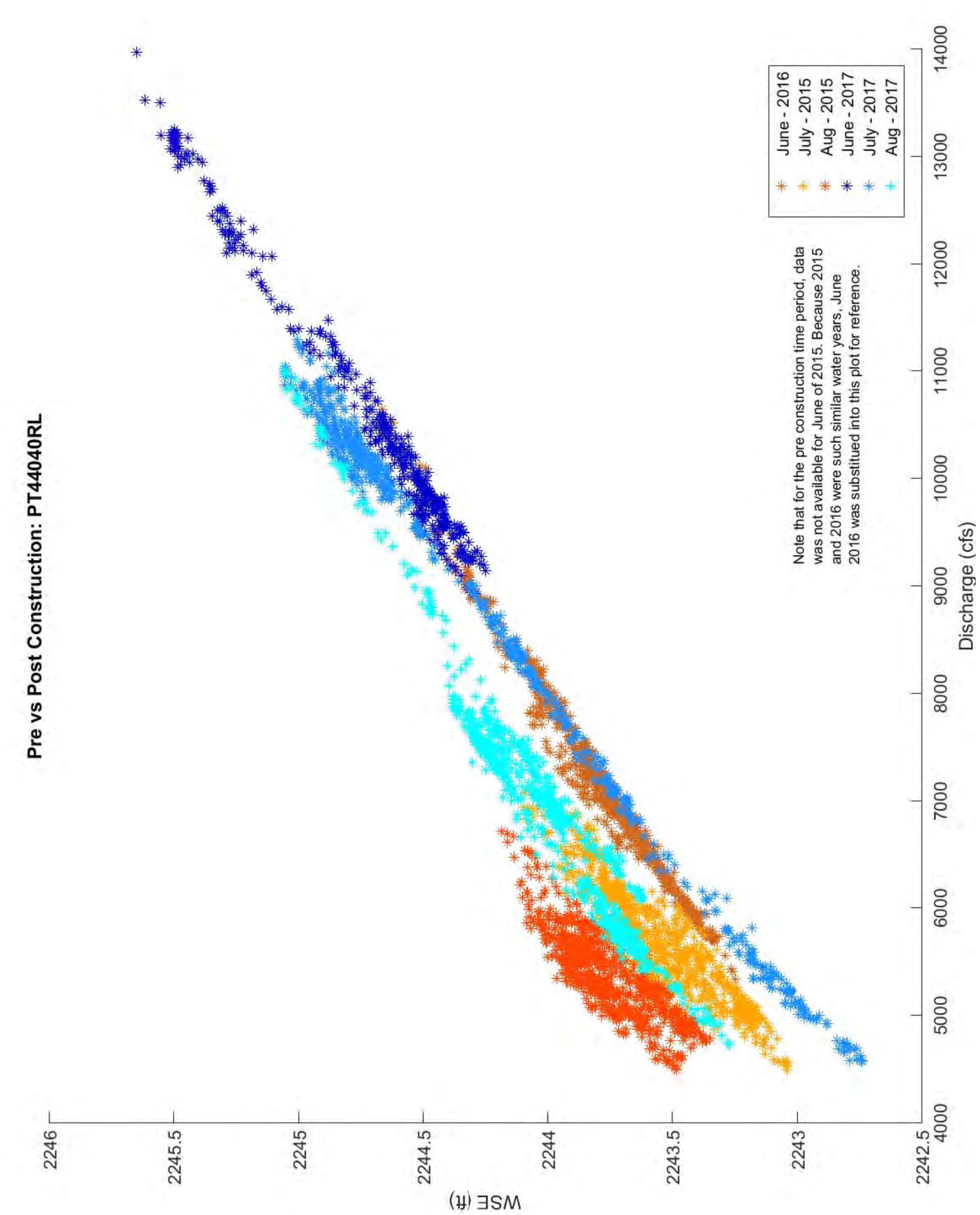
0 100 200 400 Feet

IDAHO POWER®
An IDACORP Company

DECEMBER 2017

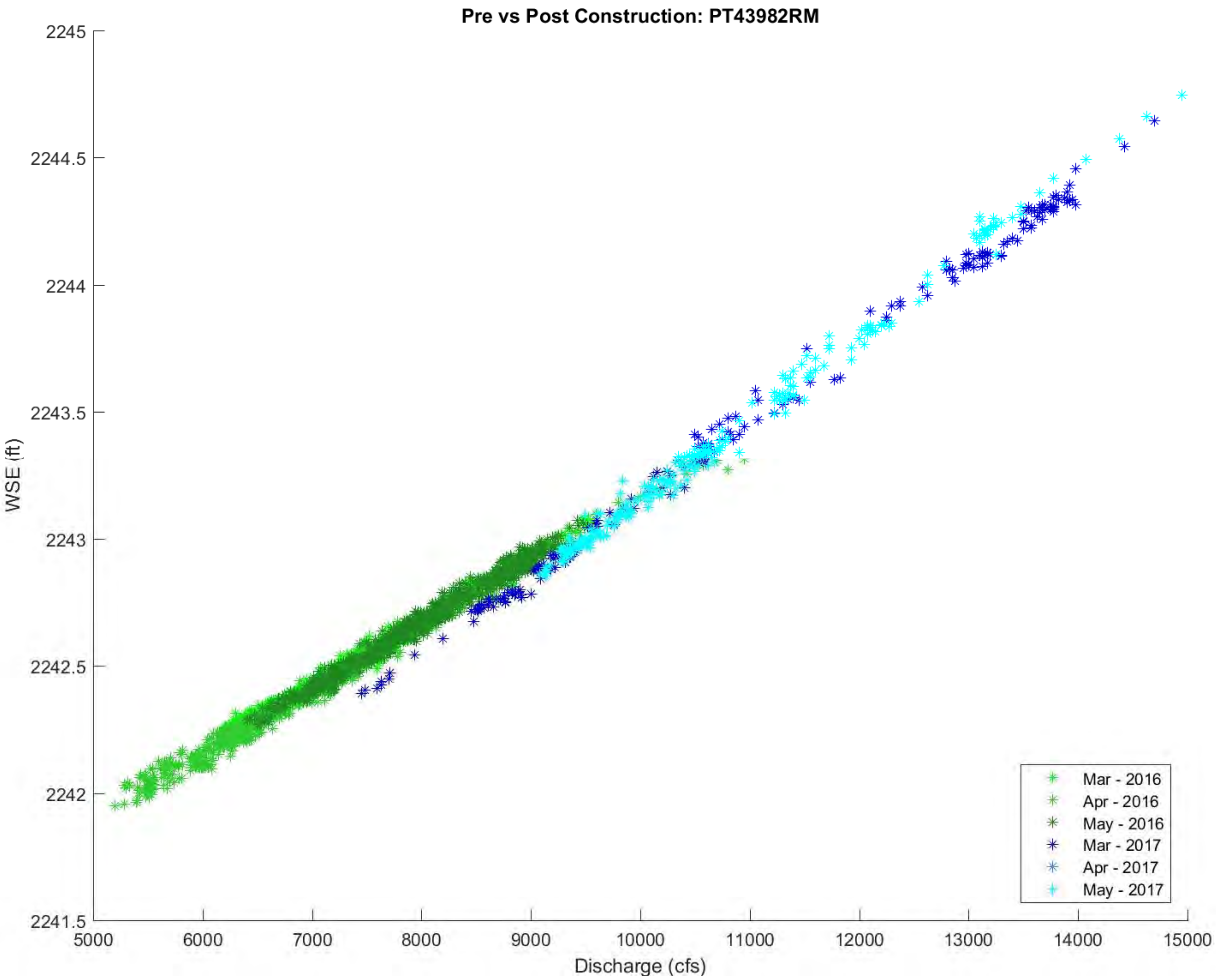
Document Path: \\fresno\Enviro_GIS\WaterManagement\MidSnake\SnakeRiverStewardship\Bayha\MXDs\WaterLevelLoggers.mxd


Pre vs Post Construction: PT44040RL
WSE (ft)
2246.5
2246
2245.5
2245
2244.5
2244
2243.5
2243
Discharge (cfs)
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
Mar - 2016
Apr - 2016
May - 2016
Mar - 2017
Apr - 2017
May - 2017

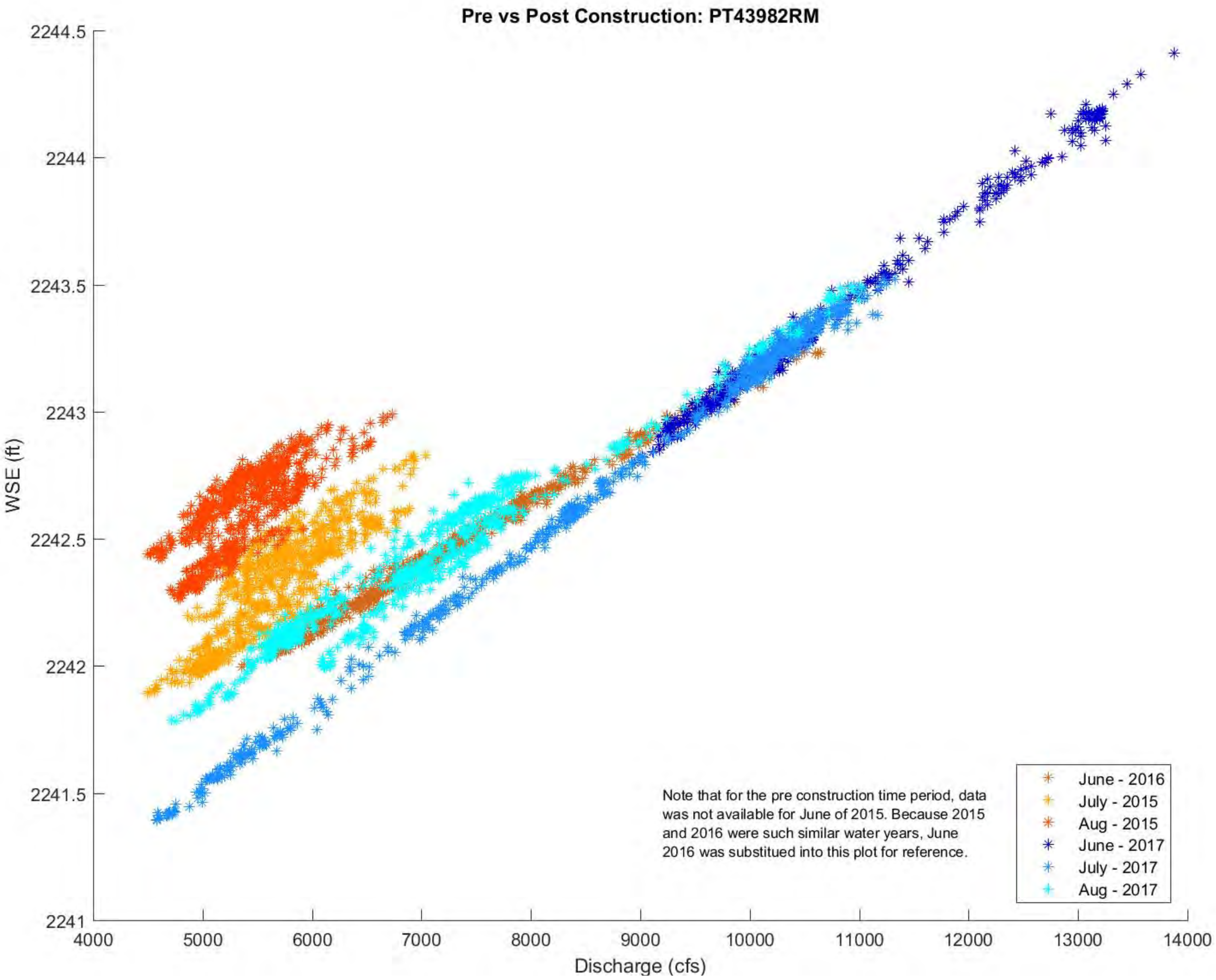


Pre vs Post Construction: PT44040RL

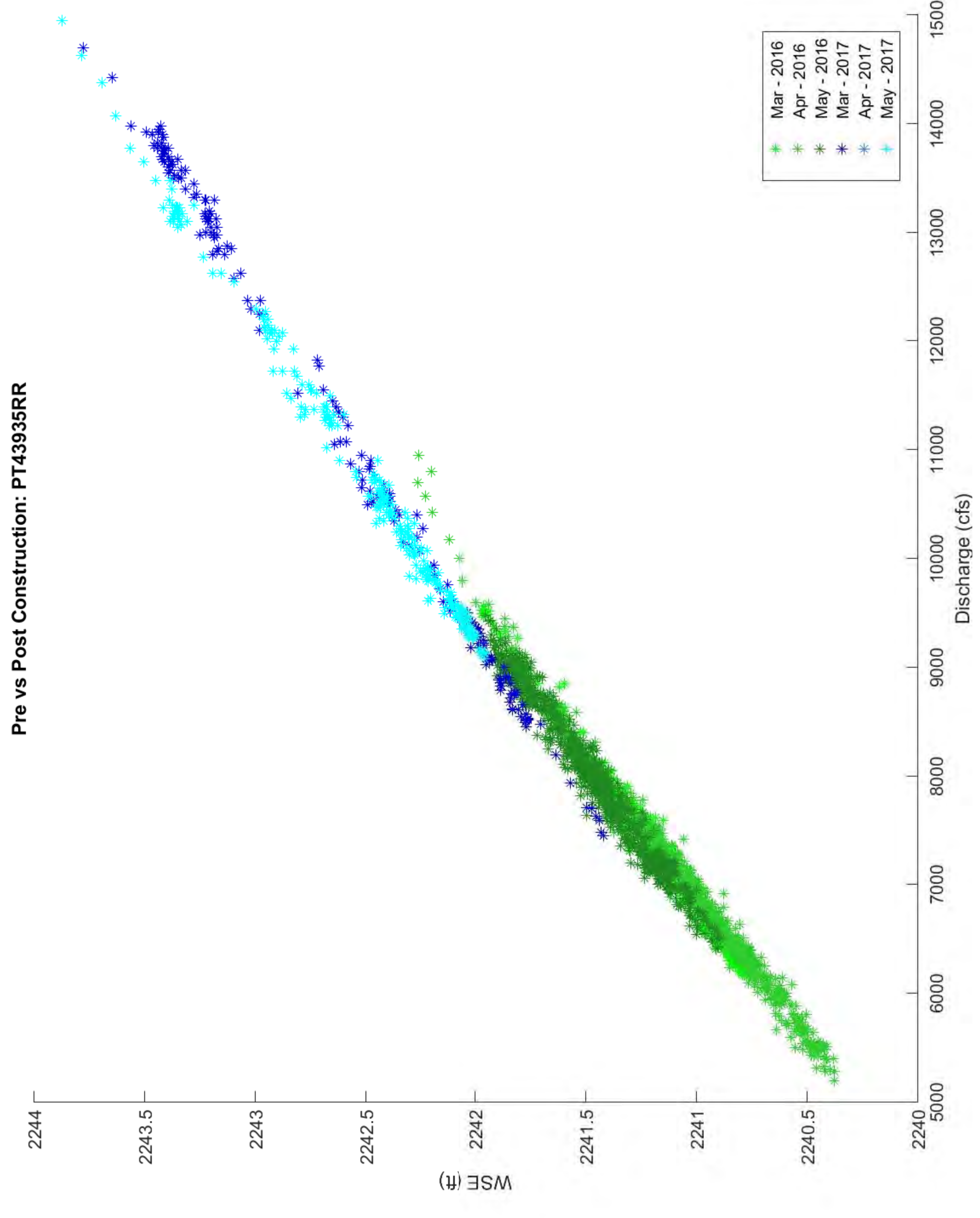
Note that for the pre construction time period, data was not available for June of 2015. Because 2015 and 2016 were such similar water years, June 2016 was substitued into this plot for reference.



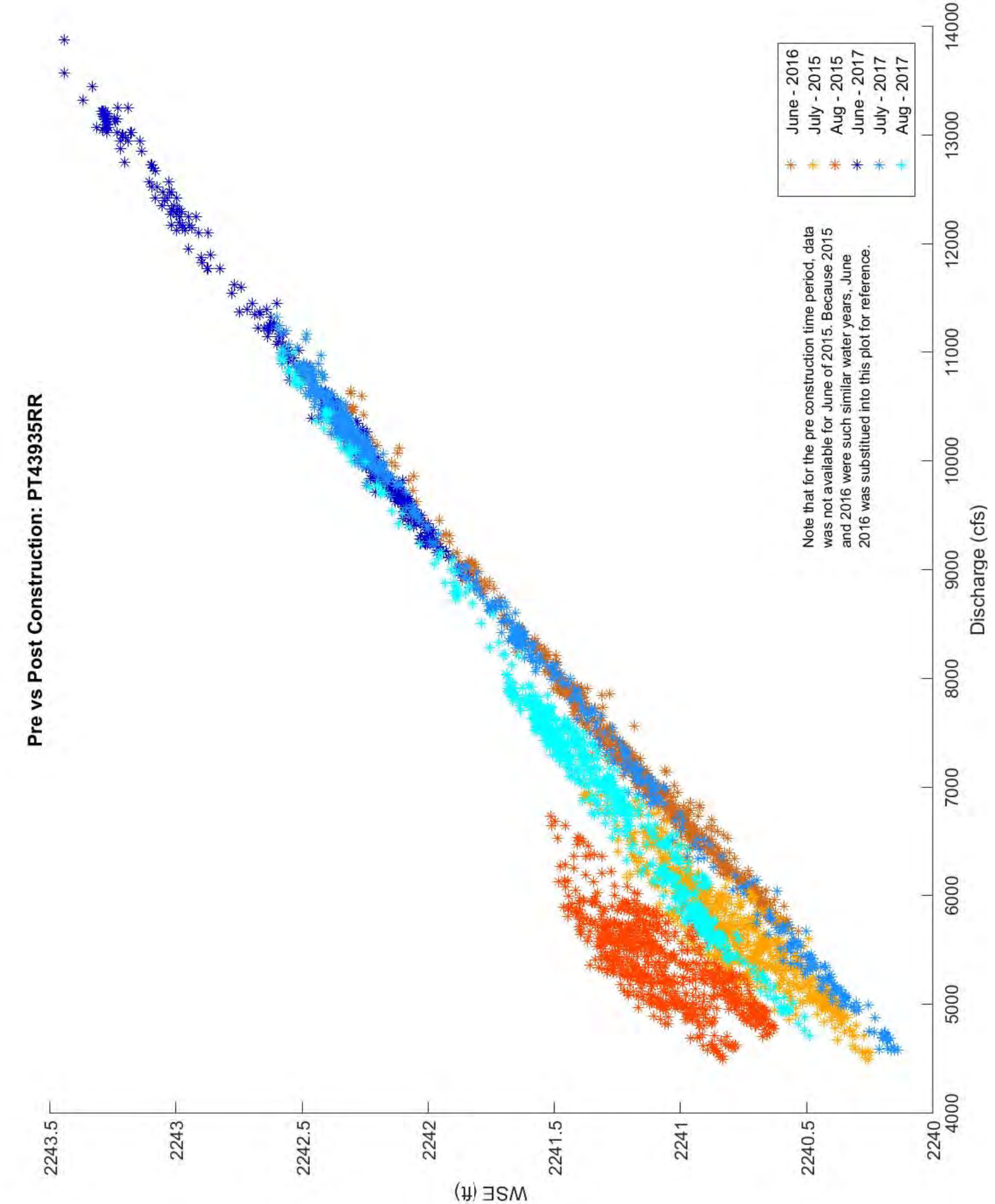
Pre vs Post Construction: PT43982RM



Note that for the pre construction time period, data was not available for June of 2015. Because 2015 and 2016 were such similar water years, June 2016 was substitued into this plot for reference.



Pre vs Post Construction: PT43935RR



Pre vs Post Construction: PT43935RR

Note that for the pre construction time period, data was not available for June of 2015. Because 2015 and 2016 were such similar water years, June 2016 was substitued into this plot for reference.

Appendix D

Powder River RM 9.8 Photo Point Monitoring Report

The Freshwater Trust®

This report has been generated by The Freshwater Trust’s StreamBank Monitoring App.

Powder River RM 9.8
Middle Snake-Boise
River: Daly Creek
Reach number/name: Phase 1
Implementation start date: 10/01/2016

Procedure Name: Photo Point
Photo Point monitoring purpose: Year 1
Number of camera points: 4
Surveyor(s): Hilary Cosentino, Christy Meyer, Kelly Wilde, Sarah Funk, Josh Pearson,Sierra Virtue,
Date surveyed: 08/08/2017

Photo Points

Camera Point 1 (44.74482°, -1 17.16925°) Bank : River Right

A - Upstream 291° Y ear 1


08/09/2017 07:20 AM

Figure 1.

Camera Point 2 (44.74533°, -1 17.17981°) Bank : River Right

A - Upstream 319° Y ear 1

Figure 2.

B - Across 21° Y ear 1

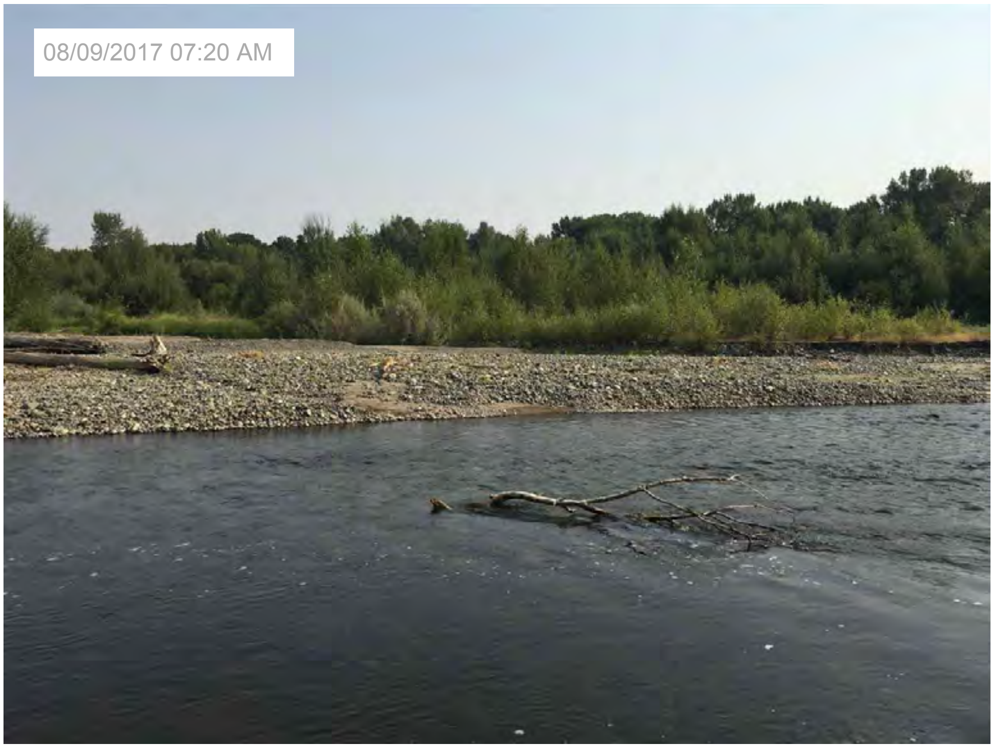


Figure 3.

C - Downstream 107° Y ear 1

Figure 4.

Camera Point 3 (44.74601°, -1 17.17227°) Bank : River Right

A - Downstream 120° Y ear 1

Figure 5.

Camera Point 4 (44.44429°, -1 17.10149°) Bank : River Right

A - Upstream 310° Y ear 1

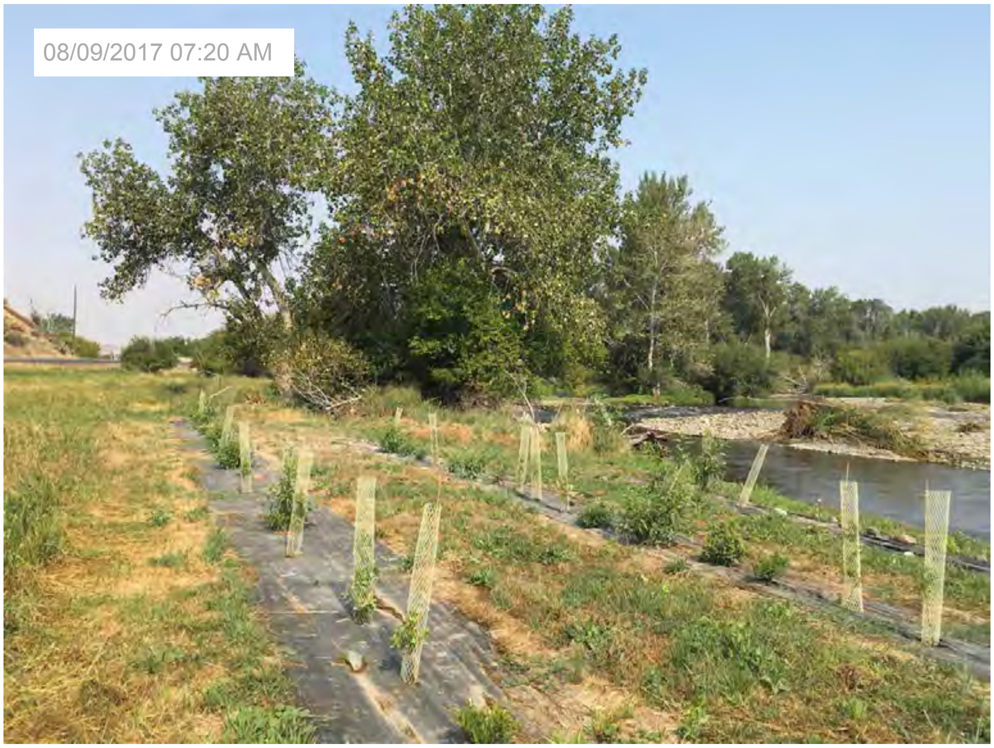


Figure 6.

B - Across 20° Y ear 1

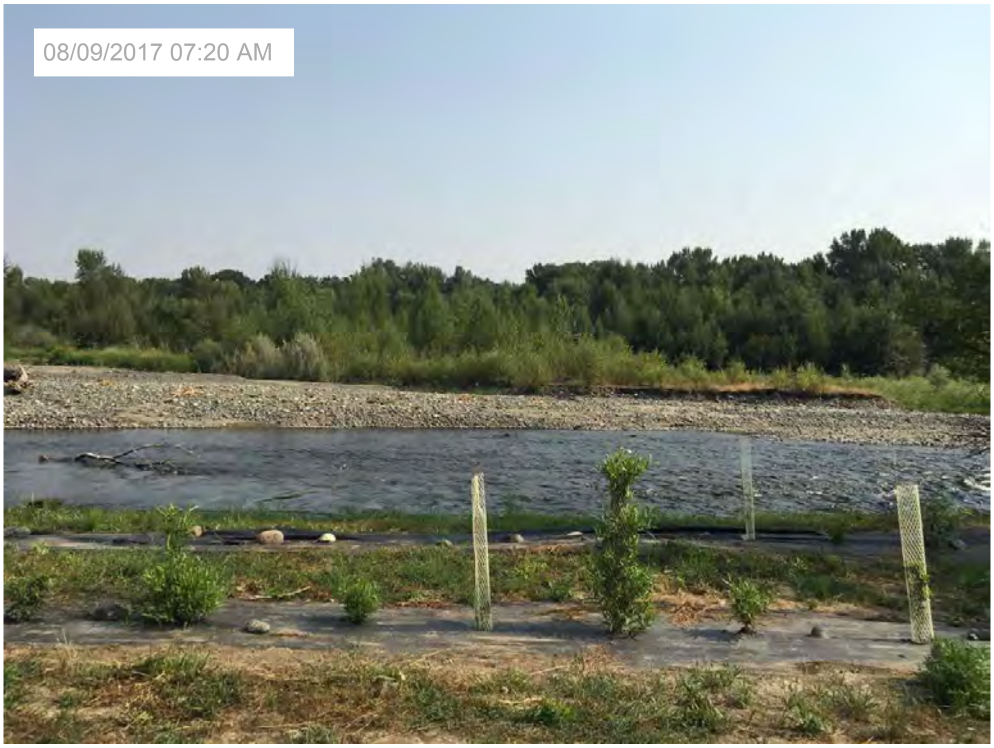


Figure 7.

C - C 104° Year 1

Figure 8.

Appendix E

Powder River RM 44.8 Photo Point Monitoring Report

The Freshwater Trust®

This report has been generated by The Freshwater Trust's StreamBank Monitoring App.

Rex Nelson
Lower Snake
River: Powder River
Reach number/name: Powder RM 44.8
Implementation start date: 06/26/2017

Procedure Name: Photo Point
Photo Point monitoring purpose: Pre-Project
Number of camera points: 3
Surveyor(s):
Date surveyed: 07/19/2017

Photo Points

Camera Point 1 (45.66292°, -496.63012°) Bank : River Left

A - South 198° Pre-Project

07/20/2017 05:28 AM

Figure 1.

B - West 280° Pre-Project

07/20/2017 05:28 AM

Figure 2.

C - North 0° Pre-Project

07/20/2017 05:28 AM

Figure 3.

Camera Point 2 (45.65795°, -496.61353°) **Bank : River Left**

A - Nw 312° Pre-Project

07/20/2017 05:28 AM

Figure 4.

B - N 350° Pre-Project

07/20/2017 05:28 AM

Figure 5.

Camera Point 3 (45.65861°, -496.63673°) **Bank : River Right**

A - W 278° Pre-Project

07/20/2017 05:28 AM

Figure 6.

B - N 350° Pre-Project

07/20/2017 05:28 AM

Figure 7.

C - South 160° Pre-Project

07/20/2017 05:28 AM

Figure 8.

Appendix F
Latin Binomial and Common Names

Latin Binomial	**Common Name**
Vegetation	
Acer glabrum	rocky mountain maple
Achillea millefolium	common yarrow
Ailanthus altissima	tree of heaven
Alnus incana	mountain alder
Amelanchier alnifolia	western serviceberry
Artemisia ludoviciana	western mugwort
Asclepias speciosa	showy milkweed
Bassia scoparia	kochia
Betula occidentalis	water birch
Cardaria draba	whitetop
Cirsium arvense	Canada thistle
Clematis ligusticifolia Nutt. Var. ligusticifolia	western clematis
Cornus stolonifera	redosier dogwood
Crataegus douglasii	black hawthorn
Cyperus sp.	nutsedge
Elaeagnus angustifolia	russian olive
Helianthus annuus	common sunflower
Iris pseudacorus	yellow flag
Lepidium latifolium	broadleaved pepperweed
Linum lewisii	Lewis flax
Lythrum salicaria	purple loosestrife
Lythrum tribracteatum	threebract loosestrife
Onopordum acanthium	scotch thistle
Persicaria lapthifolia	curltop ladysthumb
Phalaris arundinacea	reed canarygrass
Philadelphus lewisii	Syringa; mock orange
Polygonum lapathifolium	curltop ladysthumb
Populus fremontii	Fremont cottonwood
Populus trichocarpa	black cottonwood
Prunus virginiana	common chokecherry
Ribes aureum	golden currant
Robinia pseudoacacia	black locust
Rosa sp.	rose
Rosa woodsii	wood's rose
Salix amygdaloides	peachleaf willow
Salix exigua	sandbar willow
Salix lasiolepis	arroyo willow
Salix lasiandra v. lasiandra	greenleaf willow
Salix lutea	yellow willow
Salsola tragus	tumbleweed
Sambucus spp.	elderberry
Schoenoplectus acutus	tule
Solidago canadensis	Canada goldenrod

Latin Binomial	Common Name
Tamarix ramosissima	saltcedar
Tribulus terrestris	goathead; puncture vine
Typha latifolia	common cattail
Ulmus sp.	Elm
Wildlife	
Branta canadensis	Canada goose
Castor canadensis	beaver
Charadrius vociferus	kill deer
Danaus plexippus	monarch butterfly
Larus californicus	California gull
Megaceryle alcyon	belted kingfisher
Micropterus dolomieu	small mouth bass
Odocoileus hemionus	mule deer
Pelecanus onocrotalus	great white pelican

Exhibit 7.1-7

SRSP water quality trading cosswalk

On June 29 2016, the Oregon Department of Environmental Quality (ODEQ) submitted an additional information request to the Idaho Power Company (IPC) requesting that IPC submit additional information demonstrating whether and how the Snake River Stewardship Program (SRSP) and the Riverside Program are consistent with Oregon's water quality trading rules (OAR 340-039). In response to that request, IPC is submitting the following comparative tables.

While the Idaho Department of Environmental Quality (IDEQ) rule IDAPA 51.01.02.055.06 authorizes pollutant trading, and IDEQ is currently updating its trading guidelines, IDEQ has advised that the SRSP and Riverside Program will be treated as offsets under Idaho's rules and guidelines, and not as trades.

The tables below demonstrate that the SRSP and Riverside Program are fully consistent with the Oregon and Idaho water quality standards, the SR-HC TMDL, and any applicable Oregon or Idaho water quality trading and offset rules and guidelines. IPC is proposing the SRSP and Riverside Program for the purposes of the CWA section 401 certification for the licensing of the Hells Canyon Complex (HCC) by the Federal Energy Regulatory Commission (FERC) and has not characterized either program as a trade under Oregon or Idaho rules or guidelines. Nevertheless, ODEQ and IDEQ have advised IPC that classifying and analyzing the SRSP and Riverside Program as a trade or as an offset does not have material regulatory consequences to the SRSP or Riverside Program, nor will doing so result in the alteration of any of the compliance, monitoring or enforcement obligations associated with the 401 certification for the HCC FERC license.

The following comparative table includes all of the Oregon water quality trading rule provisions (left column), and an explanation of how the SRSP addresses those provisions, where applicable. In the right column, references have been made to the overall 401 application (IPC 401 Application), Section 7.1. and associated Exhibit 7.1-1 contained within the 401 application (SRSP), and the Snake River-Hells Canyon TMDL (SR-HC TMDL). Consistent with its stated purpose, the 2016 Oregon water quality trading Internal Management Directive (Trading IMD) has been used to supplement explanations where helpful.[1]

Oregon Water Quality Trading Rule	Explanation of How SRSP Addresses Oregon WQT Provision
340-039-0001 **Purpose and Policy** (1) Purpose. This rule implements ORS 468B.555 to allow entities regulated under the Clean Water Act to meet pollution control requirements through water quality trading. This rule establishes the requirements for water quality trading in Oregon. (2) Policy. The Oregon Department of Environmental Quality may approve water quality trading only if it promotes one or more of the following Environmental Quality Commission policies: (a) Achieves pollutant reductions and progress towards meeting water quality standards; (b) Reduces the cost of implementing Total Maximum Daily Loads (TMDLs); (c) Establishes incentives for voluntary pollutant reductions from point and nonpoint sources within a watershed; (d) Offsets new or increased discharges resulting from growth; (e) Secures long-term improvement in water quality; or (f) Results in demonstrable benefits to water quality or designated uses the water quality standards are intended to protect.	• (1): The purpose statement in the trading rules aligns with intent of SRSP offset program [SRSP Ex. 7.1-1, § 2]. • (2): The SRSP promotes at least one of the listed EQC policies, and is therefore within DEQ's discretion to approve consistent with these rules. Specifically, the SRSP helps achieve thermal loading reduction above the Hells Canyon Complex (HCC), establishes incentives to engage other nonpoint sources in the program area, and helps to restore dynamic processes to reaches of the Snake River and its tributaries, including increased riparian shade, increasing water velocity (and potentially volume), decreasing temperature and aquatic macrophyte proliferation, and providing cold-water habitat for native species [SRSP Ex. 7.1-1, § 1].
340-039-0003 **Water Quality Trading Objectives** Water quality trading authorized under this rule must: (1) Be consistent with anti-degradation policies; (2) Not cause or contribute to an exceedance of water quality standards; (4) Be designed to result in a net reduction of pollutants from participating sources	• (1, 2, 4, 8): Oregon's antidegradation policy is found in OAR 340-041-0004. As stated in the Oregon trading IMD, Oregon's anti-degradation policy generally prohibits the lowering of existing water quality. Trading IMD, at 9. In the 2003 federal Trading Policy,

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[1] "DEQ expects the majority of trading activity to be driven by the need to comply with NPDES permit requirements developed to implement a total maximum daily load (TMDL).This IMD is, therefore, primarily focused on water quality trades between nonpoint sources and NPDES permittees to comply with the latter's water quality-based effluent limitations. To the extent it is relevant and helpful, this IMD may also be used by DEQ staff to evaluate trading proposals that are part of the water quality certification of a federal permit or other approval issued under Clean Water Act (CW A) section 401 and Oregon Administrative Rules (OAR) chapter 340, division 048 (referred to throughout this IMD as a "401 WQC")." ODEQ, Trading IMD, at 6.

Oregon Water Quality Trading Rule	Explanation of How SRSP Addresses Oregon WQT Provision
in the trading area; (8) Not create localized adverse impacts on water quality and existing and designated beneficial uses.	U.S. EPA states that it "does not believe that trades and trading programs will result in 'lower water quality' as that term is used in 40 CFR § 131.12(a)(2) ... when the trades or trading programs achieve a no net increase of the pollutant traded and do not result in any impairment of designated uses." Trading IMD, at 9. In line with EPA guidance, the Trading IMD instructs DEQ staff to ensure that trades are designed to result in a net reduction of pollutants in the trading area as required in OAR 340-039-0003(4), and that the proposed trade does not create localized adverse impacts on water quality and existing and designated beneficial uses as required in OAR 340-039-0003(8). Trading IMD, at 9. The HCC does not add heat to the system, but shifts heat impacts temporally [IPC 401 Application, § 6.1]. As such, the HCC will not cause or contribute to violations of water quality standards after implementation of the SRSP. By reducing thermal load through upstream watershed projects, the SRSP has been designed to achieve a net reduction in thermal loading in the program area. The SR-HC TMDL did not find that salmonid spawning below the Hells Canyon Dam (HCD) was impaired by temperature below the HCD [SR-HC TMDL, § 3.6.2]; these findings were reaffirmed in recent studies [IPC 401 Application, §§ 6.1.3, 7.1.1]. The SRSP was designed to avoid localized adverse impacts on water quality, aquatic species and habitat that could be caused by other technological options [IPC 401 Application, § 7.1.2.4.1.1].
(3) Be consistent with local, state, and federal water quality laws;	• (3): The SRSP has been designed to be consistent with all other laws [SRSP Ex. 7.1-1, § 2.5.2.1 (regulatory baseline); SRSP Ex. 7.1-1, Attachment 1 (document compatibility with local land use and cultural resource requirements, work permits obtained)].
(4) [*excerpted and addressed above with explanation for subsection (1)*]	
(5) Be designed to assist the state in attaining or maintaining water quality standards;	• (5): The SRSP has been designed to address the HCC's exceedance above the Oregon salmonid spawning temperature criterion, as defined in the SR-HC TMDL [IPC 401 Application, § 7.1.2.1].
(6) Be designed to assist in implementing TMDLs when applicable;	• (6): The SRSP is designed to help implement the SR-HC TMDL [IPC 401 Application, § 7.1.2.1; SRSP Ex. 7.1-1, § 1].
(7) Be based on transparent and practical Best Management Practices (BMPs) quality standards to ensure that water quality benefits and credits are generated as planned; and	• (7): The SRSP includes quality standards designed specifically for the proposed BMPs [SRSP Ex. 7.1-1, Attachment 1]. These standards ensure thermal benefits are created, monitored, and

Oregon Water Quality Trading Rule	Explanation of How SRSP Addresses Oregon WQT Provision
(8) [*excerpted and addressed above with explanation for subsection (1)*]	tracked as part of the program.
340-039-0005 **Definitions** (1) Best Management Practices (BMPs): In-water or land-based conservation, enhancement or restoration actions that will reduce pollutant loading or create other water quality benefits. BMPs include, but are not limited to, structural and nonstructural controls and practices and flow augmentation. (2) BMP Quality Standards: Specifications for the design, implementation, maintenance and performance tracking of a particular BMP that ensure the estimated water quality benefits of a trading project are achieved, and that allow for verification that the BMP is performing as described in an approved trading plan. (3) Credit: A measured or estimated unit of trade for a specific pollutant that represents the water quality benefit a water quality trading project generates at a location over a specified period of time, above baseline requirements and after applying trade ratios or any other adjustments. (4) Public Conservation Funds: Public funds that are targeted to support voluntary natural resource protection or restoration. Examples of public conservation funds include United States Department of Agriculture (USDA) cost share programs, United States Environmental Protection Agency (EPA) section 319 grant funds, United States Fish and Wildlife Service Partners for Fish and Wildlife Program funds, State Wildlife Grants, and Oregon Watershed Enhancement Board restoration grants. Public funds that are not considered public conservation funds include: public loans intended to be used for water quality infrastructure projects, such as Clean Water State Revolving Funds, USDA Rural Development funds, and utility sewer storm water and surface water management fees. (5) Trading Area: A watershed or other hydrologically-connected geographic area, as defined within a water quality management plan adopted for a TMDL, trading framework or trading plan. A trading area must encompass the location of the discharge to be offset, or its downstream point of impact, if applicable, and the	• (1): The SRSP details two restoration action types—in-river channel adjustments, riparian revegetation—that will reduce pollutant loading and create additional water quality benefits [SRSP Ex. 7.1-1, § 2.2]. These actions are consistent with Oregon guidance on BMPs [Oregon Trading IMD, § 5(I)(F)(i)]. • (2): The SRSP includes specifications for design, implementation, maintenance and performance tracking for in-river and riparian revegetation BMPs [SRSP Ex. 7.1-1, Attachment 1]. • (3): In the SRSP, the equivalent to a credit is a "thermal benefit", which is a calculated estimate of the benefits that will accrue from an implemented restoration project once it fully matures. [SRSP Ex. 7.1-1, Definitions]. Thermal benefits are "aggregated" and must be sufficient to offset the "cumulative thermal load exceedance" (CTLE) at the outflow of the HCC. [SRSP Ex. 7.1-1, Definitions]. The CTLE accounts for the SR-HC TMDL margin of safety, and a reservoir attenuation factor, while thermal benefits from projects are also attenuated [IPC 401 Application, § 7.1.2.1]. • (4): In the SRSP, public conservation funds are similarly defined and restricted from use to develop thermal benefits [SRSP Ex. 7.1-1, § 2.5.2.2, FN 29]. • (5): In the SRSP, the trading area is defined as the "program area" [SRSP Ex. 7.1-1, § 2.1].

Oregon Water Quality Trading Rule	Explanation of How SRSP Addresses Oregon WQT Provision
trading project to be implemented.	
(6) Trading Baseline: Pollutant load reductions, BMP requirements, or site conditions that must be met under regulatory requirements in place at the time of trading project initiation.	• (6): In the SRSP, trading baseline is defined as “regulatory baseline” [SRSP Ex. 7.1-1, § 2.5.2.1].
(7) Trading Framework: A description contained in a TMDL water quality management plan, or water pollution control plan, adopted by rule or issued by order under ORS 468B.015 or 468B.110, that identifies trading elements applicable to one or more entities in a trading area.	• (7): No such framework exists for the SRSP.
(8) Trading Plan: A plan that describes the design, implementation, maintenance, monitoring, verification and reporting elements of a water quality trade.	• (8): The SRSP is analogous to the trading plan definition included in the rules [SRSP Ex. 7.1-1, Definitions].
(9) Trading Project: A site-specific implementation of a trading plan used to generate credits.	• (9): The SRSP includes a similar definition of trading projects, also referred to as “sites.” [SRSP Ex. 7.1-1, Definitions].
(10) Trading Ratio: A numeric value used to adjust the number of credits generated from a trading project, or to adjust the number of credits that a credit user needs to obtain.	• (10): The 401 includes ratios that increase the number of benefits IPC needs to obtain [IPC 401 Application, § 7.1.2.1].
(11) Verification: A process to confirm and document that a trading project is implemented and performing according to the approved trading plan and BMP quality standards, and to confirm the quantity of credits generated by the trading project.	• (11): The SRSP includes a process to confirm implementation and performance consistent with BMP quality standards, and an ongoing project audit process [SRSP Ex. 7.1-1, § 2.6.3].
(12) Water Quality Benefit: The quantifiable water quality improvement or net pollutant reduction that can be reasonably attributed to BMPs at a trading project site.	• (12): The SRSP defines “thermal benefits” similarly to and consistent with the rule [SRSP Ex. 7.1-1, Definitions].
(13) Water Quality Trading or Trade: The use of water quality credits generated at one location in a trading area to comply with water quality-based requirements at another location within the trading area.	• (13): The SRSP is designed to be consistent with the definition of trading found in the OARs.
340-039-0015 **Eligibility**	
(1) An entity regulated by a National Pollutant Discharge Elimination System (NPDES) permit or a federal permit or license for which DEQ has issued a water quality certification pursuant to Clean Water Act section 401 and OAR chapter 340, division 048 (a “401 water quality certification”) is eligible to enter into a trade.	• (1): As a licensee seeking a CWA section 401 certification from DEQ, IPC is eligible to enter into a trade.
(2) Water quality parameters eligible for water quality trading: (a) DEQ may authorize water quality trading for the following water quality parameters: temperature, ammonia, sediment, total suspended solids, and nutrients and other oxygen-demanding substances, including biochemical oxygen demand.	• (2a): The SRSP only addresses temperature [SRSP Ex. 7.1-1, § 1], which is an approved pollutant for trading under the rule.
(b) Water quality trading for pollutants that are toxic and either persist in the	• (2b): The SRSPP does not propose any actions that implicate

Oregon Water Quality Trading Rule	Explanation of How SRSP Addresses Oregon WQT Provision
environment or accumulate in the tissues of humans, fish, wildlife or plants is prohibited, except if trading is an element of a pollution reduction plan in a variance that has been issued by DEQ or the EQC and approved by EPA pursuant to OAR 340-041-0059. (c) Water quality trading authorized under this division may not be used to meet technology-based effluent limitations. (d) DEQ may authorize trading for other water quality parameters on a case-by-case basis provided it does not cause or contribute to an exceedance of a water quality standard. (3) Water bodies where trading may occur: (a) High quality waters. DEQ may authorize trading to maintain or improve water quality in water bodies that meet water quality standards, including but not limited to, trading projects designed to offset new or increased pollutant loads. (b) Water quality limited waters. DEQ may authorize trading where it is consistent with the water quality management plan in a TMDL or other water pollution control plan adopted by rule or issued by order under ORS 468B.015 or 468B.110, or in water bodies: (A) That are water quality limited but not subject to a TMDL; or (B) Where trading projects are designed to achieve progress towards meeting water quality standards before or while a TMDL is being developed. (4) BMPs eligible for credit generation must be quantifiable and have BMP quality standards.	pollutants described in Subsection (2)(b) of the rule. • (2c): This provision applies only to point sources and therefore does not apply to the HCC, a nonpoint source. • (2d): IPC is not seeking DEQ approval of any parameters that have not yet been approved in the rule. • (3): The SR-HC TMDL assigned a load allocation to the HCC to address exceedances of fall Chinook spawning criteria. The SR-HC TMDL water quality management plan (WQMP) includes trading among the implementation strategies that can be pursued [TMDL, § 6.1, Ch. 1]. • (4): The SRSP includes quality standards for the BMPs from which thermal benefits will be measured [SRSP Ex. 7.1-1, Attachment 1]. Thermal benefits from these projects will be quantified in kilocalories per day, using Shade-a-lator and wetland energy budgeting [SRSP Ex. 7.1-1, § 2.3].
340-039-0017 **Regulatory Mechanisms for Water Quality Trading** (1) NPDES Permitting: (a) Trading in Permits: DEQ may authorize water quality trading in an NPDES permit to meet water quality-based effluent requirements. (b) Compliance Schedules. Water quality trading may be included in an NPDES permit compliance schedule only if the trade is consistent with the requirements of OAR 340-041-0061 and any applicable regulations of the EPA. (c) Permit Variances. Water quality trading may be included as a component of the pollution reduction plan in a variance issued under OAR 340-041-0059. (2) 401 Water Quality Certifications. DEQ may condition a 401 water quality certification based on water quality trading consistent with this division.	• (1): The contents of this subsection are inapplicable because the SRSP is not related to NPDES permitting. • (2): ODEQ may condition a 401 certification upon consistency with

Oregon Water Quality Trading Rule	Explanation of How SRSP Addresses Oregon WQT Provision
(3) Annual Reporting. The regulated entity must submit an annual report to DEQ that describes trading plan implementation and performance over the past year. The annual report must include information specific to each trading project implemented including: (a) The location of each trading project and BMPs implemented in the preceding year; (b) The trading project baseline; (c) The trading ratios used; (d) Trading project monitoring results; (e) Verification of trading plan performance including the quantity of credits acquired from each trading project, and the total quantity of credits generated under the trading plan to date; (f) A demonstration of compliance with OAR 340-039-0040(4), if applicable; and (g) Adaptive management measures implemented under the trading plan, if applicable.	the water quality trading rules. • (3): The SRSP provides for submission of annual monitoring reports to the DEQs [SRSP Ex. 7.1-1, § 2.6.2]. SRSP annual reports will describe the monitoring efforts and results generated from the year, and the volume of thermal benefits implemented during the year. In addition, annual monitoring reports for each implemented project, and the results of the performance confirmations and ongoing audits, will be made available. Moreover, at adaptive management intervals [see SRSP Ex. 7.1-1, § 3], IPC will provide progress reports documenting that programmatic assumptions related to thermal benefit estimates are consistent with observations to date. The SRSP will document the location and nature of all trading projects as part of ongoing tracking and reporting [SRSP Ex. 7.1-1, § 2.6.4]. The results of implementation and performance confirmations—which requires review of project documentation for consistency with quality standards, including baseline and ratio information—will be documented on the publicly accessible tracking and reporting website [SRSP Ex. 7.1-1, § 2.6.4; Attachment 1].
340-039-0020 **Trading Frameworks** (1) DEQ may establish one or more trading frameworks in a TMDL water quality management plan or water pollution control plan adopted by rule or issued by order under ORS 468B.015 or ORS 468B.110. If established, a trading framework must specify pollutants that are eligible for trading, the trading area, any priority areas, as well as regulations and applicable TMDL allocations and implementation schedules that will be used to derive trading baseline. (2) DEQ must provide an opportunity for public notice and comment before issuing a trading framework. (3) A trading framework is not required in order for DEQ to approve a water quality trading plan.	• (1): ODEQ has not established a trading framework for the Snake River-Hells Canyon TMDL. • (2): As no framework exists for this TMDL area, this provision does not apply. • (3): As noted in the rules, a trading framework is not required for DEQ to approve a trading plan.
340-039-0025 **Requirements of a Water Quality Trading Plan** (1) An eligible entity may not engage in water quality trading unless DEQ has reviewed and approved that entity's water quality trading plan. The use of credits will be authorized after all elements of a DEQ-approved trading plan required by subsection (5) of this rule are incorporated as enforceable conditions of an NPDES	• (1): As DEQ has determined the SRSP must be consistent with the water quality trading program, DEQ's approval of the SRSP as part of the 401 certification process constitutes approval of the trading plan.

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permit issued under OAR chapter 340 division 045 or a 401 water quality certification issued under OAR chapter 340 division 048.	
(2) For NPDES permittees trading may be proposed as part of a permittee's application for permit renewal or modification.	• (2): This subsection is inapplicable because the proposed SRSP is not part of an NPDES permit.
(3) DEQ must provide an opportunity for public notice and comment on a trading plan before approving the trading plan. DEQ may amend the trading plan or require amendments to the trading plan prior to approval. Individual trading projects must be consistent with an approved trading plan. Individual trading projects do not require separate public notice and comment.	• (3): DEQ will provide a public comment opportunity on the draft 401 certification [OAR 340-048-0027], which will include the SRSP.
(4) A trading plan must be consistent with an applicable DEQ-issued trading framework if such a framework exists at the time DEQ approves the trading plan.	• (4): This subsection is inapplicable because no framework.
(5) A trading plan must include all of the following elements and a description of how the elements were derived or calculated: (a) The parameter for which water quality trading is proposed;	• (5a): The SRSP is focused on thermal benefits, measured in kilocalories of thermal load [SRSP Ex. 7.1-1, § 2.3].
(b) Trading baseline: A trading plan must identify any applicable regulatory requirements from OAR 340-039-0030(1) that apply within the trading area and that must be implemented to achieve baseline requirements;	• (5b): The 401 application [§ 6.1] and SRSP discuss the regulatory baseline requirements in Idaho and Oregon that could apply [SRSP Ex. 7.1-1, § 2.5.2.1].
(c) Trading area: A description of the trading area including identification of the location of the discharge to be offset, its downstream point of impact, if applicable, where trading projects are expected to be implemented, and the relationship of the trading projects to beneficial uses in the trading area;	• (5c): IPC must address temperature load below the HCD [IPC 401 Application, § 7.1.1]. The SRSP includes a description of the program area in which projects may be located. The SRSP program area allows for projects: 1) located below Swan Falls Dam and upstream of HCD in the Snake River, and 2) located on hydrologically connected tributaries to the Snake River upstream of the HCD (including but not limited to): Boise River, Brownlee Reservoir creeks, Burnt River, Malheur River, Middle Snake-Payette River, Owyhee River, Payette River, Pine Creek, Powder River, Succor Creek, and Weiser River. Thermal benefit modeling of riparian areas in these tributaries does not extend upstream beyond any reservoir or substantial impoundment [SRSP Ex. 7.1-1, § 2.3]. The SRSP is designed to provide temperature and other ancillary water quality, and habitat benefits to the Snake River watershed [IPC 401 Application, § 7.1.2].
(d) BMPs: A description of the water quality benefits that will be generated, the BMPs that will be used to generate water quality benefits, and applicable BMP quality standards;	• (5d): The SRSP describes how "thermal benefits" will be generated [SRSP Ex. 7.1-1, § 2.3], the BMPs that will be used to generate thermal benefits [SRSP Ex. 7.1-1, § 2.2], and includes applicable BMP quality standards [SRSP Ex. 7.1-1, Attachment 1].

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(e) Trading ratios: A description of applicable trading ratios, the basis for each applicable trading ratio, including underlying assumptions for the ratio, and a statement indicating whether those ratios increase or decrease the size of a credit obligation or the number of credits generated from an individual trading project;	• (5e): The 401 Application describes how the following ratios were determined and how/where they apply: 10% margin of safety from SR-HC TMDL increases size of the cumulative thermal load exceedance (CTLE) offset need [§ 7.1.2.1]; 50% in-reservoir attenuation doubles the size of the CTLE offset need [§ 7.1.2.1.1]; in-river attenuation reduces value of thermal benefit projects by 22-25% [§ 7.1.2.1.2].
(f) Credits: A description of the credits needed to meet water quality-based requirements of an NPDES permit or 401 water quality certification, including: (A) Quantity and timing: The number of credits needed and any credit generation milestones, including a schedule for credit generation; (B) Methods used: How credits will be quantified, including the assumptions and inputs used to derive the number of credits; and (C) Duration of credits: A description of the length of time credits are expected to be used.	• (5f): The 401 Application calculates the "thermal load exceedance" needed to offset impacts to salmonid spawning, and describes how all daily exceedances during this critical period are summed into a "cumulative thermal load exceedance" (CTLE) that IPC must offset [IPC 401 Application, § 6.1.2.3.2]. The SRSP describes how the thermal benefit milestones were developed, including an assessment of thermal benefit supply compared against thermal benefit need, and recruitment feasibility [SRSP Ex. 7.1-1, §§ 2.4, 2.6.5]. The quantification methods used, including assumptions and details on inputs, are described [SRSP Ex. 7.1-1, § 2.3]. Thermal benefits from projects are used to offset the CTLE during the salmonid spawning period [IPC 401 Application, § 6.1.3.2]. Thermal benefits from a single restoration project may be counted in multiple years so long as the restoration action is still functioning that year in accord with performance confirmation audits [SRSP Ex. 7.1-1, § 2.5.3]. Thermal benefits become valid for use upon implementation confirmation [SRSP Ex. 7.1-1, § 2.6.3].
(g) Monitoring. The trading plan must include a description of the following: (A) Proposed methods and frequency of trading project BMP monitoring; and (B) Proposed methods and frequency of how water quality benefits generated by a trading project will be monitored;	• (5g): The SRSP includes a description of the three tiered monitoring method proposed for the SRSP, as well as a description of how frequently those monitoring activities will take place [SRSP Ex. 7.1-1, § 2.6.2].
(h) Trading Plan Performance Verification: A description of how the entity will verify and document for each trading project that BMPs are conforming to applicable quality standards and credits are generated as planned; and	• (5h): The SRSP relies on a hybrid "audit" verification procedure comprised of two key components: 1) third-party confirmation that every project has been implemented consistent with restoration quality standards and guidelines; and 2) annual randomized project site audits of a percentage of projects by independent third party reviewers to confirm that projects are being maintained, monitored and tracked consistent with restoration quality standards and guidelines such that they are likely to achieve the modeled thermal benefits at the program's

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	conclusion [SRSP Ex. 7.1-1, § 2.6.3].
(i) Tracking and Reporting: A description of how credit generation, acquisition and usage will be tracked and how this information will be made available to the public.	• (5i): SRSP progress will be tracked via a publicly accessible tracking and reporting website [SRSP Ex. 7.1-1, § 2.6.4]. This website serves as a registry (i.e., ledger) for tracking thermal benefit totals as they accrue, and will host project design and monitoring information (including photo points), and the results of implementation and performance confirmations.
(6) Adaptive Management: Trading plans must include a description of how monitoring and other information may be used over time to adjust trading projects and under what circumstances;	• (6): The SRSP acknowledges the multi-decadal timeframe of the anticipated 401 certification and FERC license. The SRSP therefore incorporates the ability to adapt implementation, maintenance, monitoring, and performance tracking practices to reflect new knowledge and information as it emerges [SRSP Ex. 7.1-1, § 3].
(7) Trading Plan Revision: An approved trading plan must be revised during permit or 401 water quality certification renewal or if there is a change in circumstances that affects a trading plan element required by subsection (5) of this rule. Revised trading plans must be submitted to DEQ for review and approval and must be given an opportunity for public notice and comment. DEQ will reopen and modify the permit or 401 water quality certification for any revisions affecting an enforceable condition.	• (7): the SRSP will undergo adaptive management review by the DEQs on a five-year cycle [SRSP Ex. 7.1-1, § 3.1]. A five-year review cycle provides a regular opportunity to review available data from the previous years of implementation, maintenance, and monitoring, and to incorporate new technologies and lessons learned through previous implementation cycles into restoration quality standards and guidelines, as well as monitoring, maintenance, and performance tracking protocols. Periodic agency review of implementation and performance progress will also allow for course correction with respect to implementation milestones and obligations, and for updates to the regulatory baseline determinations associated with the SRSP, should any of these updates be needed.
340-039-0030 **Requirements for Trading Baselines** (1) Trading baseline must account for the following regulatory requirements applicable to the trading project at the time of trading project initiation:	• (1): "Because baseline is determined at the time of project initiation, much of the information necessary to determine site-specific baseline information will likely be unknown at the time of trading plan review and approval." Trading IMD, § 5(II)(C). The current regulatory baseline assessment included in the SRSP will be updated on a five-year basis that aligns with the SRSP adaptive management cycle [SRSP Ex. 7.1-1, § 3.1]. The results of this periodic assessment will constitute the regulatory baseline requirements associated with project sites implemented in the SRSP program area during the subsequent five-year period. For the

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	purposes of determining the extent of thermal benefits credited towards compliance with the cumulative thermal load exceedance, once a SRSP project site has been implemented, the regulatory baseline analysis associated with that project site will remain in effect for as long as the project site continues to be supported and maintained in a manner consistent with the SRSP.
(a) NPDES permit requirements;	• (1a): If IPC obtains thermal benefits from a NPDES permit holder in the SRSP program area, it will ensure that the actions generating those benefits are not already required by that NPDES permit.
(b) Rules the Oregon Department of Agriculture issued for an agricultural water quality management area under OAR chapter 603 division 095;	• (1b): The SRSP program area overlaps with four Oregon agricultural management plan (AgWQMP) areas: Owyhee (OAR 603-095-2700), Malheur (OAR 603-095-0900), Burnt (OAR 603-095-3200), and Powder/Brownlee (OAR 603-095-3600). While these potentially applicable AgWQMP area rules protect against activities that will degrade riparian vegetation at potential SRSP riparian project sites, they do not establish any affirmative restoration obligations on those project sites. Rather, these passive, non-disturbance regulations only require that land be left alone so that vegetation can be established.
(c) Rules the Oregon Board of Forestry issues under OAR chapter 629 divisions 610-680;	• (1c): The SRSP did not identify any areas where currently applicable BOF rules would overlap with SRSP program area potential sites [SRSP Ex. 7.1-1, § 2.5.2.1]. In some instances, no baseline obligations exist: “If no regulatory requirements described in OAR 340-039-0030(1) exist or apply within the trading area, the trading plan may state that baseline is ‘existing conditions.’” Trading IMD, § 5(II)(C).
(d) Requirements of a federal land management plan, or an agreement between a federal agency and the state;	• (1d): The SRSP notes that demonstrating additionality on publicly owned land involves the consideration of management actions, if any, which are already required by the federal or state management statute and plans governing that parcel. If any of those statutes or management plans already require active restoration of the riparian area where SRSP project sites would be implemented, it would be necessary to discount the thermal benefits generated from that project site so as to ensure that those benefits are not “double-counted.” [SRSP Ex. 7.1-1, § 2.5.2.1]. If projects are planned on lands covered by such plans, any requirements stemming from those plans would be applied.

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(e) Requirements established in a Clean Water Act Section 401 water quality certification;	• (1e): The IMD notes that if a 401 license holder would like to generate credits, it would need to complete actions beyond the general and mitigation conditions included in its 401 application [Trading IMD, § 5(I)(H)(iii)]. However, IPC's proposed temperature mitigation in its 401 application is to generate thermal benefits, so the baseline considerations that apply are those related to other nonpoint source generators of thermal benefits [Trading IMD, § § 5(I)(H)(iv)].
(f) Local ordinances;	• (1f): Depending on a property's location within the SRSP program area, it may be subject to county or city comprehensive plan, zoning ordinances, subdivision ordinances or other local code requirements. Baseline requirements at the county and city level may therefore vary depending on location, land use type, applicable overlay districts (if any) and the type of BMP employed to generate thermal benefits. No county and city regulations in the SRSP program currently affirmatively require riparian restoration work. Site-specific local requirements will be documented as part of project eligibility [SRSP Ex. 7.1-1, Attachment 1].
(g) Tribal laws, rules, or permits; (h) Other applicable rules affecting nonpoint source requirements;	• (1g, h): In some instances, no baseline obligations exist: "If no regulatory requirements described in OAR 340-039-0030(1) exist or apply within the trading area, the trading plan may state that baseline is 'existing conditions.'" Trading IMD, § 5(II)(C). The SRSP did not identify any tribal laws, rules or permits, or other currently applicable rules affecting nonpoint source requirements [SRSP Ex. 7.1-1, § 2.5.2.1].
(i) Projects completed as part of compensatory mitigation, or projects required under a permit or approval issued under Clean Water Act section 404, or a supplemental environmental project used to settle a civil penalty imposed under OAR chapter 340 division 012 or the Clean Water Act; and	• (1i): As part of SRSP project eligibility screening and documentation, IPC will ensure that such projects are not used to generate thermal benefits for the purposes of 401 compliance [SRSP Ex. 7.1-1, § 2.5.1, Attachment 1].
(j) Regulatory requirements a designated management agency establishes to comply with a DEQ-issued TMDL, water quality management plan or another water pollution control plan adopted by rule or issued by order under ORS 468B.015 or 468B.110.	• (1j): Pursuant to the SR-HC TMDL WQMP, affirmative obligations to restore instream or riparian areas would be derived from implementation plans issued by designated management agencies (DMAs). Relevant DMAs identified in the DEQ SR-HC TMDL WQMP include IPC, ODA, ODEQ, ODOF [SR-HC TMDL, § 6.1, Ch. 5]. The SR-HC TMDL "implementation plans" created by these DMAs incorporate and rely on existing regulatory mechanisms (e.g.,

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(2) BMPs required to meet baseline requirements and BMPs used to generate additional water quality benefits and trade credits may be installed simultaneously.	AgWQMP area rules), but do not create stand-alone obligations to restore riparian or in-river areas. • (2): The SRSP does not explicitly address this issue, but will do so if applicable baseline requirements must be implemented at sites.
340-039-0035 **Requirements for Trading Areas** (1) DEQ may establish trading areas in trading frameworks. (2) All trading areas must be consistent with any applicable TMDL water quality management plan, independent state water quality management plans, or trading framework.	• (1): inapplicable because no trading framework. • (2): The SRSP establishes a program area [SRSP Ex. 7.1-1, § 2.3] that is consistent with Oregon's SR-HC TMDL water quality management plan (WQMP) [TMDL, § 6.1, Ch. 3]. The Oregon WQMP notes that one primary factor driving temperature impacts in the "geographic region of interest" is "riparian vegetation disturbance in upstream reaches and tributaries."
340-039-0040 **Requirements for Credits** (1) Credits used for compliance with NPDES permit and 401 water quality certification requirements must be generated within the trading area of an approved trading plan. (2) A credit may not be used to meet a regulatory obligation by more than one entity at any given time. (3) Credits may be generated only from BMPs that result in water quality benefits above trading baseline requirements. (4) Credits generated under an approved trading plan may not include water quality benefits obtained with public conservation funds. Where public sources of funding are used for credit-generating activities, it is the entity's responsibility to demonstrate compliance with this requirement in its annual report. (5) Credits may be used for compliance with NPDES permit requirements and 401 water quality certifications once implementation of BMPs has been verified as consistent with applicable BMP quality standards according to OAR 340-039-0025(5)(h). (6) Credits may be generated from BMPs installed before DEQ approves a trading plan if BMPs are verified as having been implemented consistent with BMP quality standards identified in a subsequently approved trading plan and are functioning effectively.	• (1): Only thermal benefits generated within the SRSP trading area will be eligible for use in the 401 [SRSP Ex. 7.1-1, Attachment 1, quality standard section on eligibility]. • (2): SRSP thermal benefits will only be used by IPC, and will be tracked accordingly [SRSP Ex. 7.1-1, § 2.5.2 (financial additionality); § 2.6.4 (tracking)]. • (3): The SRSP describes how regulatory baseline applies to the thermal benefit generating actions in the program area [SRSP Ex. 7.1-1, § 2.5.2.1]. • (4): SRSP thermal benefits will not be funded via public conservation funds [SRSP Ex. 7.1-1, § 2.5.2]. • (5): Before thermal benefits can be used by IPC toward its 401 obligation, they will be confirmed as having been implemented consistent with the BMP quality standards attached to the SRSP [SRSP Ex. 7.1-1, § 2.5.4]. • (6): If IPC implements thermal benefit producing projects prior to DEQ approval of the 401, those projects will be implemented consistent with SRSP quality standards and will need to be verified prior to being used for 401 compliance.

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340-039-0043 **Requirements for Trading Ratios**	
(1) Water quality trades must include one or more trading ratios that apply to credits. Ratio components and underlying assumptions must be clearly documented in the trading plan.	• (1): The 401 includes three ratio components, which affect the size of the offset obligation, and the value of thermal benefits from projects. The assumptions underlying these ratios are described in the 401 application [§ 7.1.2.1].
(2) Trading ratios may be used to account for variables associated with a trading project including the following: (a) Attenuation of a water quality benefit between the location where credit-generating BMPs occur and the point of use;	• (2a): The 401 Application discounts the value of thermal benefits by 22% (instream projects) and 25% (riparian shade projects), respectively, to account for in-river attenuation of benefits between project sites and the in-flow into the HCC [§ 7.1.2.1.2]. The 401 Application doubles the size of the CTLE offset need to account for the 50% in-reservoir attenuation of thermal benefits as they travel the HCC reservoirs [§ 7.1.2.1.1].
(b) Pollutant equivalency;	• (2b): Pollutant equivalency is not applicable since all actions measured are in kcals/day, thereby making a ratio unnecessary.
(c) Uncertainty of BMP performance or water quality benefit measurement or estimate; (d) Types of risk not associated with BMP performance;	• (2c, d): The 401 Application increases the size of the cumulative thermal load exceedance by 10% to account for the SR-HC TMDL margin of safety factor [§ 7.1.2.1]. This factor is meant to cover uncertainty in the load calculation.
(e) Time lag after BMP installation before a BMP produces full water quality benefit;	• (2e): N/A. Anticipated compliance required at end of FERC license term (approximately year 50), which aligns with the multi-decade timeframe that may be necessary to implement the SR-HC TMDL [§ 6.1, Ch. 1]. Unlike the shorter NPDES horizon—where there is a time lag ratio in place to align the 5-year permit term with a 20-year growth period—full tree growth will be achieved before the license expires. Instream projects, which may constitute a significant portion of the SRSP, will yield full benefits immediately.
(f) Credit for trading projects located in priority areas; or	• (2f): N/A. While SRSP projects are designed to generate additional habitat benefits in priority areas, IPC does not seek a ratio for implementing these projects.
(g) Credit retirement to ensure a net reduction in water pollution.	• (2g): N/A. SRSP projects will produce thermal benefits all year long. However, IPC will only be claiming aggregate thermal benefits during the July – October period of the year.

Exhibit 7.1-8

Section 7.1 of the September 2010 Hells Canyon Complex (HCC) Section 401 application

The SR-HC TMDL addressed narrative standards associated with nuisance growths and the formation of organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry. IPC has identified its contribution in Section 6.4.3.

The EPA and the ODEQ point source discharge permits address oily sheens or the coating of aquatic life with oil films. IPC must not exceed levels or requirements as stated in permits.

The creation of tastes or odors or toxic or other conditions are discussed in Section 6.6.
The mercury TMDL was scheduled for 2006. IPC fully anticipates to cooperate in developing the mercury TMDL and to implement PME measures to address any allocations.

The *Hells Canyon Resource Management Plan*, developed by IPC as part of the HCC license application to the FERC, establishes guidelines for management of its lands. Road building and maintenance activities and aesthetic conditions narrative standards are addressed directly in the *Hells Canyon Resource Management Plan* while others are indirectly addressed. Exhibit 4.3-2 discusses compatibility with local land-use plans.

7. PROPOSED PROTECTION, MITIGATION, AND ENHANCEMENT MEASURES

7.1. Temperature Proposed Measures

The SR-HC TMDL assigned a temperature load allocation to the HCC based on downstream numeric criteria during the salmonid spawning period. The salmonid species that spawn in the Snake River downstream of Hells Canyon Dam include fall Chinook salmon and Mountain Whitefish. IPC's requirement identified in the SR-HC TMDL is to ensure that outflows from Hells Canyon Dam do not exceed the salmonid spawning criteria from October 23 through April 15. To address the SR-HC TMDL temperature load allocation, IPC is proposing a hypolimnetic pump system (HPS) in Brownlee Reservoir, which will blend cold water from the lower strata of the reservoir with warmer upper strata waters.

The HPS will be designed and operated to meet the SR-HC TMDL load allocation assigned to IPC to address temperature exceedences immediately below Hells Canyon Dam. The SR-HC TMDL identified the period of the temperature load allocation as the period during salmonid spawning when water temperatures flowing into Brownlee Reservoir meet the salmonid spawning criteria, but the discharge from Hells Canyon Dam does not. Discharge temperatures measured from 1991 through 2009 indicate that during low flow conditions, an average of a 2.3 ºC reduction (i.e., 15.6 minus 13.3 °C) in discharge seven-day average maximum temperature on October 29 could be required (Table 7.1-1). This required reduction would taper off to zero during the duration of the criteria exceedence which is 12 days on average. No action is necessary to meet the standard during high flow years, such as 1997. The SR-HC TMDL requires that IPC address this short period of exceedence from October 29 until the seven-day average maximum temperature is no greater than the salmonid spawning criteria.

Table 7.1-1. Hells Canyon Dam outflow temperature exceedence of the salmonid spawning criterion (13.0 °C plus the 0.3 °C human use allowance on October 29), duration of exceedence, and water conditions for the calendar year. Water year category is based on three categories (Low, Medium, and High) summarized for the period of record (1911–2009) Snake River flow measured at Weiser, Idaho.

Year	HC Outflow Oct. 29 7-Day Average Max (°C)	HC Outflow Duration >13.3 °C (Days)	Annual Average Flow (cfs)	Water Year Category
1991	16.4	12	10,400	Low
1992	15.8	16	8,400	Low
1993	15.7	Na	16,500	Medium
1994	15.5	12	10,800	Low
1995	14.6	7	17,500	Medium
1996	14.8	8	24,600	High
1997	13.3	0	32,000	High
1998	14.0	6	23,000	High
1999	14.5	8	22,900	High
2000	15.0	9	15,100	Medium
2001	Na	Na	9,800	Low
2002	15.3	8	11,000	Low
2003	16.8	13	11,700	Low
2004	16.3	15	10,900	Low
2005	15.7	15	11,100	Low
2006	15.3	8	21,500	High
2007	14.5	9	11,000	Low
2008	14.9	10	12,700	Low
2009	14.6	7	14,400	Low
Low-Water Average	15.6	12.0	11,200	Low

Note: Na indicates data not available. Low-water average is the average of all available data in each column for low-water years.

As explained in Section 6.1, the narrative natural seasonal thermal pattern (NSTP) standard does not apply to the HCC, as restoration of historic temperatures would cause potentially catastrophic harm to fall Chinook salmon, giving rise to “jeopardy” within the meaning of the Endangered Species Act. Therefore, this § 401 application contains no proposal for compliance with the NSTP standard.

The operation of the HPS, or any other device that accesses and moves water from the hypolimnion of the reservoir to downstream, poses a level of risk for natural resources in the river and the three reservoirs within the HCC. Hypolimnetic water in Brownlee Reservoir is currently degraded primarily due to heavy nutrient and organic matter loads produced upstream in the Snake River. Blending of cooler water from the thermally stratified reservoir may further degrade downstream conditions and have an effect on beneficial uses downstream. The operation of a HPS will also change or influence the current stratification within Brownlee Reservoir which may have adverse effects upon the in-reservoir aquatic community. The precise nature and extent of these adverse effects cannot be predetermined, as a complete evaluation cannot occur until the HPS is constructed and operated, and the effects on in-reservoir and downstream resources analyzed. These issues, and potential mitigation to address them, are discussed in more detail below.

7.1.1. Conceptual Project Description

The HPS consists of a system of high flow, low head pumps designed to move cold water from the hypolimnion of Brownlee Reservoir to discharge into the intake channel in front of the turbine penstocks (Figure 7.1-1). Initial engineering assessment indicates this system is feasible to construct and operate. The details of the design will be developed as engineering and design continue. The cold water discharged into the intake channel in front of the turbines would mix with warmer water being drawn through the powerhouse to cool Brownlee Project outflow during the period of operation. Cooler Brownlee Project outflows would then propagate through Oxbow and Hells Canyon reservoirs, resulting in cooler outflows from the Hells Canyon Project.

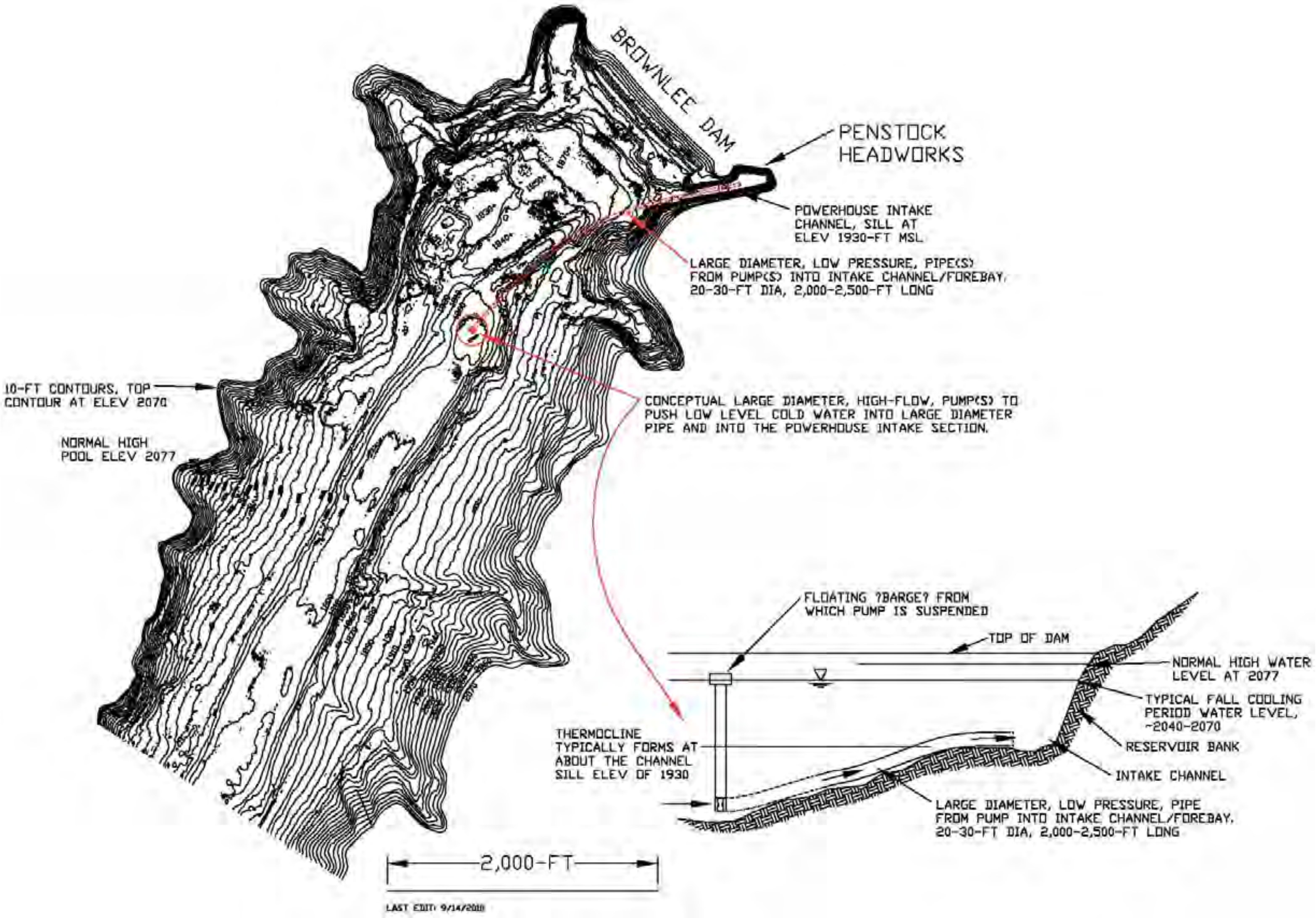


Figure 7.1-1. Conceptual project plan sketch.

The capacity of the HPS to meet temperature objectives is the subject of ongoing evaluation and will be influenced by a variety of factors, two of which are the flow rate and volume of cold water available for cooling. A preliminary analysis of these two factors, using historical conditions measured from 1991–2009 described below, shows that sufficient volume of cold water exists in Brownlee to provide for the flows necessary to sufficiently cool Brownlee outflows.

The volume and temperature of cold water available in Brownlee Reservoir were estimated using Brownlee Reservoir historic measured data of temperature profiles and the volume elevation relationship based on reservoir bathymetry. Temperature stratification in Brownlee Reservoir is characterized by thermocline and metalimnion development at about 1,930 ft msl, the same elevation as the bottom of the intake channel. Measured temperature profiles show that, in the majority of years analyzed, the rapid metalimnion temperature change slows and more consistent hypolimnion temperatures begin near elevation 1,920 ft msl (Figures 7.1-2 and 7.1-3). The temperature of the hypolimnion is strongly related to spring Brownlee Reservoir inflow and resulting water surface elevations managed regionally for flood control. In years when spring inflow is high and Brownlee Reservoir is correspondingly required to drawdown for flood control, water in the hypolimnion is typically warmer (e.g., 1999, 2006). In most other years, the hypolimnion at lower depths is cooler (i.e., about 5 °C).

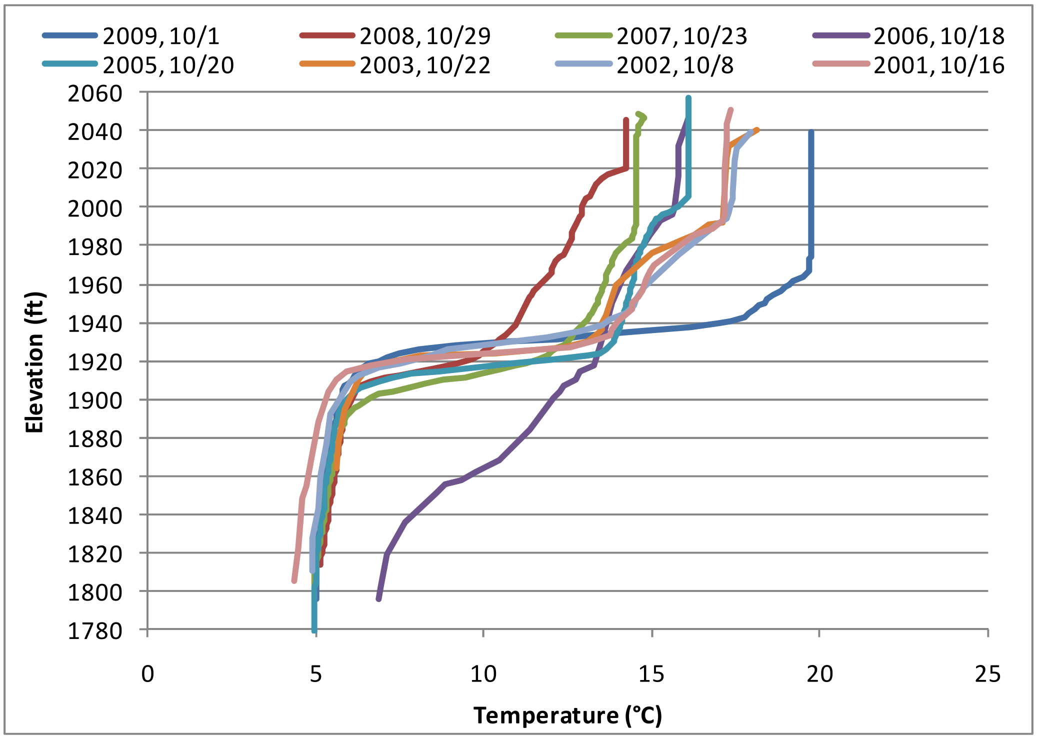


Figure 7.1-2. Brownlee Reservoir temperature profiles measured near Brownlee Dam in October from 2001–2009. Note no data is available for October 2004.

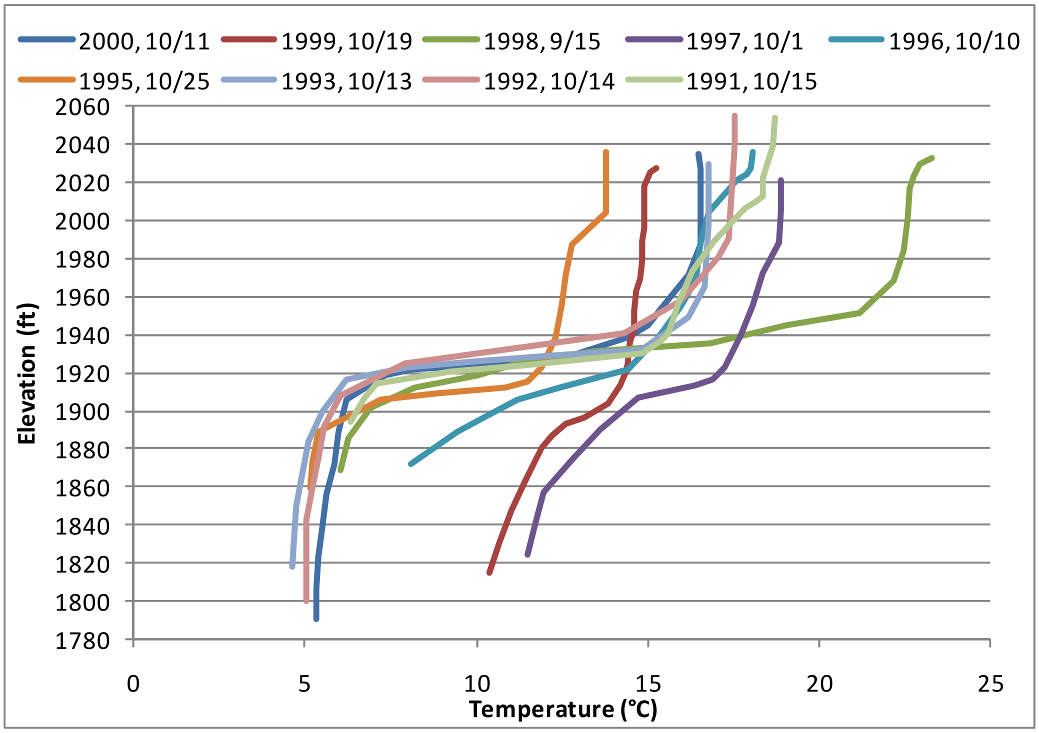


Figure 7.1-3. Brownlee Reservoir temperature profiles measured near Brownlee Dam in October or September from 1991–2000. Note no data is available for October or September 1994.

The volume of water below 1,920 ft msl in Brownlee Reservoir is approximately 157,300 acre-feet (Figure 7.1-4). Reservoir volume increases rapidly with increasing elevation up to 1,920 ft msl (Figure 7.1-4). The temperature of this 157,300 acre-feet can be variable depending on water conditions as discussed previously (e.g., 2006 where hypolimnion temperatures show a gradient). For these reasons, measured temperature profiles were used to calculate a volume weighted average temperature of water below 1,920 ft msl for each year to characterize the temperature of the cold water volume for this analysis. In 13 of the 19 years (i.e., low and medium water years), the volume weighted average temperature of the cold water was 5.3–7.0 °C. The cold water temperature was then used in a flow-weighting analysis, as described below, to evaluate whether sufficient cold water volume exists in Brownlee Reservoir to meet the SR-HC TMDL load allocation below Hells Canyon Dam.

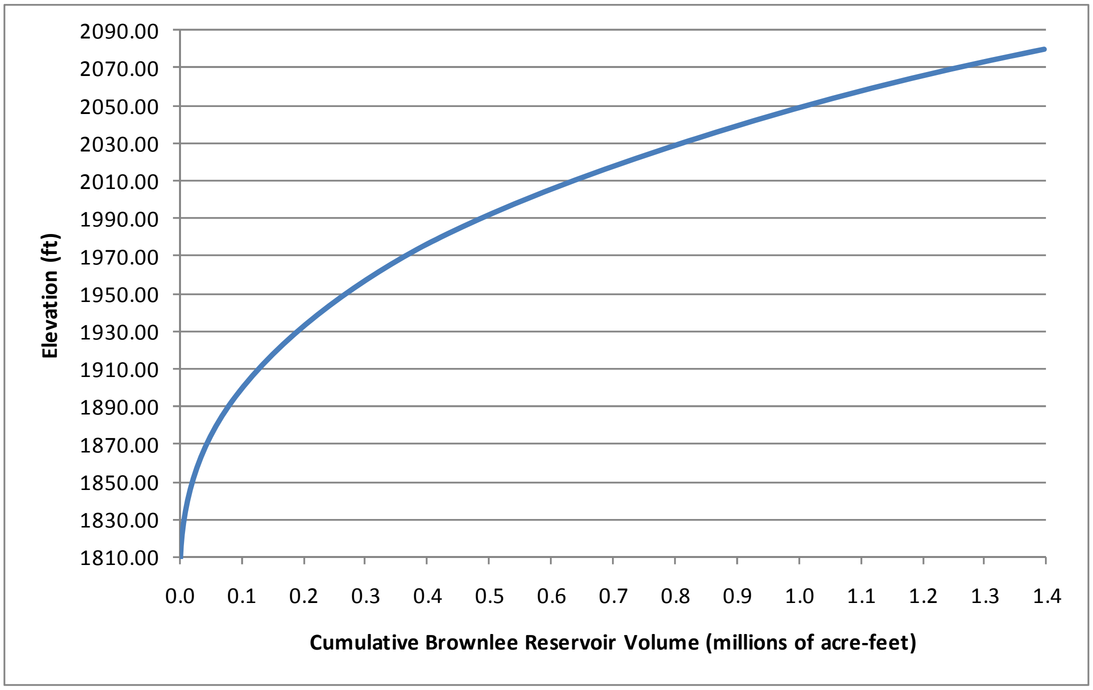


Figure 7.1-4. Volume elevation relationship for Brownlee Reservoir.

The cold water temperature in Brownlee Reservoir, along with outflow temperature and flow from Hells Canyon Dam, were used in the flow weighting analysis. The basic equation shown below was used in this analysis and the cold water flow rate iteratively adjusted to meet 13.3 °C. This cold water flow rate was then used with the measured duration of the criteria exceedence for that year to estimate the cold water volume needed.

$$\text{TempHC}_{\text{predicted}} = (((\text{FlowHC}_{\text{out}} - \text{Flow}_{\text{pump}}) * \text{TempHC}_{\text{out}}) + (\text{Flow}_{\text{pump}} * \text{Temp}_{\text{Hypo}})) / \text{FlowHC}_{\text{out}}$$

Where:

- $\text{TempHC}_{\text{predicted}}$ is calculated flow weighted HCC outflow temperature including cool water from Brownlee Project.
- $\text{FlowHC}_{\text{out}}$ is average HCC outflow from 10/23 to 10/29 for that year. This is representative of fall Chinook flows that are typically held flat through the period.
- $\text{Flow}_{\text{pump}}$ is flow of cool water from Brownlee Reservoir.
- $\text{TempHC}_{\text{out}}$ is measured 7-day average maximum HCC outflow temperature on October 29. This does not account for the “tapering” of the temperature exceedence over the duration of flows.
- $\text{Temp}_{\text{Hypo}}$ is volume weighted average hypolimnetic temperature below 1,920 ft msl in Brownlee Reservoir based on measured conditions for that year.

Assumptions in this analysis include:

- No tapering as exceedence declines, i.e., HCC outflow temperatures are assumed to be constant at the measured value for the duration of exceedence. Actual conditions are cooling (i.e., tapering) to 13 °C over the duration. This is a conservative assumption because a tapering, not constant, cold water flow rate would be sufficient to remain below criteria and would use less cold water volume.
- Future HCC outflows are similar to measured flows for specific years.
- Regionally managed flood control operations for Brownlee Reservoir will remain as they were historically. The hypolimnion temperatures in Brownlee are related to mandated flood control drawdowns of Brownlee Reservoir.

Based on this flow weighting analysis there was sufficient volume of cold water in Brownlee Reservoir in October to cool historical conditions at the HCC outflow to meet the SR-HC TMDL load allocation (Table 7.1-2). In 95 percent of years analyzed, there was sufficient volume of cold water in Brownlee to also provide a margin of safety relative to the availability of cold water. With the exception of 1999, pumping rates from 1,000 to 4,200 cfs would be adequate for cooling the outflows.

Table 7.1-2. Temperature flow-weighting analysis of historical (1991–2009) Hells Canyon outflow conditions during October 23–29, Brownlee Reservoir cold water volume and flow rate of cold water necessary for cooling. Brownlee cold water temperature is characterized as a volume-weighted average temperature below 1,920 feet elevation (157,300 acre-feet), based on measured temperature profiles.

Year	Water Year Category	HC Outflow Average Oct. 23-29 (cfs)	HC Outflow Oct. 29 7-Day Average Max (°C)	HC Outflow Duration >13.3 °C (Days)	Brownlee Cold Water Temperature (°C)	Est. Cold Water Flow (cfs)	Est. Cold Water Volume used for Duration (acre-feet)	Estimated HC Outflow Temperature (°C)
1991	Low	9,700	16.4	12	6.7	3,100	73,800	13.3
1992	Low	9,400	15.8	16	5.8	2,350	82,500	13.3
1993	Medium	9,500	15.7	Na	5.4	2,200	Na	13.3
1994	Low	9,300	15.5	12	Na	Na	Na	13.3[1]
1995	Medium	9,700	14.6	7	7.0	1,600	27,800	13.3
1996	High	9,600	14.8	8	10.1	3,100	57,100	13.3
1997[2]	High	12,200	13.3	0	13.9	Na	Na	Na
1998	High	9,600	14.0	6	7.0	1,000	16,700	13.3
1999	High	13,000	14.5	8	12.6	8,000	126,900	13.3
2000	Medium	9,800	15.0	9	6.2	1,900	39,300	13.3
2001[1]	Low	8,500	Na	Na	5.3	Na	Na	13.3[1]
2002	Low	9,100	15.3	8	5.7	1,900	34,900	13.3
2003	Low	8,500	16.8	13	6.0	2,750	77,400	13.3
2004[1]	Low	8,700	16.3	15	Na	Na	Na	13.3[1]
2005	Low	8,700	15.7	15	6.4	2,200	65,500	13.3
2006	High	8,700	15.3	8	11.2	4,200	76,200	13.3
2007	Low	8,600	14.5	9	6.9	1,400	30,300	13.3
2008	Low	9,000	14.9	10	6.3	1,700	39,700	13.3
2009	Low	8,900	14.6	7	5.7	1,300	22,200	13.3

Note: Na indicates data not available and/or calculations not applicable.

[1] Based on data for other low water years it's assumed sufficient cold water existed in these years.

[2] 1997 measured data met the criterion so calculations were not conducted.

7.1.2. Conceptual Project Risk Assessment

Potential risks of operating a HPS are primarily related to changes in downstream water quality caused by the discharge of low DO water with elevated levels of toxics. This is because of the water quality conditions of the hypolimnion of Brownlee Reservoir. Operation of the HPS can also change or influence the current stratification and related hydrodynamics within

Brownlee Reservoir, which may have adverse effects upon the in-reservoir aquatic community. The potential for adverse effects due to these changes is being evaluated.

Background information and a conceptual assessment of downstream risks are provided below. However, it is should be acknowledged that the precise nature and extent of these potential adverse effects cannot be precisely predicted as a complete evaluation cannot occur until the HPS is constructed and operated. IPC has identified its preferred mitigation process for DO and is assessing the potential for impacts relative to elevated levels of toxics and mitigation measures to address this potential.

7.1.2.1. Downstream risk

In October, the cold water in the hypolimnion of Brownlee Reservoir is anoxic and pumping this water to the intake channel to be drawn through the turbines will correspondingly result in reduced DO immediately downstream of Brownlee Reservoir and at the HCC outflow. Increased levels of methane, sulfides, dissolved nutrients, methylmercury and other dissolved inorganics associated with the anoxic conditions in the hypolimnion of Brownlee Reservoir may also be released downstream. Some of these products (e.g., methane, sulfides) are oxidized when oxygen is added to the water and can create additional oxygen demand. Others, such as methylmercury, are a concern due to aquatic toxicity.

7.1.2.1.1. Downstream dissolved oxygen

Currently Brownlee Reservoir receives inflows that are high in nutrients and organic matter (IDEQ and ODEQ 2004). As these excessive loads are processed in the reservoir anoxic conditions develop in the upper end of the reservoir as early as April or May. As the year progresses, DO is steadily depleted throughout much of the reservoir until July or August when anoxia has typically developed throughout the water column from about 2000 ft msl (77 feet deep from full pool) to the bottom (Figure 7.1-5). Moving into October, the hypolimnion is typically anoxic but plunging cool fall inflows begin to improve metalimnion conditions (Figure 7.1-6). However, while the entire hypolimnion may be anoxic in October, the water quality (i.e., dissolved nutrients, methane, sulfides) is variable depending on the duration of anoxia and the accumulation of products of anoxia at that location. DO and water quality conditions in the hypolimnion are also variable depending on water year and resulting temperature of the hypolimnion, as discussed previously (Figure 7.1-7). Because of this flow and temperature variability, DO and water quality of the upper strata that is drawn through the Brownlee powerhouse can also vary substantially by year.

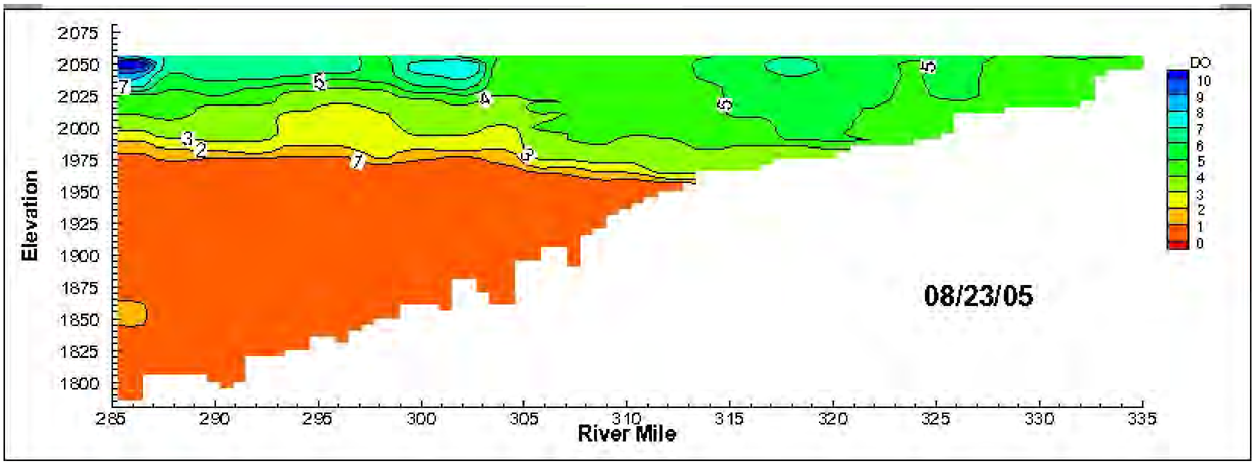
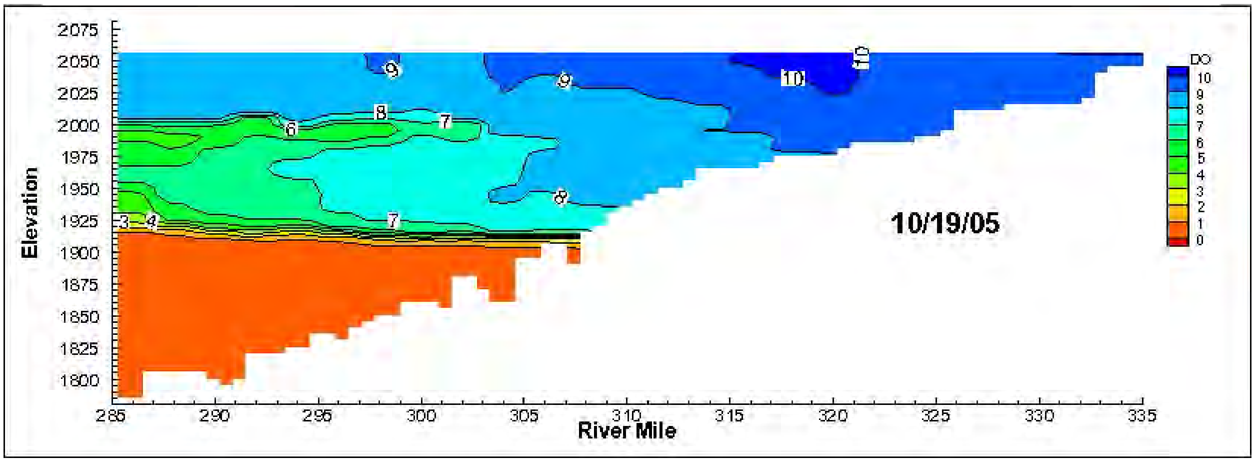


Figure 7.1-5. Dissolved oxygen (mg/L) isopleth plot of Brownlee Reservoir on August 23, 2005, from the dam (River Mile [RM] 285) to the inflow (RM 335).



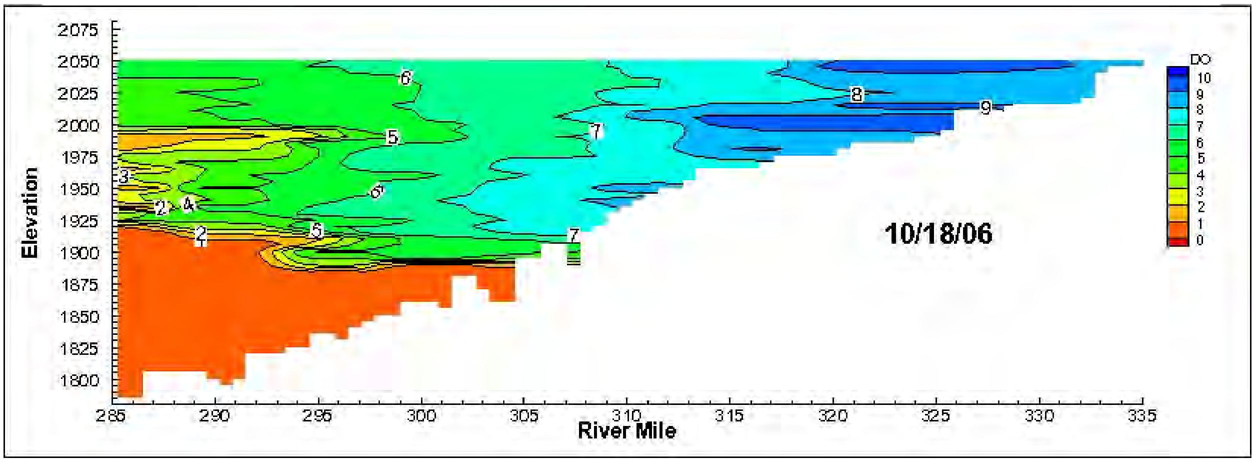


Figure 7.1-6. Dissolved oxygen (mg/L) isopleth plots of Brownlee Reservoir on October 19, 2005, and October 18, 2006, from the dam (River Mile [RM] 285) to the inflow (RM 335).

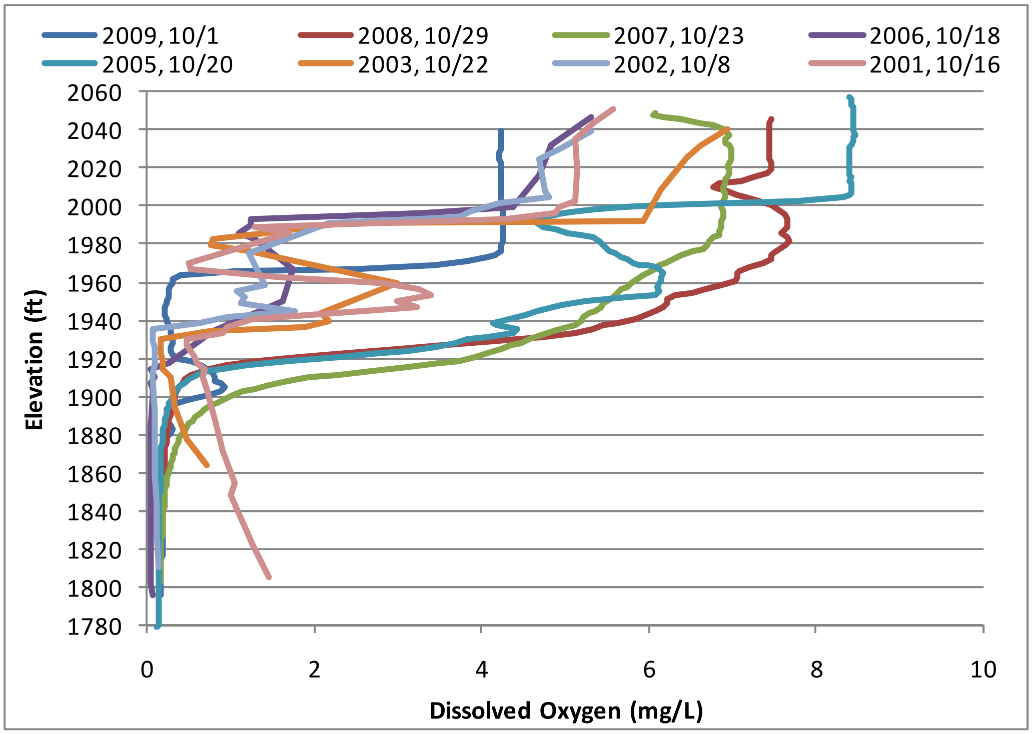


Figure 7.1-7. Brownlee Reservoir DO profiles measured near Brownlee Dam in October from 2001–2009. Note no data is available for October 2004.

The reduction in downstream DO resulting from operation of the HPS is dependent on the cold water flow rate and the DO concentrations of the warmer water that mixes with the cold water. In order to evaluate the potential reduction in Hells Canyon Dam outflow DO, a flow-weighting analysis using measured data from 1991–2009, similar to the temperature analysis (see Table 7.1-2), was conducted. For this analysis it was assumed that the cold water being pumped was anoxic, but that there was no additional demand from anoxic products. The minimum daily minimum DO concentration measured at Hells Canyon Dam from October 23 to November 6 was assumed to be the concentration of the warmer water into which the cold water mixes. The results suggest that downstream DO could be reduced 1-3 mg/L from historical conditions due to operation of the system (Table 7.1-3). As anticipated, the larger the cold water flow rate, the larger the DO deficit.

The preliminary flow weighting analysis assumes that there is no additional oxygen demand from reduced substances such as labile organic matter, ammonia, methane and sulfides. Oxidation of these materials can consume oxygen over various periods and some require weeks for complete oxidation. Pilot level sampling shows that some of these materials are present in Brownlee Reservoir hypolimnion in October (Table 7.1-4). The laboratory testing for biochemical oxygen demand (BOD) in the hypolimnion water indicates that 1 to 2.5 mg/L of oxygen was consumed in the first 3 days following addition of oxygen (Table 7.1-4). After 30 days 3.3 to 9.8 mg/L of oxygen was consumed. These BOD results are based on laboratory tests that do not provide for continuous atmospheric reaeration.

Table 7.1-3. Dissolved oxygen (DO) flow-weighting analysis of historical (1991–2009) Hells Canyon outflow conditions during October 23–29, Brownlee Reservoir cold water DO and flow rate of cold water necessary for cooling. Brownlee cold water DO is assumed to be zero based on measured DO profiles.

Year	Water Year Category	HC Outflow Average Oct. 23–29 (cfs)	HC Outflow Minimum Daily Minimum DO Oct. 23–Nov. 6 (mg/L)	Brownlee Cool Water DO(mg/L)	Est. Cool Water Flow (cfs)	Est. HC Outflow Daily Minimum DO (mg/L)	DO Deficit (mg/L)	DO Load (tons/day)
1991	Low	9,700	4.2	0	3,100	2.9	1.3	34
1992	Low	9,400	6.5	0	2,350	4.9	1.6	41
1993	Medium	9,500	3.4	0	2,200	2.6	0.8	20
1994	Low	9,300	5.5	Na	Na	Na	Na	Na
1995	Medium	9,700	4.9	0	1,600	4.1	0.8	21
1996	High	9,600	5.6	0	3,100	3.8	1.8	47
1997[1]	High	12,200	5.2	0	Na	Na	Na	Na
1998	High	9,600	4.7	0	1,000	4.2	0.5	13
1999	High	13,000	4.0	0	8,000	1.5	2.5	88
2000	Medium	9,800	4.2	0	1,900	3.4	0.8	21
2001[1]	Low	8,500	Na	0	Na	Na	Na	Na
2002	Low	9,100	5.6	0	1,900	4.4	1.2	29
2003	Low	8,500	5.8	0	2,750	3.9	1.9	44
2004[1]	Low	8,700	6.3	Na	Na	Na	Na	Na
2005	Low	8,700	7.0	0	2,200	5.2	1.8	42
2006	High	8,700	6.1	0	4,200	3.2	2.9	68
2007	Low	8,600	6.5	0	1,400	5.4	1.1	26
2008	Low	9,000	6.0	0	1,700	4.9	1.1	27
2009	Low	8,900	4.8	0	1,300	4.1	0.7	17

Note: Na indicates data not available and/or calculations not applicable.

[1] 1997 measured data met the temperature criterion so calculations were not conducted.

Table 7.1-4. Selected Brownlee Reservoir hypolimnion water quality constituents sampled in October 2005 and 2006.

Sample Date	River Mile	Sample Elevation (ft msl)	Ammonia (mg/L)	Methane (ug/L)	Sulfide (mg/L)	Dissolved Orthophosphate (mg/L)	UBOD[1] 3-day (mg/L)	UBOD[1] 30-day (mg/L)
10/26/2005	286	1,803	0.28	380	<0.05	0.207	2.6	5.2
10/26/2005	286	1,836	0.24	260	<0.05	0.205	2.6	4.3
10/26/2005	286	1,915	0.06	0.4	<0.05	0.130	2.5	4.3
10/27/2005	296	1,869	0.69	970	<0.05	0.293	2.0	6.3
10/27/2005	296	1,902	0.59	900	<0.05	0.274	2.0	6.0
10/27/2005	296	1,915	0.54	520	<0.05	0.253	2.2	6.2
10/4/2006	286	1,847	0.28	290	Na	0.167	1.3	3.8
10/4/2006	286	1,853	0.33	340	Na	0.186	1.6	3.7
10/4/2006	286	1,952	0.02	0.54	Na	0.097	<1.0	2.3
10/4/2006	296	1,860	1.23	2,000	0.22	0.413	1.6	9.8
10/4/2006	296	1,893	0.32	420	Na	0.17	1.2	3.3
10/4/2006	296	1,952	0.07	0.76	Na	0.072	1.2	2.9
10/18/2006	286	1,803	0.88	800	Na	0.311	1.7	7.4
10/18/2006	286	1,836	0.48	500	Na	0.234	1.6	5.4
10/18/2006	286	1,908	0.14	99	Na	0.14	1.6	3.6
10/18/2006	296	1,849	0.12	12	Na	0.063	1.3	3.9
10/18/2006	296	1,882	0.25	4.9	Na	1.02	1.7	5.3
10/18/2006	296	1,951	0.13	0.34	Na	0.072	1.7	3.9

Note: Na indicates data not available.

[1] Ultimate Biochemical Oxygen Demand (UBOD) methodology is a modification of the standard 5-day BOD test that uses no bacerial seeds, dilutions, or nitrification inhibitors.

As discussed in Section 7.1.3., mitigation measures are being assessed to address the DO deficit caused by operation of the HPS. However, IPC recognizes that DO levels in the discharge from HCC are currently below criteria during the operational period of HPS (Section 6.2.2.2.2). IPC has proposed mitigation measures to increase DO levels within the reservoir as required to meet the SR-HC TMDL Brownlee Reservoir DO allocation. IPC has also proposed measures to address the total unallocated additional DO load that would be needed to meet criteria downstream of the HCC (see Section 7.2). Thus, by implementing measures that address 1) allocated loads as established in the SR-HC TMDL, 2) unallocated loads to meet downstream DO criteria, and 3) any additional HPS DO deficit, the DO criteria below HCC will be met in the future with full SR-HC TMDL and IPC implementation.

7.1.2.1.2. Downstream toxics and nutrients

Toxics occur in Brownlee Reservoir due to Snake River and tributary inflows and in-reservoir conversion of materials into more toxic forms as decomposition of dead algae, organic sediments, and other organic matter depletes oxygen. Inflowing toxics include organic and inorganic materials. Inorganics may be naturally occurring, while both organic and inorganic materials can occur from anthropogenic sources.

A primary concern is the methylation of mercury (IDEQ and ODEQ 2004). Low DO and the presence of substantial amounts of organic matter near the sediment and water interface can result in higher levels of methylmercury and other inorganic constituents affected by redox processes such as iron, manganese, sulfur and other trace metals.

Both Oregon (ODHS 2005) and Idaho (IDHW 2005) have issued fish consumption advisories for mercury in Brownlee Reservoir. The SR-HC TMDL identified the primary sources of mercury as legacy mining and natural loading; both are associated with geological deposits within the Owyhee and Weiser river watersheds (IDEQ and ODEQ 2004). Based on these findings, a mercury TMDL was recommended, but has not been developed. The need for TMDLs to address other potential toxics has not been identified.

Soluble nutrients and trace levels of inorganic metals occurring in the hypolimnion would also be pumped downstream. However, the potential for a short term increase in total nutrient and trace inorganic levels has not been determined. While short term increases are possible, annual or longer term increases are less likely. In fact, outflow inorganic levels may be lower (and DO higher) later in the fall after reservoir turnover has occurred and the reservoir fully mixed.

7.1.3. Mitigation measures

Installation and operation of the HPS for temperature reductions at Brownlee will affect outflow DO. The preferred measure to address DO concerns is turbine aeration at the Brownlee powerhouse. One promising method of turbine aeration currently being assessed is aerating runners at the Brownlee Powerhouse. Aerating runners would increase Brownlee outflow DO by introducing air into the draft tube using air passages that lead to the trailing edge of the runner. Oxygen from the air is dissolved into the water and increases DO in the turbine discharges. Oxygen transfer is obtained in the turbulent flow of the draft tube and as the bubbles rise to the surface in the tailrace. However, as air is dissolved into the water, both nitrogen and oxygen are dissolved and TDG pressures are increased.

Preliminary modeling by Voith Hydro indicates that an aerating runner design for Brownlee turbines (1–4) may be capable of increasing the DO concentration of 5000 cfs by approximately 2.5 mg/L. This modeling was conducted based on an incoming DO of 2 mg/L and temperature of 23°C. Oxygen solubility increases with decreasing temperature and incoming DO levels so the preliminary results may be conservative.

IPC is currently assessing the potential for other water quality impacts, such as those attributable to toxics, and mitigation measures to address these potential impacts of the HPS.

7.1.4. Conceptual implementation timeline

Implementation timeline for the HPS will depend on many factors that are currently being studied including: 1) system design, permitting, construction, operation and maintenance, 2) Brownlee Reservoir hydrodynamics with hypolimnetic pumping, 3) Oxbow and Hells Canyon hydrodynamics, thermal dynamics and downstream propagation of cool water, 4) Brownlee hypolimnetic water quality, 5) Brownlee turbine aeration, and 6) field testing. While some of these studies may be completed in a relatively short time frame actual operation of the HPS cannot be conducted until Brownlee turbine aeration measures are implemented and operational.

IPC is committed to implementing the HPS in a timely manner. Because of the size and potential risk of the HPS it is imperative that implementation entail adequate time for design and evaluation. IPC is proposing a phased implementation schedule. The initial phase, to be implemented immediately upon issuance of the 401 certification, will be final engineering design of the HPS. This will include specific details of the location, intake and pump configuration, and piping system. Within 6 months of FERC issuance of the license, IPC will submit details and design drawings for approval. By October 23, following installation of turbine aeration at Brownlee powerhouse, IPC will have a pump system installed and capable of pumping cold water downstream. If the system is not capable of pumping the full amount of water necessary to address the downstream criteria, IPC will provide a schedule for installation and operation of the full capacity HPS. The schedule will provide for a fully operational HPS within five years of installation of turbine aeration at Brownlee Powerhouse.

7.2. Dissolved Oxygen Proposed Measures

The SR-HC TMDL established a DO allocation for Brownlee Reservoir of 1,125 tons of oxygen per year (IDEQ and ODEQ 2004). The SR-HC TMDL did not address DO below Hells Canyon Dam. IPC conducted analyses to determine the HCC's contribution to low DO downstream of the HCC. IPC modeling indicates that, with anticipated water quality following full SR-HC TMDL implementation, a DO load of 1,733 tons per year is needed during the summer and fall to meet criteria. This load represents the unallocated additional DO load that would need to be addressed and allocated to upstream sources, including the HCC, in a future DO TMDL. Of this total 1,733 tons, an appropriate allocation to the HCC, based on its contribution, would be a maximum of 637 tons (see Section 6.2.). However, the final allocation cannot be known with certainty until such time as a downstream TMDL for DO is established.

IPC proposes the following measures to address DO concerns:

- Implement one of two measures to fully meet the SR-HC TMDL Brownlee Reservoir DO allocation: in-reservoir aeration or upstream phosphorus trading.

- In order to address DO deficits below Hells Canyon Dam, IPC proposes to aerate Hells Canyon outflows using a forced air (blower) system at the Hells Canyon powerhouse. Such a blower would add 1,500 tons/year of DO downstream. This level of downstream DO augmentation is substantially higher than that which IPC considers proportionate to its actual contribution. However, because of the uncertainty of the correct load in the absence of a TMDL, and because the additional DO would provide

Exhibit 7.1-9

August 2011 conceptual level cold water pumping plan study final report, Brownlee Reservoir

August 5, 2011

Idaho Power Company
Attention: Mr. Pete Newton, Hydro Engineering
1221 W. Idaho St (83702)
P.O. Box 70
Boise, ID 83707

Subject: Brownlee Cold Water Pumping Plan Concept Design And Construction Cost Estimate

Dear Mr. Newton:

We are pleased to present our final report on the Brownlee Cold Water Pumping Plan Concept Design and construction and O&M cost estimates. In compliance with your request, this document is being transmitted to you electronically and one hard copy will be sent via Federal Express.

The scope of the work was to prepare a conceptual design and 11 by 17 sketches of an inexpensive scheme to be able to pump cold water from the bottom of the Brownlee Reservoir to the power intakes for the Brownlee Hydroelectric Project.

Results of our conceptual design and construction cost estimate in August 2011 dollars for the floating pumping station yields a total project estimated cost of $39.2 million and $401 thousand for the annual operation and maintenance cost of the project.

We appreciate the opportunity to be of service to Idaho Power Company. Please advise us if you wish to pursue further work, such as detailed design and construction contract documents for implementation of this conceptual design. Please feel free to contact me at 425-451-4263 or Doug Hartsock at 425-451-4658.

Sincerely,

Robert Zylman

Robert Zylman, PE, CCE

Enclosure: As noted

cc: Wayne Pietz, URS
Doug Hartsock, URS
File

URS Corporation
10900 NE 8th Street, Suite 500
Bellevue, WA 98004
Tel: 425.451.4500
Tel: 425.451.4190

URS

Conceptual Level
Cold Water Pumping Plan Study
Final Report

BROWNLEE

RESERVOIR

for

IDAHO POWER
COMPANY

URS

August 2011

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1.0 EXECUTIVE SUMMARY

This study presents the conceptual design, estimated construction cost and estimated annual operations and maintenance cost for a cold water pumping plan that is capable of pumping from 250 cfs to 5,000 cfs, in 250 cfs increments, from the bottom of the Brownlee Reservoir up to the power intakes of the Brownlee Hydroelectric Project. URS identified three alternative schemes for achieving the pumping rate goal and focused on preparing a conceptual level design for the preferred scheme to prepare quantity takeoffs and a construction cost estimate that is well within the range of accuracy of plus or minus 50 percent. Several piping material supply vendors, an axial flow pump manufacturer, a supplier of marine floatation equipment and an electrical equipment manufacturer/supplier were contacted to get realistic prices on commercially available and proven materials and equipment for the project.

The preferred scheme is better described in Section 4.0, and sketches of the arrangement are presented in the Figures portion of this report following the report text. Simply stated, the selected scheme consists of a floating platform that supports twenty axial flow pumps, each capable of pumping 250 cfs by suctioning cold water up through telescoping vertical fiberglass reinforced pipes and transmitting the cold water horizontally through twenty individual nine foot diameter delivery pipes to within about 200 feet of the Brownlee Power Intake structure. The 2,000 foot long delivery pipes are held together in three rows by nineteen structural steel bands that are each connected to a float that keeps the pipes just under the reservoir water surface. Power to run the pumps, illuminate the pumping station, and provide for communication to the land based controls is to be provided by a 12.47kV overhead distribution line and a floating power cable connection from shore to the floating pumping plant.

Construction of the scheme will require all piping to be manufactured adjacent to the Brownlee Reservoir and transported by marine equipment, barge and crane for assembly on the reservoir surface. The axial flow pumps will be shop preassembled into steel framework and shipped to the site for placement into the floating platform. The estimated cost to construct the selected scheme is about $39.2 million in 2011 dollars. The estimated construction cost also includes engineering, owner's direct costs, and a contingency factor for unknowns. The estimated annual operation and maintenance cost for the project is conservatively estimated at $401 thousand in 2011 dollars, based on an assumed continuous five week full capacity pumping operation with electricity rates of $.10 per kilowatt hour.

2.0 INTRODUCTION

The purpose of the proposed cold water pumping structure at Brownlee Reservoir is to allow withdrawal of cold water from near the bottom of the Brownlee Reservoir to be directed to the power intake channel, and thus result in a modification of the downstream water temperature release from the Brownlee Powerhouse. URS was commissioned by IPC to develop a cost effective conceptual plan for achieving cold water pumping capability from 250 to 5,000 cfs, using commercially available equipment and materials, and to provide estimates of project capital cost within an accuracy range of plus or minus 50% for the selected concept. In addition to the request for proposal project description and scope of work, IPC provided an aerial photo of the Brownlee Reservoir and a general alignment for the project piping shown on a layout plan with reservoir bottom contours.

URS identified three alternative schemes to achieve the cold water release goal of pumping from 250 to 5,000 cfs for a period of three to five weeks per year to the power intake structure channel. All three of these schemes are capable of achieving the pumping requirements, including being able to operate with a reservoir water surface that can fluctuate by up to 100 feet, The three alternatives are briefly described as follows:

1) ***Pumps Submerged in Reservoir near the reservoir bottom*** at the point of withdrawal

   This alternative would place the pumps at the point of cold water withdrawal, 2,000 feet upstream of the power intakes, and in as much as 270 feet of water depth. Considerations for this optional arrangement include the need to keep water from entering pump motors and gear boxes, the supply of power to the pumps, and maintenance access to the mechanical and electrical equipment if the pumps were to remain at depth on the bottom of the reservoir between operating seasons. If engineering solutions to these potential problems or hazards can be found, this alternative has the potential to be the least visible and most aesthetically acceptable, but may be the costliest solution.

2) ***Pumps Submerged Near Power Intakes***

   Locating the pumps submerged at the powerhouse intakes about 2,000 feet from the point of water withdrawal would take advantage of a nearby source of electrical power and would facilitate operation of a mobile crane for removing and installing the pumps. It also has the potential to be less visible and more aesthetically acceptable. To avoid collapse, the cold water suction withdrawal pipes would need to be rigid wall—adding to cost—whereas the other two alternatives could utilize a lower cost flexible pipe delivery system and shorter length of suction piping. This alternative would also likely be capable of delivering the coldest water to the power intakes (minimal dilution or heat gain as the water from the bottom of the reservoir flows to the intake).

3) ***Pumps mounted on Floating Pump Station***

Locating the pumps directly above the point of water withdrawal near the reservoir surface lessens the water intrusion potential for the electric motors and controls and considerably improves maintenance access, both during operations and non-operating periods. However, the cold water intake piping becomes somewhat more complex, as the pumps, mounted just below the reservoir water surface on a floating platform would rise and fall with changes in reservoir elevation. This change in reservoir elevation would require that the length of the pump suction pipe (or piping) be extended and/or shortened by as much as 100 feet. The floating platform for the pumps would also need to be secured in position, likely requiring a series of adjustable tethers extending to the shore or to the reservoir bottom. The delivery pipe (or pipes) would be supported by floats and extend some 2,000 feet to discharge near the power intakes. In addition to being the least costly, this alternative will probably be the easiest to maintain.

To develop these alternative concepts, URS considered major project components that could be used to makeup the three optional configurations. The major project components considered for incorporation into the cold water pumping plant alternatives included commercially available axial flow pumps, types of piping for water conductors, and marine floats for supporting piping and pumps.

As IPC has already determined, there currently do not exist commercially available axial flow pumps large enough to deliver 5,000 or even 2,500 cfs. Adding to the challenge of pump selection is the fact that large capacity axial flow pumps are, by design, limited to low head loss applications. In the design of the Floating Surface Collector (FSC) for Puget Sound Energy (PSE), URS utilized the largest submersible axial flow pumps commercially available at the time (2007)—the Flygt Model PP7900 sized for 250 cfs. An array of 20 of these same pumps could easily be adapted for use at Brownlee.

The Delivery of 5,000 cfs of water by pipeline with only low head losses requires a large diameter conduit or conduits to limit friction head loss. Three types of pipe – steel, reinforced fiberglass (RFP) and flexible membrane liners (FML) were considered for both suction and delivery conduits. Steel pipe could be fabricated on-site in almost any size, and could be used for both suction (negative pressure) and delivery (positive pressure) piping but would prove very expensive, heavy and subject to corrosion. RFP can be manufactured in fairly large diameters, and would not be subject to corrosion, but is limited to only positive pressure or low negative pressure applications. So it would work well for delivery flows but may be limited to high suction applications. Even the largest commercially available extruded HDPE pipe is limited to 54 inches in diameter, which would require an unwieldy array of pipes to convey the necessary flow. To explore the availability of inexpensive piping materials, URS contacted manufacturers and fabricators of flexible membrane liners (FML) to inquire about the possibility of fabricating large diameter (7 to 15 foot diameter) "socks" from low density polyethylene (60 or 80 mil thick) materials. At least one fabricator finds the concept feasible and was willing to work with URS to develop further details as well as provide cost estimates for fabrication and supply of materials. Such flexible pipelines could only be used to deliver cold water under pressure (downstream of the pumps) — they would not be suitable for suction of water upstream of the pumps.

For permanent floating supports of project components, as well as temporary working barge platforms and crane support barges, URS selected Robishaw Engineering's Flexifloats that are commercially available in three basic sizes. These floating platforms are sized to be highway transportable and are widely used in marine construction for temporary and permanent applications. They also have a wide range of accessories available for either temporary or permanent mounting to facilitate winching, mooring, anchoring, and floatation support.

The three schemes shown in Appendix A were screened for rough costs and practicality of construction and operation and maintenance to select the least cost, practical solution.

3.0 COMPARISON OF ALTERNATIVES

Initially URS selected Alternative 3, the Floating Pump Station as the option that would probably be the least expensive alternative to concentrate on for a quantity takeoff and cost estimate. At IPC's request, URS made a preliminary cost comparison of Alternative 2 (Pumps submerged near the intake) against Alternative 3 (Pumps mounted on a floating pump station) to allow a selection of the least cost alternative to advance to the conceptual plan and cost estimate stage of study.

After a re-examination and rethinking of the approaches to construction for the two alternatives, URS arrived at the two adjusted alternative configurations and backup information that are shown in Appendix B. We moved the Alternative No. 2 Pumping Plant about 200 feet upstream of the Brownlee Intake Structure. Also, we have not addressed the docking or parking of the Alternative No. 3 Floating Pumping Station (FPS) during the months of the year that the station is not needed. IPC advised us that the FPS would not need to be removed from the reservoir and could be moved to one side near or at the shore of the reservoir. The bottom line results of the preliminary cost comparison are summarized as follows:

1. Alternative No. 2 – The Intake Channel Bottom Piping (Suction Pipe) with Pumps Located on the Bottom of the Intake Channel near the Brownlee Intake Structure is estimated to cost about $51 million (without Electrical Power Supply to the Pumps); and
2. Alternative No. 3 – The Floating Pump Station with 60 mil LLDPE Delivery Pipes suspended just below the Reservoir Water Surface is estimated to cost about $39 million (without Electrical Power Supply to the Pumps).

The difference between these two alternatives is $12 million, or about 31% more for Alternative No. 2 over Alternative No. 3, much closer that we expected. At this point in the study, both estimates are close to the end product, but more backup and some refinements of unit pricing for the marine installation work were needed. Also the cost of electrical power supply to the pumps was not included and any loss of power during construction and operations are not included in this difference. We had expected that Alternative No. 3 would be much cheaper than Alternative No. 2. However, The choice is not so obvious, so we left the decision up to IPC as to which option to pursue for completion of the construction cost estimate and report write-up.

IPC's choice was for the less expensive Alternative 3 – the Floating Pump Station. URS agrees.

4.0 DESCRIPTION AND COSTS FOR SELECTED ALTERNATIVE

4.1 DESCRIPTION OF SELECTED CONCEPTUAL PLAN

The most promising least cost alternative turned out to be a floating surface pumping plant located above the identified cold water source in the Brownlee Reservoir. The Floating Pump Station (FPS) scheme consists of a ten unit Flexifloat barge platform linked together to form an opening or openings that house the framework for 20 250 cfs axial flow pumps stacked in two or three rows and mounted horizontally in a structural steel framework suspended about twenty feet below the reservoir water surface. Eight telescoping reinforced fiberglass pipe (RFP) suction lines extending down into the reservoir are used to pull the cold water from the bottom of the reservoir up to the floating platform by as many of the 250 cfs pumps as are needed to provide the desired flow from 250 cfs to 5,000 cfs in 250 cfs increments. The RFP suction pipes are vertical and have a steel transition structure that turns a 90 degree bend to the bottom of the floating platform where the water enters the axial flow pumps. Four winches on the FPS can raise or lower the suction line to accommodate a change in reservoir depth. The 250 foot long RFP suction lines are manufactured and assembled in 25 foot length nesting sizes to allow a telescoping change in length without excessive leakage. After passing through the pumps, the water from each pump is discharged directly into a nine foot diameter linear low density polyethylene (LLDPE) pipe that extends for 2,000 feet toward the Brownlee Power Intakes. The twenty LLDPE 60 mil thick discharge pipes, are bundled together by steel bands and attached to a Flexifloat at every 100 foot interval from the FPS to within about 200 feet of the Brownlee Power Intakes. These conduits could be rigid (fiberglass or aluminum), but a less expensive flexible fabric material is used since the internal pressure is not much greater than the external pressure.

Electrical power for operation of the 20 – 120 HP pumps, communications and control equipment and lighting on the FPS is to be provided from a 12.47 kV overhead distribution line that would extend for about 3,000 feet from an existing substation near the Brownlee Powerhouse. At peak operation, the Cold Water Pumping Plant would require about 2 MW of energy to supply all the motors, lighting and electrical power demands. The winches that move the suction pipes up or down and the winches that move the FPS on the reservoir water surface would not be operating at the same time as the pumps, and therefore would not increase or exceed the load demand of the pumps. For connecting the FPS to the power source, URS has selected a method of providing a floating power conductor attached to a steel cable that has a water proof plug at the shoreline connection to the overhead distribution line and a waterproof plug connection at the FPS. This arrangement will allow the power cable to disconnected and removed when the FPS is not in operation.

In general this configuration uses readily available equipment and materials that should be fairly inexpensive to purchase and assemble. All the conduits and piping components would be below the surface of the reservoir (except for floats), but not anchored on to the bottom of the reservoir or the walls of the Intake Channel. The floating pump station would need to be tethered to remain in place while pumping, and the delivery (pressure piping) would need to be tethered at the downstream end to keep from drifting away from the intakes. When not in use, the suction piping could be raised up to the FPS, the pressure piping could be unhooked from the intake area, the power cable unplugged and coiled up on its delivery spool, and the FPS could be moved to a boat launch ramp or dock facility and even removed from the reservoir. The entire structure could also stay in place in the reservoir or be moved to one side or shoreline of the reservoir.

4.2 CONSTRUCTION COST ESTIMATE FOR THE FLOATING PUMP STATION SCHEME

Once the conceptual pumping plan was fully developed, conceptual level quantities were estimated based on the data shown in Appendix C and a conceptual level construction cost estimate for the FSP was prepared. This construction cost estimate, found in Appendix D includes pricing for the following:

- All labor (shop and field) at prevailing wage rates for Idaho
- All materials and equipment to be incorporated into the facility
- All construction contractor equipment to be used for construction
- All contractor temporary materials and supplies
- Transportation of materials and equipment to the site
- Contractor's supervisory and overhead expense and profit
- Mobilization and demobilization
- Contingency allowance of 25% +/-
- Owner's costs of administration, Engineering and construction management allowance of 20 % +/-

The total estimated cost to construct the Cold Water Pumping Plan scheme is about $39.3 million, including engineering, project management, and a contingency allowance. This figure does not include sales tax, loss of power generation during construction, allowance for funds used during construction (AFUDC), and the value of lost generation due to head losses occurring during operation of new facilities

The URS approach to estimating the construction cost of the FPS scheme relied heavily on the use of unit prices prepared for previous cost estimates on the Brownlee Selective Withdrawal studies and the PSE Floating Surface Collector (FSC) designed by URS and built in 2007. These historic prices were escalated to 2011 dollar values for expeditious use in the current economic world. Our project team also contacted several vendors who are able to supply off the shelf technology, materials, and equipment, and who provided realistic equipment and material costs for fabrication of viable cost-effective solutions to the challenges of developing the Cold Water Pumping Concept Plan. Vendor contacts, quotations, and other vendor supplied information on materials, equipment and costs are shown in Appendix E. It is worth noting that the Flygt PP7900 pumps have been in operation for almost 10 years without a failure.

Additional sources of unit prices to represent the 2011 project costs are the following:

- RS Means Cost Data 2011 reference books for miscellaneous Site Work, Electrical, and Mechanical unit rates
- Bid unit prices from recent hydro construction projects in the Pacific Northwest (PSE's FSC, Rainbow Hydro Project)
- Estimates from recent hydro project studies performed in the Pacific Northwest by URS
- Built-up unit prices based on selecting permanent materials, labor crews, construction equipment, and productivity rates for performing the work

Items of costs not included in the estimate are as follows:

- Lost power due to outages during construction
- FERC annual fees, if any
- Sales tax
- Allowance for funds used during construction (AFUDC)
- Land costs

4.3 ANNUAL OPERATIONS AND MAINTANENCE COST ESTIMATE

URS devised a rough estimate of costs for annual operation and maintenance of the Cold Water Pumping Plan Concept Design utilizing the recommendations of Whitney Equipment Company, Inc. (Whitney) the local representative of Flygt, and a logical sequence of activities to prepare, operate, and maintain the FPS. For the value of energy, URS assumed $.10 per kilowatt hour; for labor rates, URS assumed an average of $50 per hour for general labor, $60 per hour for operators, and $60 per hour for electricians; and for other components of mobilization, motor vessel operation and temporary portable generator, URS used values from similar project construction cost estimates.

Representatives of Whitney, who met with URS to discuss the capabilities and cost of Flygt's PP7900 pumps, indicated that when not in continuous use, the pumps should be rotated about once every other month to keep the bearings from developing a flat spot and that Whitney could provide an annual maintenance contract for about $60,000. This is not mandatory, and IPC could maintain the pumps and electrical equipment, but to be conservative, the Whitney annual fee was included in the O&M estimate.

On this basis, including the assumption that the FPS would operate at full capability (5,000 cfs) requiring all 20 pumps to run continuously for five weeks, the estimated annual cost is about $401,000 to maintain and operate the FPS. Details of the estimate are included in Appendix D.

FIGURES

LIST OF FIGURES

Figure Number	Figure Title
1	Brownlee Dam and Reservoir Aerial Photo with Floating Pump Station Shown
2	Alt No. 3 Floating Pump Station Plan & Sections Sketch
3	Flexible Pipe Installation Sketch
4	Detail Sketch Showing How Flexible Pipes are Connected Together on Assembly Barges

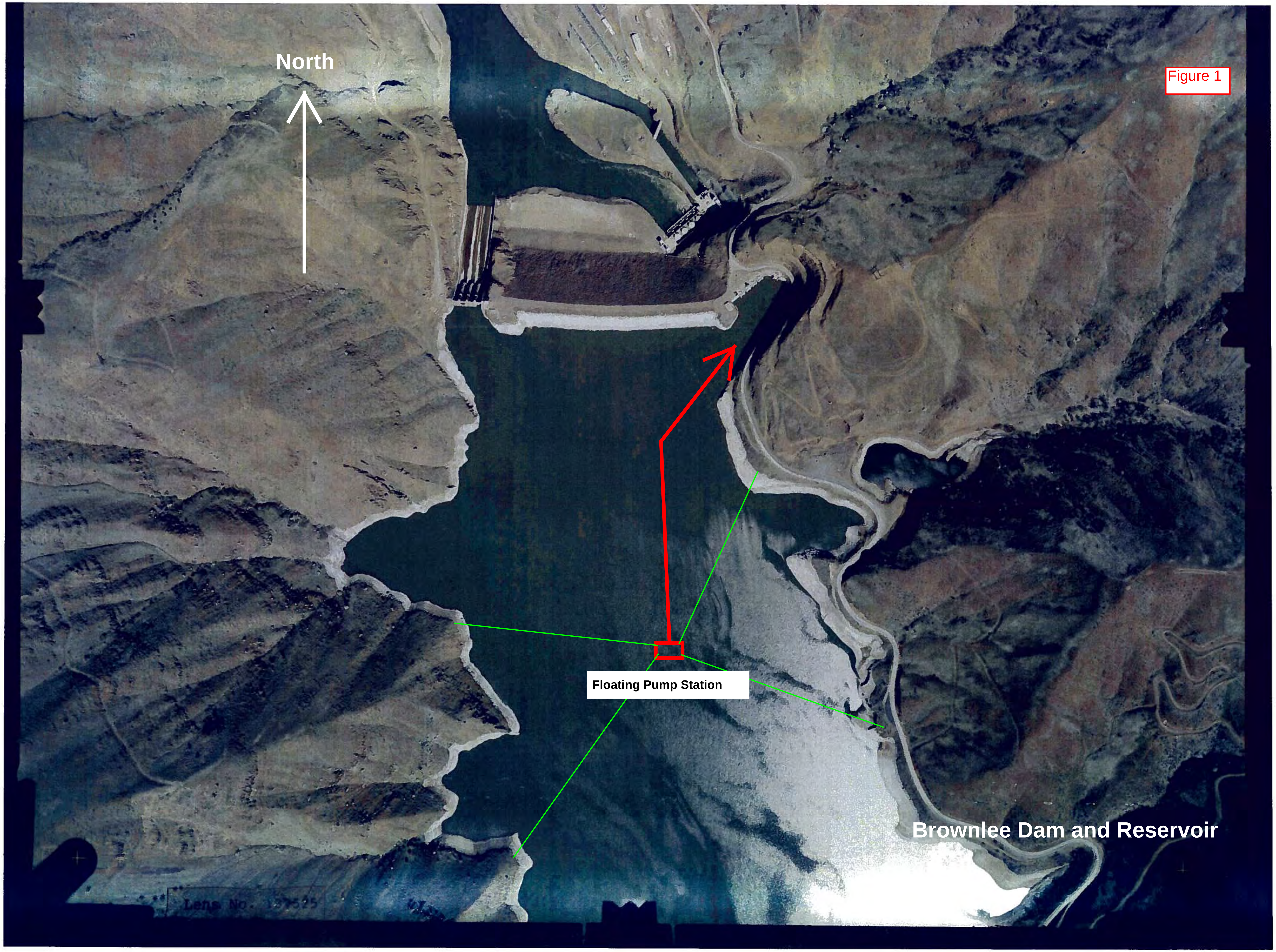
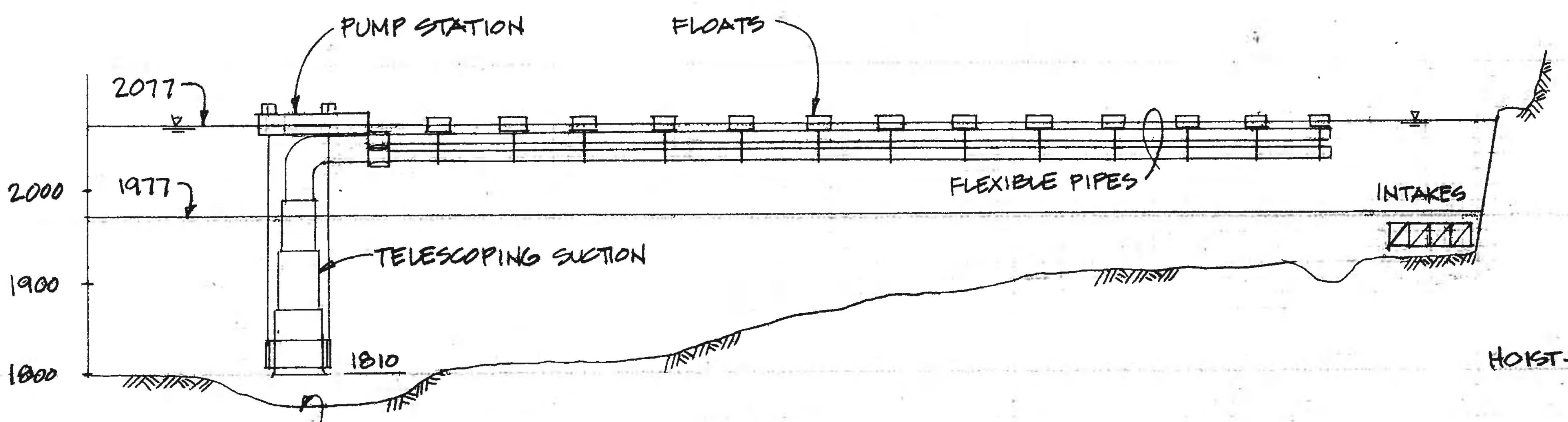


Figure 1

Brownlee Dam and Reservoir

Figure 2



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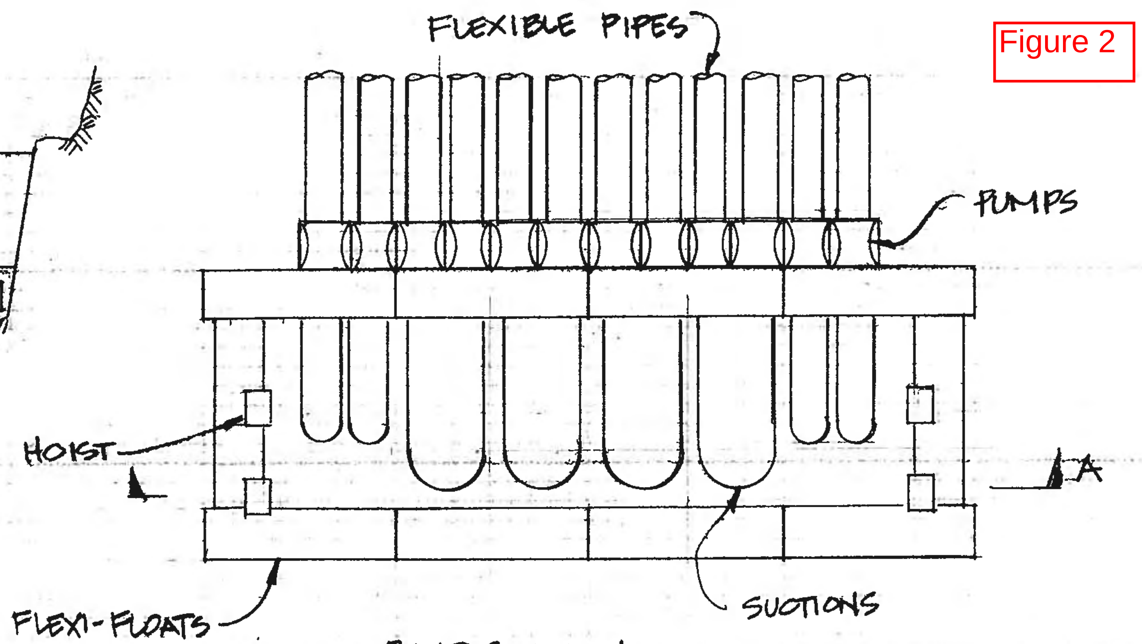
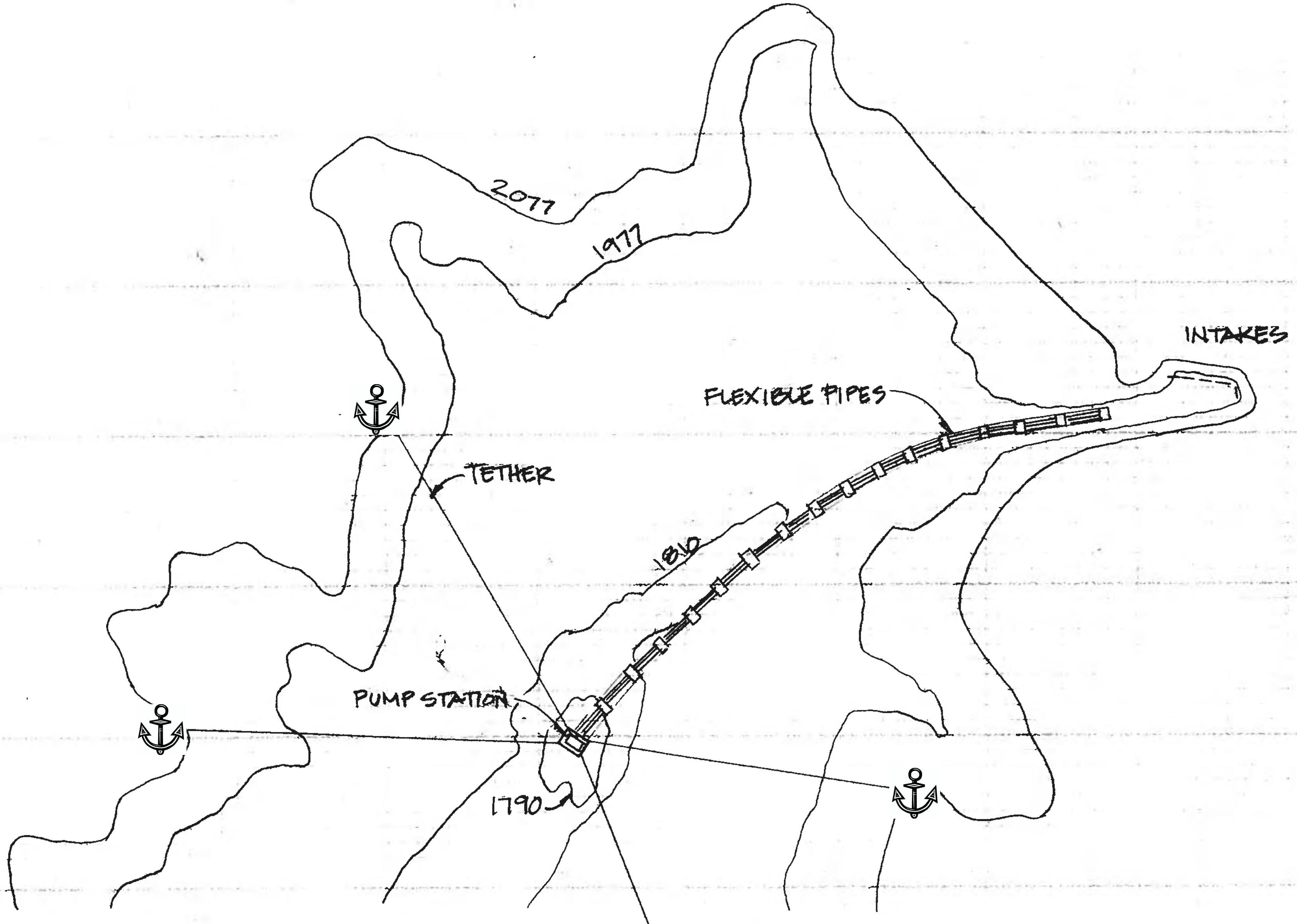
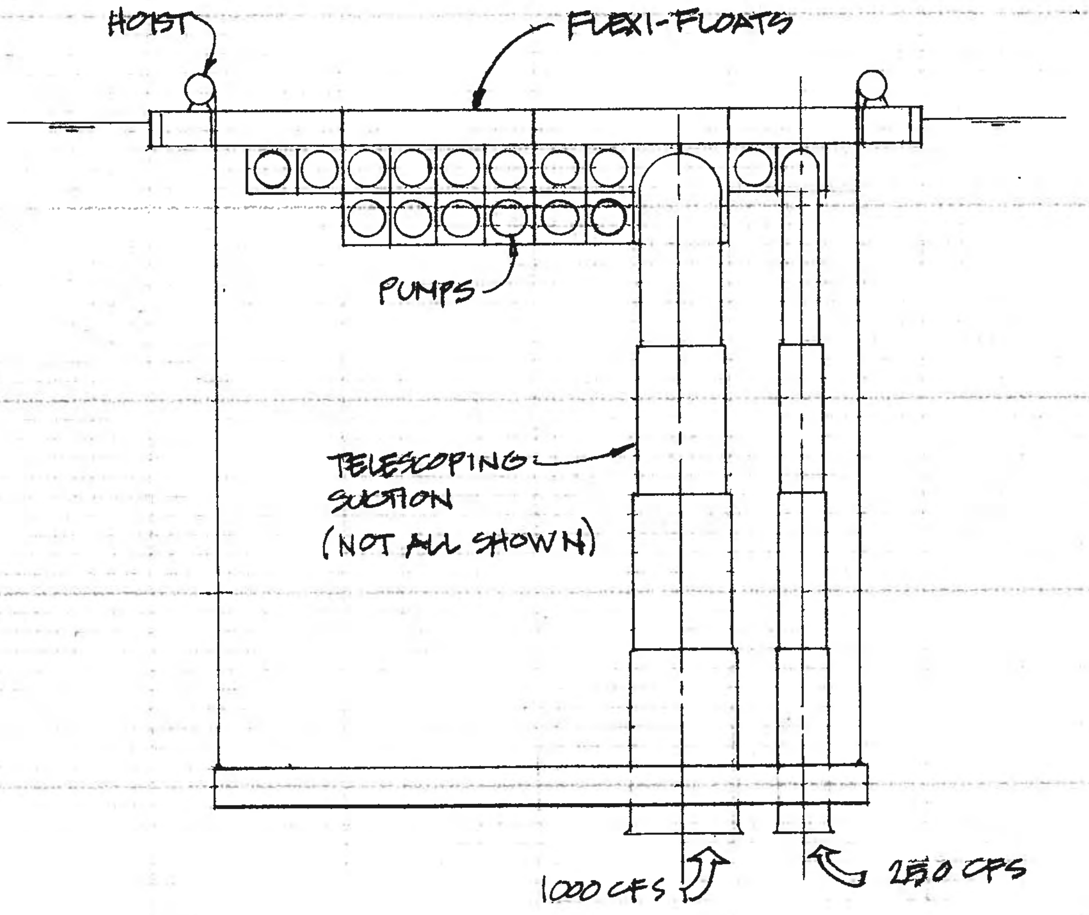


PUMP STATION
PLAN
1" ~40 Feet



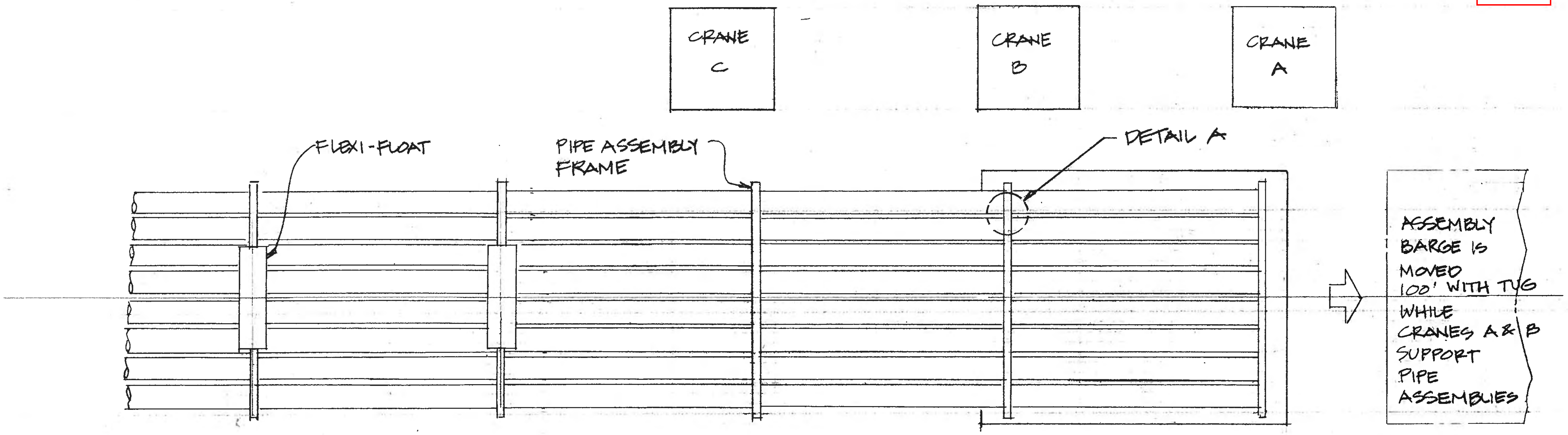
PLAN
1" ~500 Feet



SECTION A

ALT. No. 3
FLOATING PUMP STATION

Figure 3



PLAN
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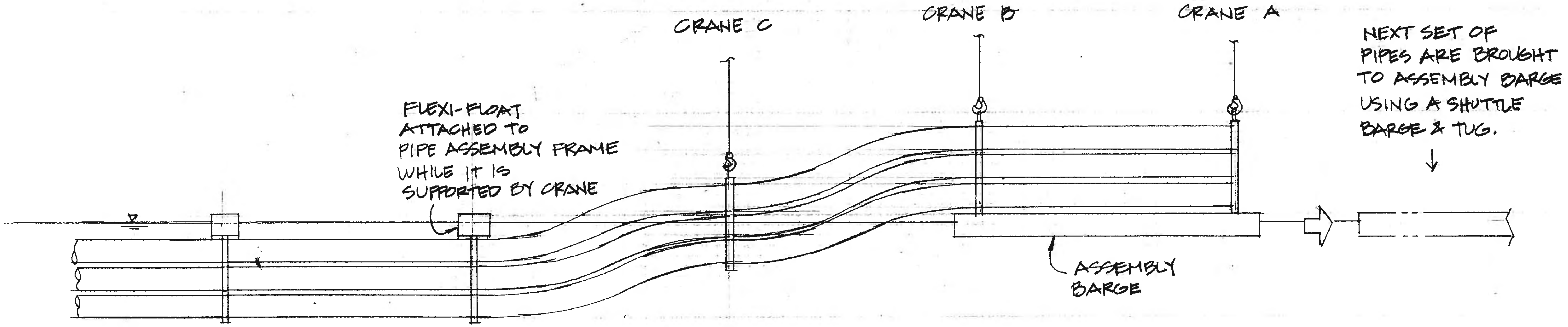
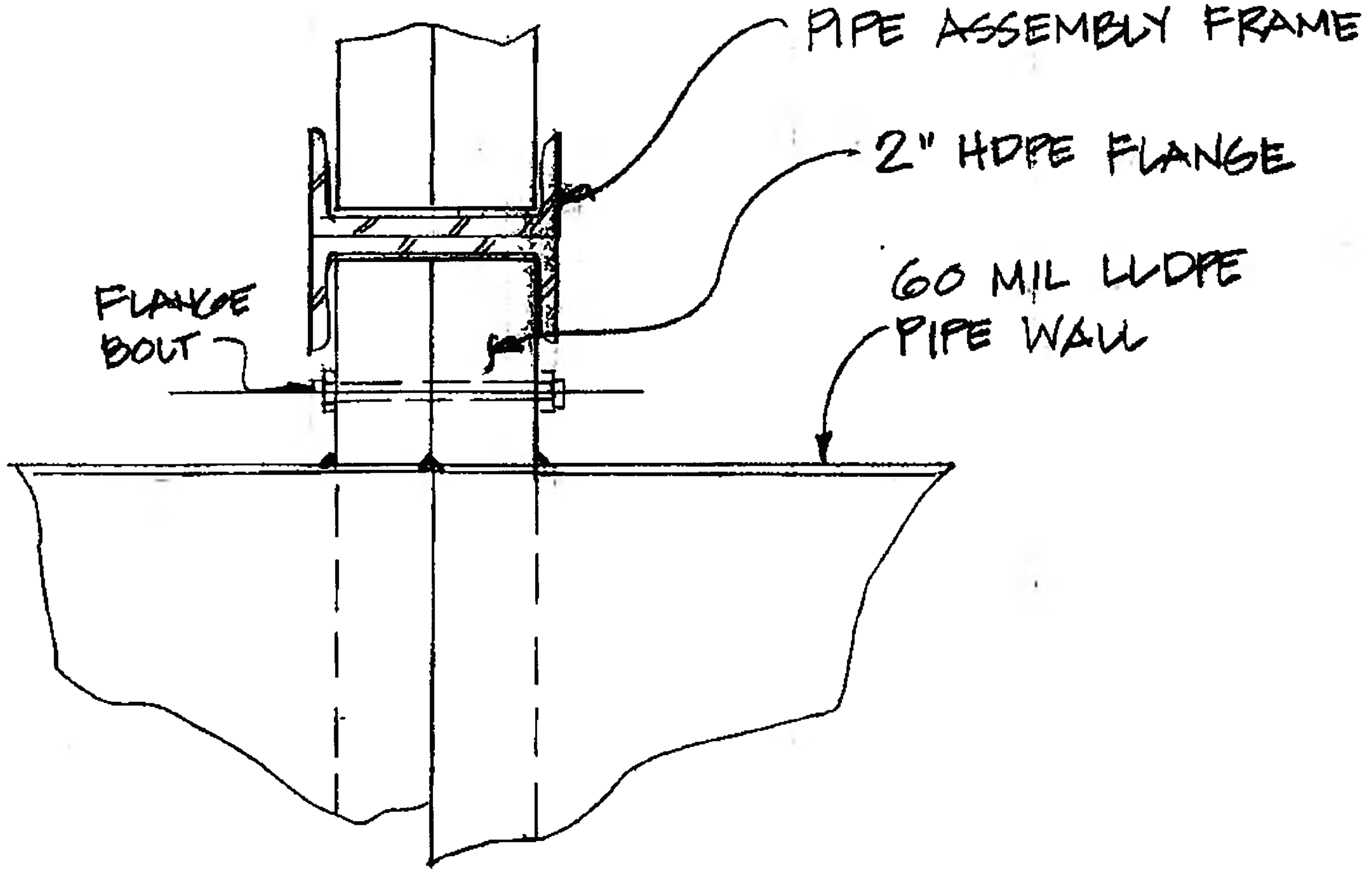


SECTION

FLEXIBLE PIPE INSTALLATION

Figure 4

DETAIL SHOWING HOW FLEXIBLE PIPES ARE CONNECTED TOGETHER ON ASSEMBLY BARGE

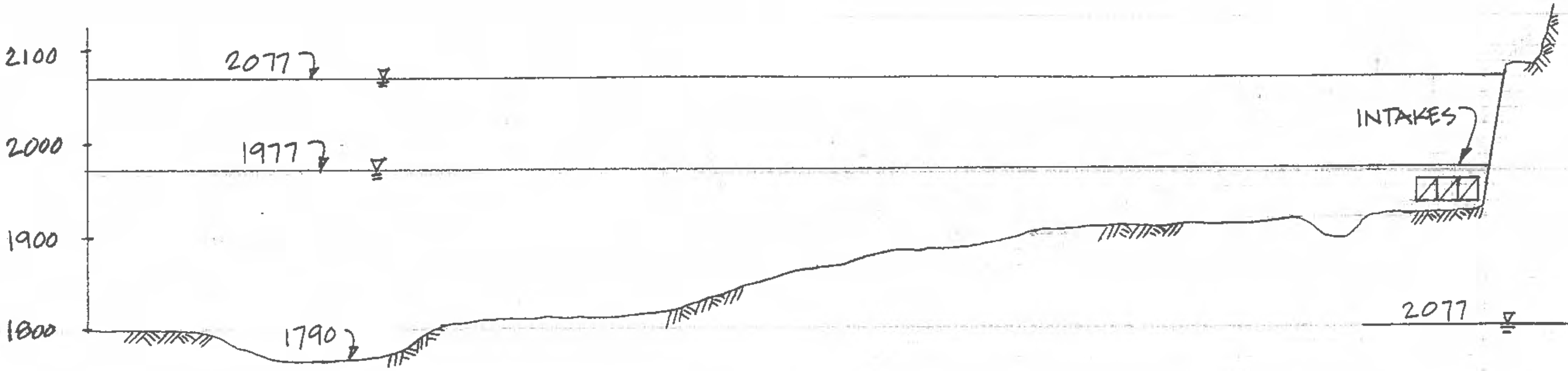


PIPES ARE FABRICATED ON SHORE AND BARGED TO ASSEMBLY BARGE.

DETAIL A

APPENDIX A

SKETCHES for THREE ALTERNATIVE PUMPING PLAN SCHEMES



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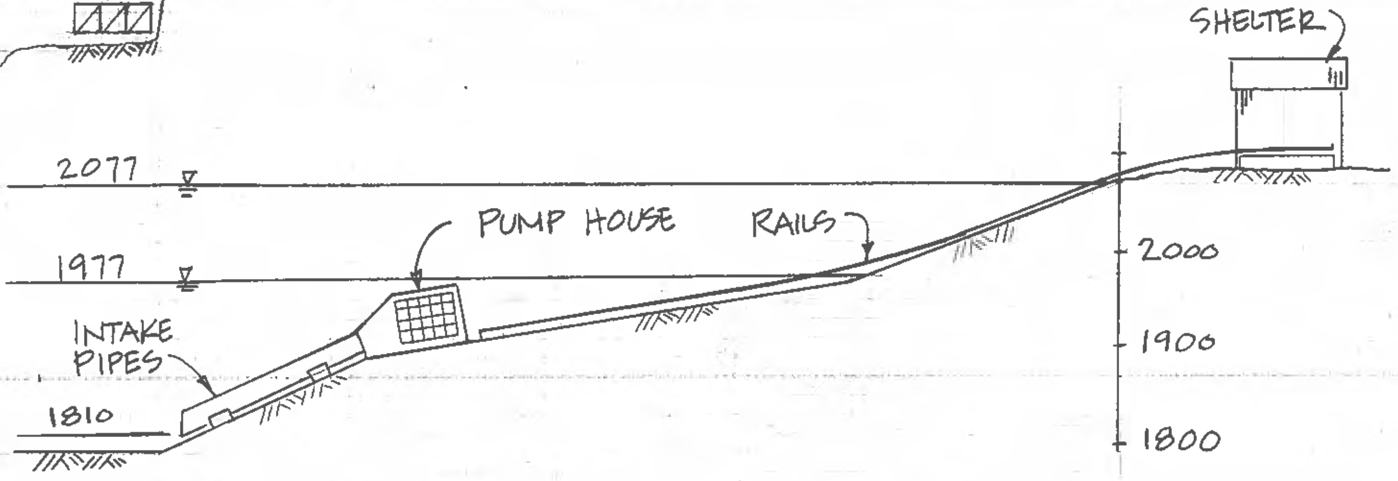
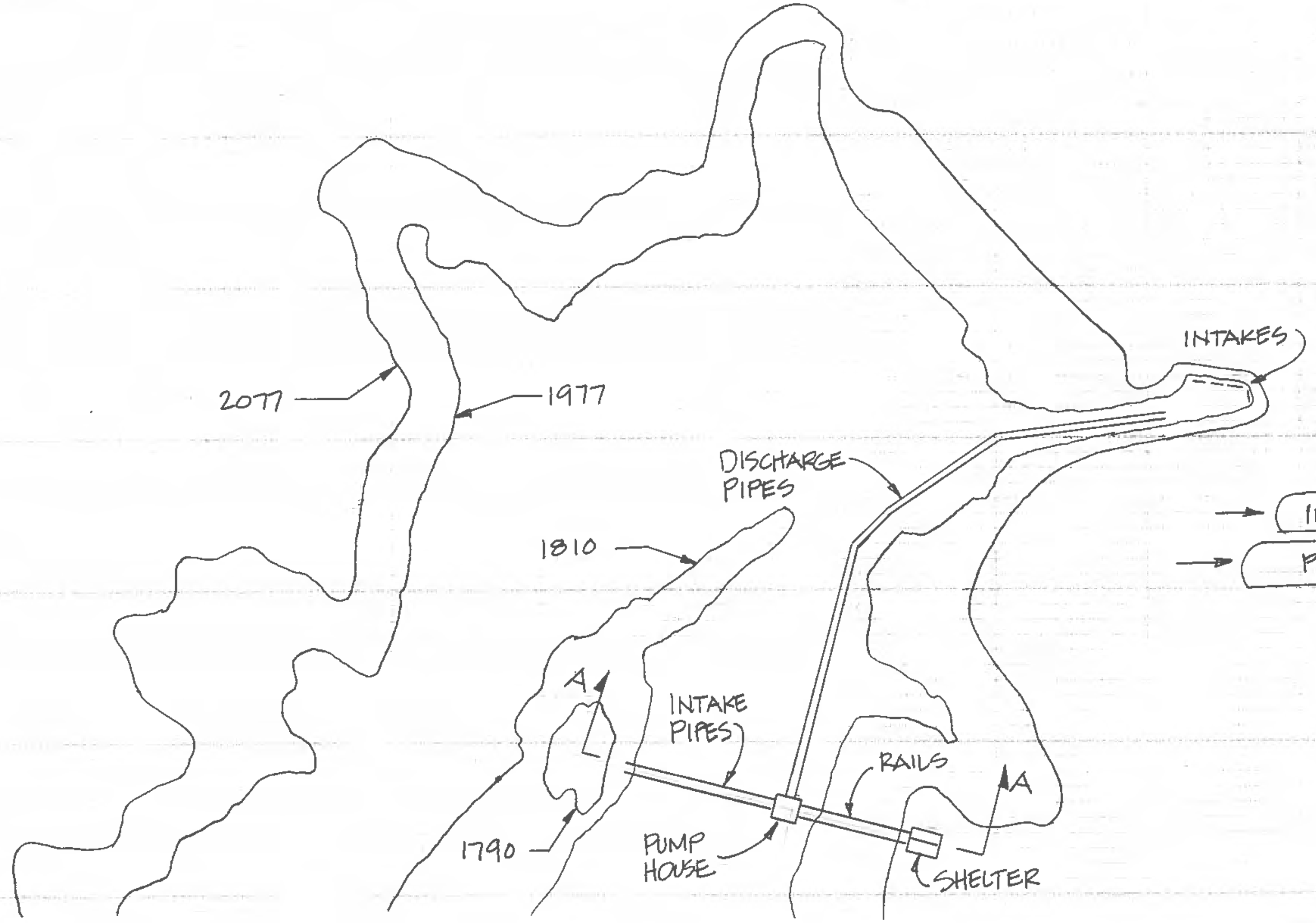
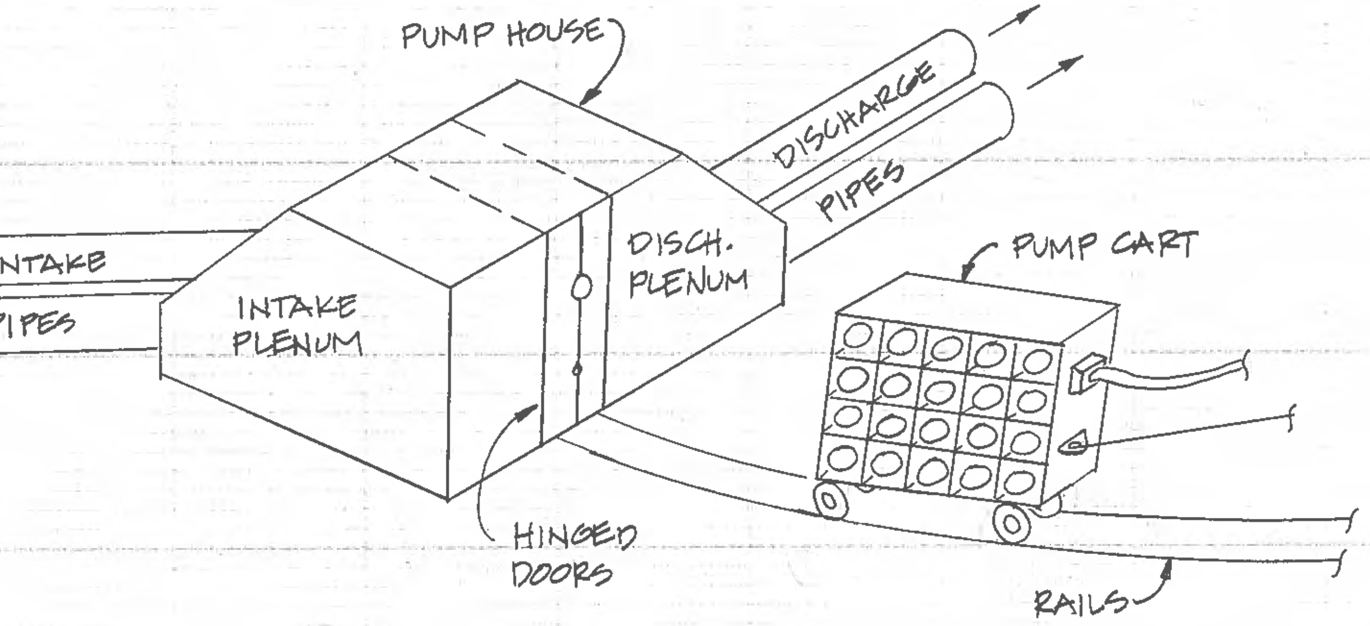


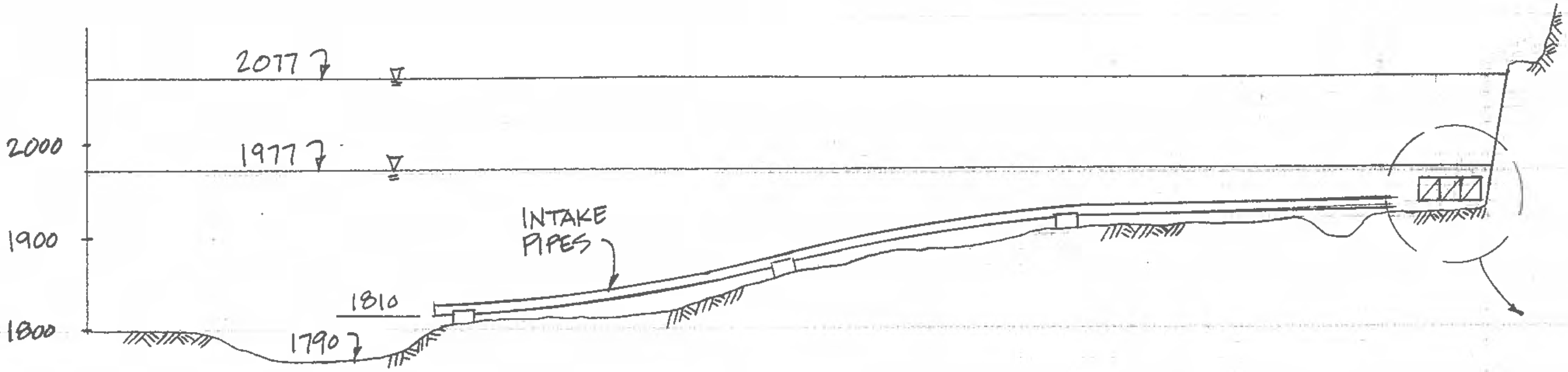
SECTION A
1:20



PLAN
1:50



ALTERNATIVE Nº 1
SUBMERGED PUMP STATION



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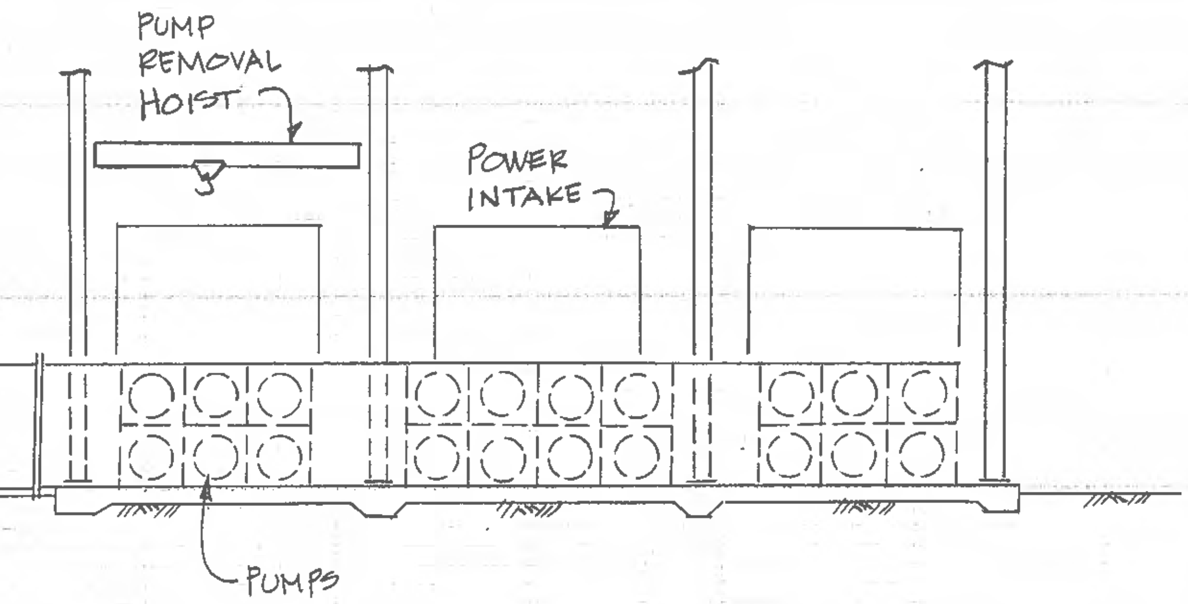

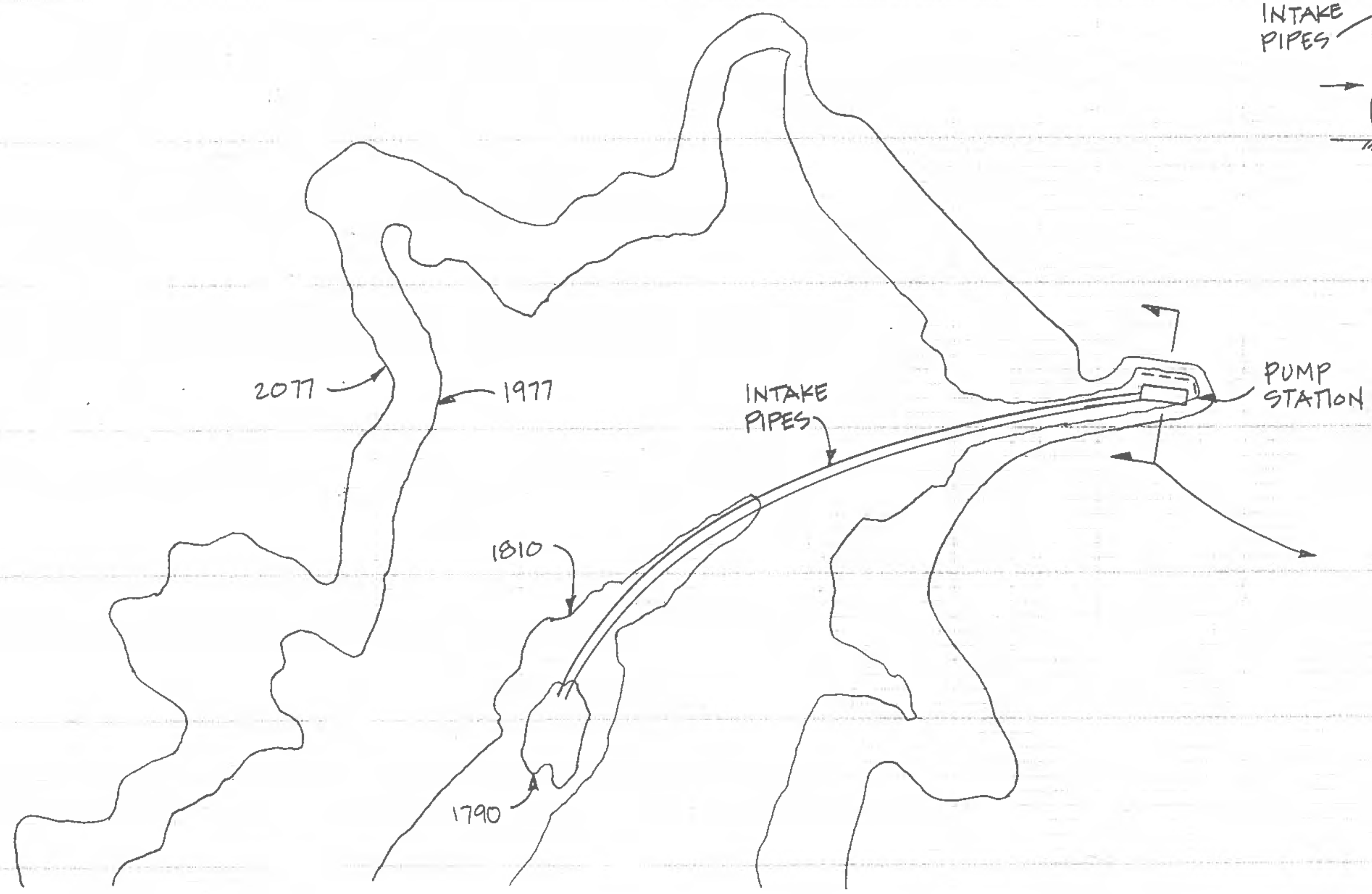

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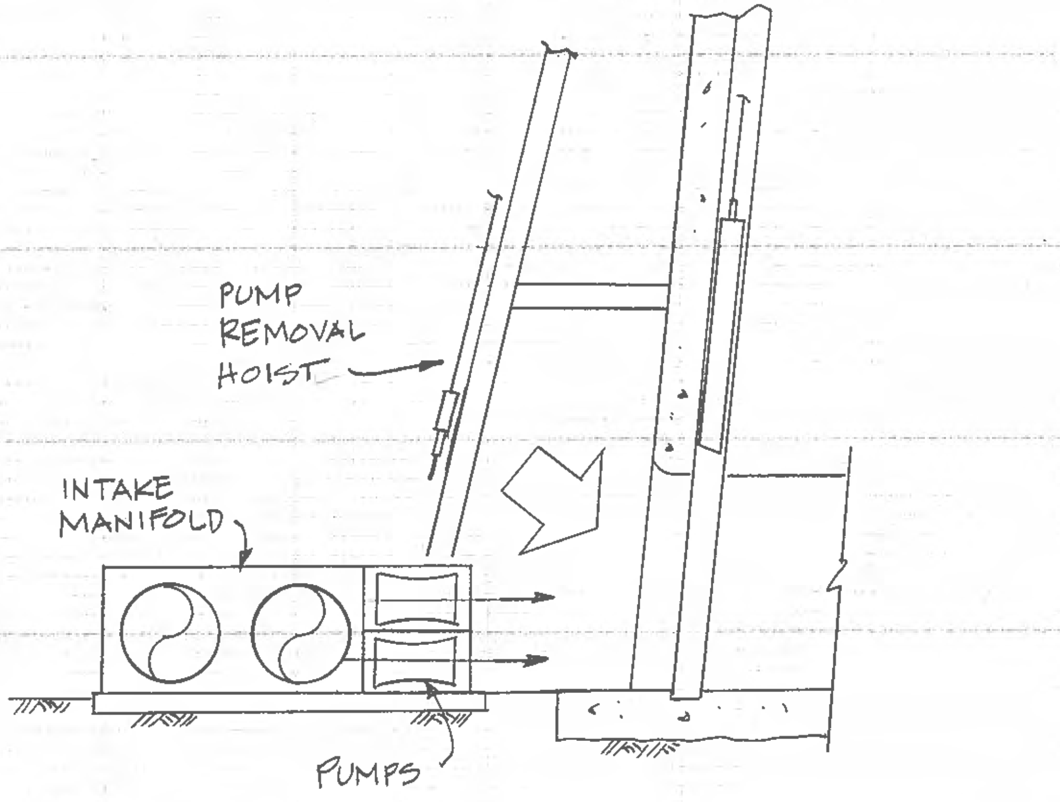
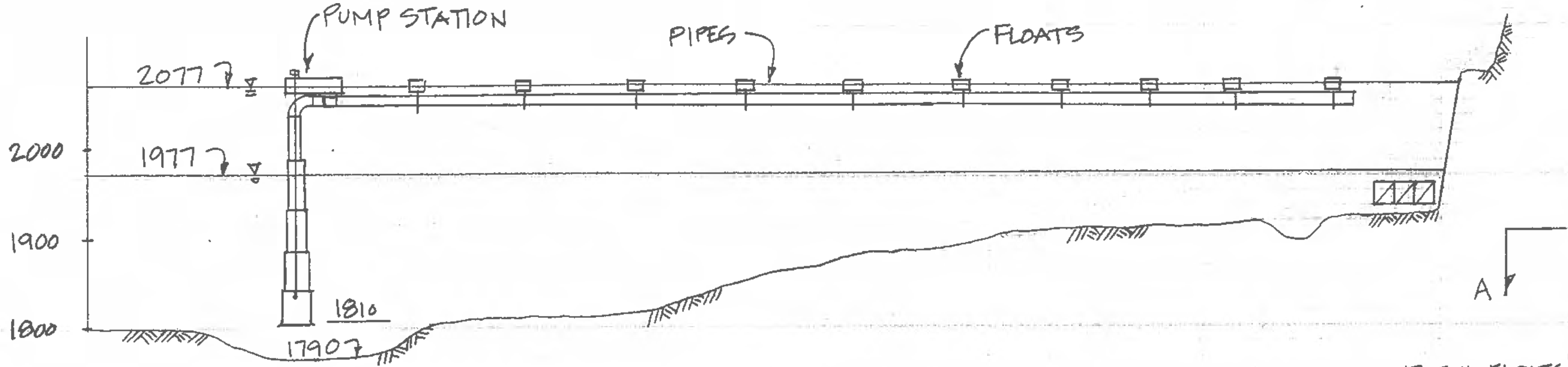


ALTERNATIVE Nº 2
INTAKE PUMP STATION



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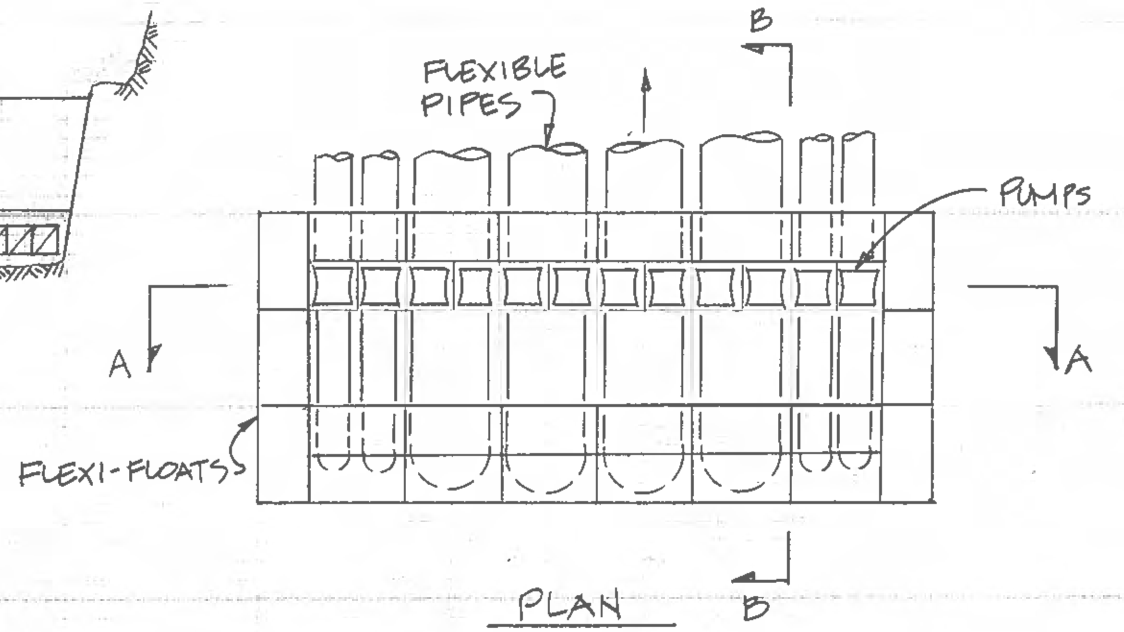

PLAN
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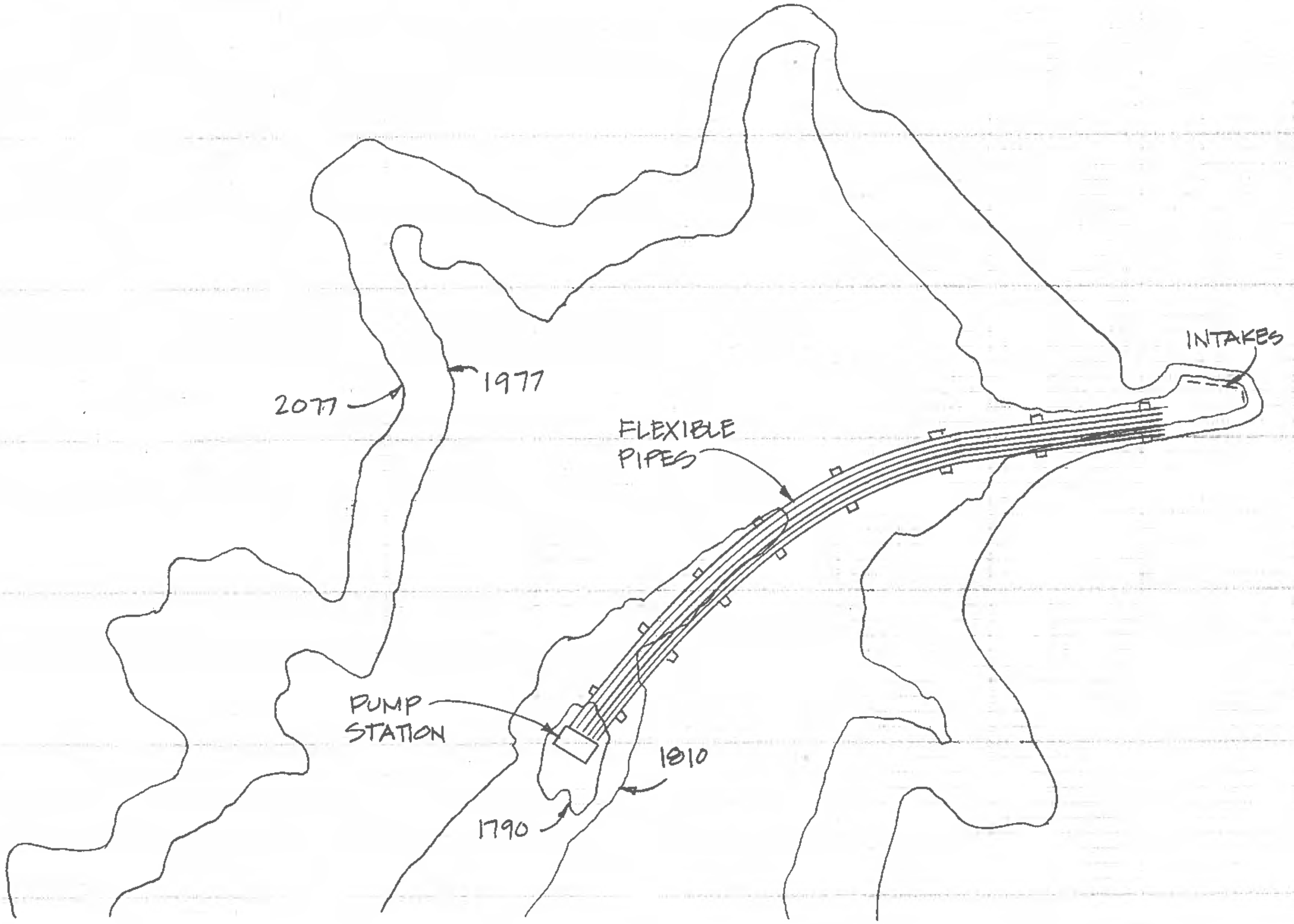
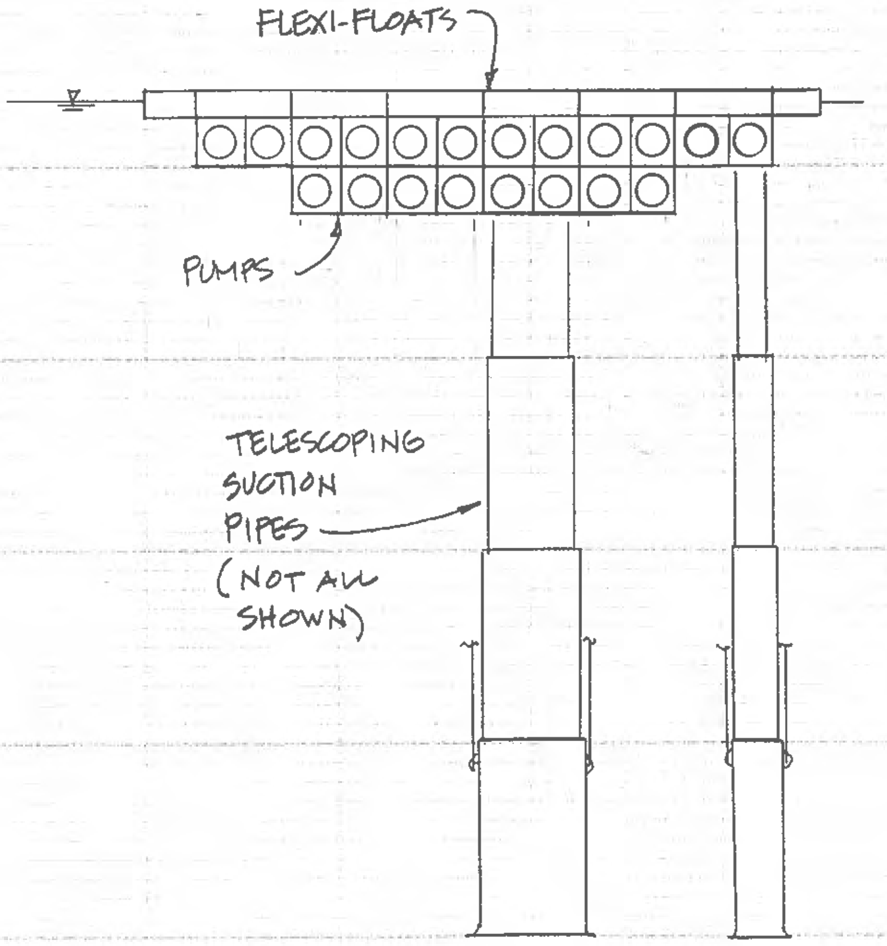
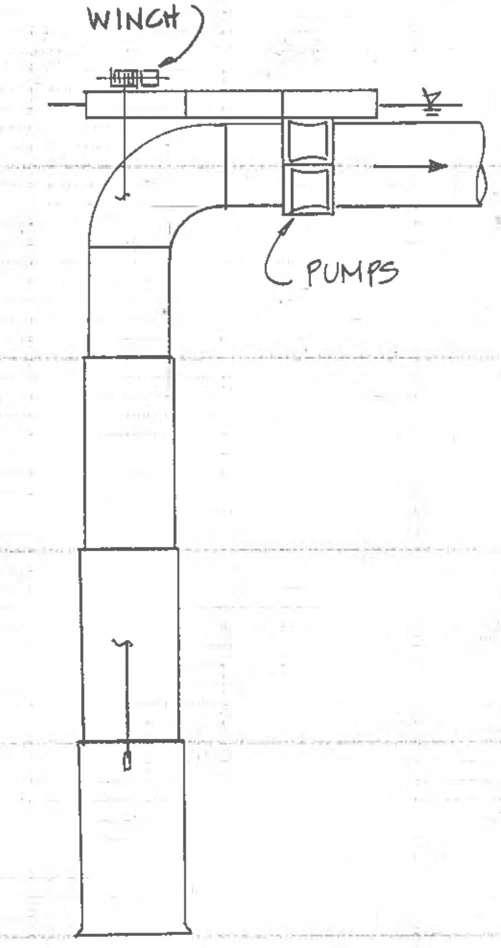


PLAN
1:500



SECTION A



SECTION B

ALTERNATIVE No 3
FLOATING PUMP STATION

APPENDIX B

COMPARATIVE CONSTRUCTION COST ESTIMATES for ALTERNATIVES NO. 2 and NO.3

COLD WATER PUMPING PLANT ALTERNATIVE No. 2

CHANNEL BOTTOM PIPING for 2,100 LF TO PUMPS NEAR INTAKE STRUCTURE

COMPARATIVE RECONNAISSANCE LEVEL CONSTRUCTION COST ESTIMATE

(2011 Dollars)

Ref No.		Project Feature	Quant	Unit Meas	Unit Rate	Amount	Comments
1		Mobilization/Demob					
	1.1	Prepare for On-Site FRP Manufacture		LS		100,000	Conc Pad, Warehouse, Elect
	1.2	Erect 1st 136 mT Crawler Crane (555) for Handling Pipe & Floats				160,000	Mob, Demob, Assmbl & Disasm
	1.3	Erect 2nd 136 mT Crawler Crane (555) for Handling Pipe & Floats				160,000	Mob, Demob, Assmbl & Disasm
	1.4	Mobilize Marine Equipment & Crane Flexi-Float		LS		150,000	Marine Equip
	1.5	Demob from Site		LS		150,000	Marine Equip
	1.6	Subtotal Mob/Demob for Site Work		720,000			
2		New Suction Piping, 2,100 LF of 2 - 22' Dia Reinforced Fiberglass Pipes (RFP)					
	2.1	Purchase 22' Dia RFP	4,200	LF	4,104	17,236,800	Ershigs Quote, Field Fab, 40' Lengths
	2.2	Temp Bridge Struct Steel for Pipe Suspension	400	TN	4,000	1,600,000	Fab & Install n FF's
	2.3	Attach Temp Struct & Winches to Floats	52	EA	7,000	364,000	3 Lab, 1 Opr, 1 Oilr; 1 50mT crane; 20 hrs/ea
	2.4	Assemble Pipe Sections on floats	105	EA	500	52,500	2 hr per joint, Fiberglass wrap
	2.5	Sink Pipe on Channel Bottom					
	2.5.1	Manitowoc 555 Crane on Floats	30	HRS	500	15,000	136 mT crawler crane
	2.5.2	Rent Flexi-Float Duofloats, Laying Pipe, 90 d	9,540	Days	36	343,440	Avg Rate for 90 days +
	2.5.3	Rent Winches for Duofloats, 90 d	9,540	Days	200	1,908,000	Assume 25/Hr Equip; 8 hr/day
	2.5.4	Inland Tug for Pipe Work	30	HRS	200	6,000	Draft Tug w/5 Man Crew
	2.6	Subtotal RFP Suction Pipe		21,525,740			
3		Pumping Plant on Channel Bottom Near Intake					
	3.1	Steel Plenum Transition RFP to Pumps					
	3.1.1	Prefab Steel Plenum Transition Structure	246,000	LBS	6	1,476,000	Galvanized Prefab
	3.1.2	Manitowoc 555 Crane on Floats	60	HRS	500	30,000	Lower Structure, 2 needed
	3.1.3	Additional Barge Rent for Plenum	5	Days	36	180	Hold Structure
	3.1.4	Shims for Plenum Leveling	1	LS	500	500	
	3.1.5	Divers for Shimming &Pipe Connect to Plenum	40	HRS	500	20,000	Diver, Tender, Stndby
	3.1.6	Add'l Diver Support	40	HRS	200	8,000	Air, tender boat, etc.
	3.2	Anchor Steel Plenum to Approach Channel Bottom, Plc 4 Anchor Bars					
	3.2.1	Drill Rig for Drilling Anchor Bar Holes	80	HRS	300	24,000	2 days per hole; 3 drillers, 1 Rig
	3.2.2	Install & Grout Anchor Bars	40	HRS	300	12,000	1 day per hole, 4 holes
	3.2.3	Manitowoc 555 Crane on Floats	40	HRS	500	20,000	Misc Crane Support
	3.2.4	Divers for Anchor Installation	40	HRS	500	20,000	Diver, Tender, Stndby
	3.2.5	Add'l Diver Support	40	HRS	200	8,000	Air, tender boat, etc.
	3.3	Inland Tug for Plenum Work	80	HRS	200	16,000	Draft Tug w/5 Man Crew
	3.4	250 cfs Pumps					
	3.4.1	Purchase 250 cfs Pumps	20	EA	300,000	6,000,000	Flygt 8' Dia Axial Flow Pump
	3.4.2	Steel Framework for Housing Pumps	24,000	LBS	6	144,000	Galvanized Prefab
	3.4.3	Assemble Pumps in Housing	160	HRS	190	30,400	1 day/ea; 3 Mlwt, 1 Opr, 1 Lt Crane work onshore
	3.4.4	Additional Barge Rent for Pumps	10	Days	200	2,000	Move shore to Installation
	3.4.5	Manitowoc 555 Crane on Floats	20	HRS	500	10,000	Set assembled Struct
	3.4.6	Divers for Pump Installation	20	HRS	500	10,000	Diver, Tender, Stndby
	3.4.7	Add'l Diver Support	20	HRS	200	4,000	Air, tender boat, etc.
	3.4.8	Inland Tug for Pump Install Work	40	HRS	200	8,000	Draft Tug w/5 Man Crew
	3.4.9	Electrical Hookup for Pumps				0	Not Included
	3.5	Subtotal Pumping Plant		7,843,080			
4		Power Supply for Pumping Plant					
	4.1	Furn & Install PowerCable	3,000	LF		0	Not Included
	4.2	Substation Mod's for Service to Pumping Plant					
	4.3	Switchgear and Disconnect Hardware				0	Not Included
	4.4	Subtotal Power Supply		0			

COLD WATER PUMPING PLANT ALTERNATIVE No. 2

CHANNEL BOTTOM PIPING for 2,100 LF TO PUMPS NEAR INTAKE STRUCTURE

COMPARATIVE RECONNAISSANCE LEVEL CONSTRUCTION COST ESTIMATE

(2011 Dollars)

Ref No.	Project Feature	Quant	Unit Meas	Unit Rate	Amount	Comments
5	Instrumentation & Controls	1	LS	200,000	200,000	Input 40 Data Pts & 2 control Stas
6	Subtotal Direct				30,288,820	
7	Contingency @ 40%				12,115,180	
8	Construction Total				42,404,000	
9	Engineering, PM/CM, Other Owner Costs @ 20% +/-	1			8,481,000	Allowance
10	Project Total				50,885,000	
	Costs not Included:	Sales Tax				
		Loss of Power Generation during Construction Outage				
		Loss of Power Generation due to Head Loss in System				
		AFUDC				
		Start-up & Testing; and Electric Power Supply				

Calculation Date: 06/29/30
Print Date: 6/30/2011

Alternate No. 2
Pump Housing and Plenum Steel QTO

Brownlee Cold Water Pumping
Idaho Power

Description	No. of Pieces	Member	Weight/ft	Length /piece (ft)	Total Weight (lbs)	
Main Lat Beam @ Pipe -Top Plate	1	W24x192	192	58	11136	
Main Lat Beam @ Pump -Top Plate	1	W24x192	192	68	13056	
Main Horizontal Beam -Top Plate	2	L8x4x1/2	20	49	1960	
Interior Lat Beams -Top Plate	2	L8x4x1/2	20	58	2320	
Interior Long Brace Beams -Top Plate	9	L8x4x1/2	20	16.5	2970	
Main Lat Beam @ Pipe - Bot Plate	1	W24x192	192	58	11136	
Main Lat Beam @ Pump - Bot Plate	1	W24x192	192	68	13056	
Main Horizontal Beam - Bot Plate	2	L8x4x1/2	20	49	1960	
Interior Lat Beams - Bot Plate	2	L8x4x1/2	20	58	2320	
Interior Long Brace Beams - Bot Plate	9	L8x4x1/2	20	16.5	2970	
Bottom Plate	1	1/4" Plate	10.3	2950	30422	
End Plate @ Pipe	1	3/8" Plate	15.5	505	7808	
Side Plate	2	3/8" Plate	15.5	2312	71512	
Top Plate	1	1/4" Plate	10.3	2950	30422	
Plenum Flange @ Pump	1	3/8" Plate	15.5	89	1377	
Pump Plate @ Plenum	1	1/2" Plate	20.6	476	9812	
Pump Plate @ Exit	1	1/2" Plate	20.6	476	9812	
	Subtotal				224047	lbs
	Misc bracing, stiffeners ect. 20% of total				44809	
	TOTAL				**268857**	**lbs**
					134	**tons**

Alternative 2 - Approximate Pipeline Headloss and QTO Estimates

With Steel Pipeline

Flow (cfs)	No. of Pipes	Diameter (ft)	Velocity (ft/s)	Length (ft)	Manning's Coeff n	Friction Loss (ft)	Velocity Head (ft)	Entrance Loss Coeff	Entrance Loss (ft)	Exit Loss Coeff	Exit Loss (ft)	Pump Loss (ft)	Minor Loss Coeff	Minor Loss (ft)	Total Loss (ft)	Minimum Thickness (in)	Weight (ton)	Weight (ton/ft)
250	1	9.00	3.9	2,000	0.013	0.81	0.240	0.3	0.072	0.8	0.192	0.15	0.5	0.120	1.3	0.32	369	0.18
250	1	8.50	4.4	2,000	0.013	1.09	0.301	0.3	0.090	0.8	0.241	0.16	0.5	0.151	1.7	0.31	333	0.17
250	1	8.00	5.0	2,000	0.013	1.51	0.384	0.3	0.115	0.8	0.307	0.18	0.5	0.192	2.3	0.29	298	0.15
250	1	7.50	5.7	2,000	0.013	2.13	0.497	0.3	0.149	0.8	0.398	0.20	0.5	0.249	3.1	0.28	265	0.13
250	1	7.00	6.5	2,000	0.013	3.08	0.655	0.3	0.197	0.8	0.524	0.23	0.5	0.328	4.4	0.26	233	0.12
250	1	6.50	7.5	2,000	0.013	4.57	0.881	0.3	0.264	0.8	0.705	0.28	0.5	0.441	6.3	0.25	204	0.10
5,000	4	17.50	5.2	2,000	0.013	0.58	0.419	0.3	0.126	0.8	0.335	0.18	0.5	0.210	1.4	0.58	5163	2.58
5,000	4	17.00	5.5	2,000	0.013	0.68	0.471	0.3	0.141	0.8	0.377	0.19	0.5	0.235	1.6	0.56	4885	2.44
5,000	4	16.50	5.8	2,000	0.013	0.80	0.531	0.3	0.159	0.8	0.425	0.21	0.5	0.265	1.9	0.55	4614	2.31
5,000	4	16.00	6.2	2,000	0.013	0.94	0.600	0.3	0.180	0.8	0.480	0.22	0.5	0.300	2.1	0.53	4351	2.18
5,000	4	15.50	6.6	2,000	0.013	1.11	0.681	0.3	0.204	0.8	0.545	0.24	0.5	0.341	2.4	0.52	4096	2.05
5,000	4	15.00	7.1	2,000	0.013	1.32	0.777	0.3	0.233	0.8	0.622	0.26	0.5	0.388	2.8	0.50	3848	1.92
5,000	2	24.00	5.5	2,000	0.013	0.43	0.474	0.3	0.142	0.8	0.379	0.19	0.5	0.237	1.4	0.77	4741	2.37
5,000	2	23.00	6.0	2,000	0.013	0.54	0.562	0.3	0.169	0.8	0.450	0.21	0.5	0.281	1.7	0.74	4367	2.18
5,000	2	22.00	6.6	2,000	0.013	0.69	0.672	0.3	0.201	0.8	0.537	0.23	0.5	0.336	2.0	0.71	4008	2.00
5,000	2	21.00	7.2	2,000	0.013	0.88	0.809	0.3	0.243	0.8	0.647	0.26	0.5	0.404	2.4	0.68	3664	1.83
5,000	2	20.00	8.0	2,000	0.013	1.14	0.983	0.3	0.295	0.8	0.787	0.30	0.5	0.492	3.0	0.65	3335	1.67
5,000	2	19.00	8.8	2,000	0.013	1.50	1.207	0.3	0.362	0.8	0.966	0.34	0.5	0.604	3.8	0.62	3022	1.51

With Fiberglass Pipe

Flow (cfs)	No. of Pipes	Diameter (ft)	Velocity (ft/s)	Length (ft)	Manning's Coeff n	Friction Loss (ft)	Velocity Head (ft)	Entrance Loss Coeff	Entrance Loss (ft)	Exit Loss Coeff	Exit Loss (ft)	Pump Loss (ft)	Minor Loss Coeff	Minor Loss (ft)	Total Loss (ft)	FRP Min. Thick. (in)	FRP Weight (ton)	FRP Weight (ton/ft)	FRP Area (sy)
250	1	9.00	3.9	2,000	0.01	0.48	0.240	0.3	0.072	0.8	0.192	0.15	0.5	0.120	1.0	1.28	296	0.15	524
250	1	8.50	4.4	2,000	0.01	0.65	0.301	0.3	0.090	0.8	0.241	0.16	0.5	0.151	1.3	1.22	266	0.13	495
250	1	8.00	5.0	2,000	0.01	0.89	0.384	0.3	0.115	0.8	0.307	0.18	0.5	0.192	1.7	1.16	238	0.12	465
250	1	7.50	5.7	2,000	0.01	1.26	0.497	0.3	0.149	0.8	0.398	0.20	0.5	0.249	2.3	1.10	212	0.11	436
250	1	7.00	6.5	2,000	0.01	1.82	0.655	0.3	0.197	0.8	0.524	0.23	0.5	0.328	3.1	1.04	187	0.09	407
250	1	6.50	7.5	2,000	0.01	2.70	0.881	0.3	0.264	0.8	0.705	0.28	0.5	0.441	4.4	0.98	163	0.08	378
5,000	4	18.00	4.9	2,000	0.01	0.30	0.375	0.3	0.112	0.8	0.300	0.17	0.5	0.187	1.1	2.30	4249	2.12	4189
5,000	4	17.00	5.5	2,000	0.01	0.40	0.471	0.3	0.141	0.8	0.377	0.19	0.5	0.235	1.3	2.24	3908	1.95	3956
5,000	4	16.00	6.2	2,000	0.01	0.56	0.600	0.3	0.180	0.8	0.480	0.22	0.5	0.300	1.7	2.18	3580	1.79	3723
5,000	4	15.00	7.1	2,000	0.01	0.78	0.777	0.3	0.233	0.8	0.622	0.26	0.5	0.388	2.3	2.12	3263	1.63	3491
5,000	4	14.00	8.1	2,000	0.01	1.13	1.024	0.3	0.307	0.8	0.819	0.30	0.5	0.512	3.1	2.06	2960	1.48	3258
5,000	4	13.00	9.4	2,000	0.01	1.68	1.377	0.3	0.413	0.8	1.102	0.38	0.5	0.689	4.3	2.00	2668	1.33	3025
5,000	2	24.00	5.5	2,000	0.01	0.26	0.474	0.3	0.142	0.8	0.379	0.19	0.5	0.237	1.2	3.08	3793	1.90	2793
5,000	2	23.00	6.0	2,000	0.01	0.32	0.562	0.3	0.169	0.8	0.450	0.21	0.5	0.281	1.4	2.96	3493	1.75	2676
5,000	2	22.00	6.6	2,000	0.01	0.41	0.672	0.3	0.201	0.8	0.537	0.23	0.5	0.336	1.7	2.84	3206	1.60	2560
5,000	2	21.00	7.2	2,000	0.01	0.52	0.809	0.3	0.243	0.8	0.647	0.26	0.5	0.404	2.1	2.72	2931	1.47	2443
5,000	2	20.00	8.0	2,000	0.01	0.68	0.983	0.3	0.295	0.8	0.787	0.30	0.5	0.492	2.5	2.60	2668	1.33	2327
5,000	2	19.00	8.8	2,000	0.01	0.89	1.207	0.3	0.362	0.8	0.966	0.34	0.5	0.604	3.2	2.48	2418	1.21	2211

BROWNLEE COLD WATER PUMPING PLANT ALTERNATIVE No. 3

IN RESERVOIR FLOATING PUMP STATION w/LLDPE DELIVERY PIPE TO INTAKE

COMPARATIVE RECONNAISSANCE LEVEL CONSTRUCTION COST ESTIMATE

(2011 Dollars)

Ref No.		Project Feature	Quant	Unit Meas	Unit Rate	Amount	Comments
1		Mobilization/Demob					
	1.1	Prepare for On-Site FRP Manufacture		LS		100,000	Conc Pad, Warehouse, Elect
	1.2	Prepare for On-Site LLDPE Pipe Manufacture		LS		100,000	Conc Pad, Warehouse, Elect
	1.3	Erect 136 mT Crawler Crane (555) for Handling Pipe & Floats				160,000	Mob, Demob, Assmbl & Disasm
	1.4	Mobilize Marine Equipment & Crane Flexi-Float				300,000	Marine Equip (3 Crane Set-ups
	1.5	F&I Log Boom	3000	LF	50	150,000	Allowance
	1.6	Demob from Site				300,000	Marine Equip
	1.7	Subtotal Mob/Demob for Site Work			1,110,000		
2		Fab & Install Permanent FlexiFloat Barge for Floating Pump Station					
	2.1	Purchase FlexiFloats S-70 for Barge	10	EA	60,000	600,000	Purch & Ship Quote 40'x10'x7'
	2.2	Assemble & Outfit FlexiFloats					
	2.2.1	Manitowoc 555 Crane on Floats	100	HRS	500	50,000	10 hrs per ea
	2.2.2	F&I four Winches for Telecope Pipe	4	EA	50,000	200,000	Allowance for Hvy Duty Equip & Hvy Cables
	2.2.3	F&I two Winches for Locating Barge during Operation	2	EA	30,000	60,000	Allowance for large drum winches
	2.2.4	Inland Tug for Pipe Work	100	HRS	200	20,000	Draft Tug w/5 Man Crew
	2.3	Subtotal Floating Pump Station Floats			930,000		
3		New Suction Piping, 4 - 22' Max Dia Reinforced Fiberglass Pipes (RFP) and 4 - 16.5' Max Dia RFP					
	3.1	Fabricate 22' Dia RFP @ Site	1,000	LF	4,104	4,104,000	Ershigs Quote
	3.2	Fabricate 16.5' Dia RFP @Site	1,000	LF	2,742	2,742,000	Ershigs Quote
	3.3	Fabricate Pipe Lifting Beams	108,000	LBS	6	648,000	Galvanized Prefab Steel
	3.4	Assemble Pipe Sections on floats	40	EA	500	20,000	2 hr per spool, 50' Lengths
	3.5	Install Lifting Beams &Telescoping Pipe to Permanent FlexiFloat Barge					
	3.5.1	Manitowoc 555 Crane on Floats	160	HRS	500	80,000	Crane & Crew on Rental Flexi-Floats, 4 hr/pipe
	3.5.2	Additional Barges for Pipe	40	HRS	100	4,000	2 Temp Barges for pipe
	3.5.3	Inland Tug for Pipe Work	160	HRS	200	32,000	Draft Tug w/5 Man Crew
	3.6	Subtotal RFP Suction Pipe			7,630,000		
4		Pumping Plant on Permanent FlexiFloat Barge					
	4.1	Steel Transition RFP to Pumps					
	4.1.1	Prefab Steel Transition Structures	242,000	LBS	6	1,452,000	Galvanized Prefab
	4.1.2	Manitowoc 555 Crane on Floats	40	HRS	500	20,000	Handle & Hold Transitions
	4.1.3	Additional Barge for Transition Sectio	40	HRS	100	4,000	Hold Structures
	4.1.4	Divers for Pipe Connect to Transitions	40	HRS	500	20,000	Diver, Tender, Stndby
	4.1.5	Add'l Diver Support	40	HRS	200	8,000	Air, boat, etc.
	4.2	Furnish & Install 250 cfs Pumps					
	4.2.1	Purchase 250 cfs Pumps	20	EA	300,000	6,000,000	Flygt 8' Dia Axial Flow Pump
	4.2.2	Steel Framework for Housing Pumps	74,000	LBS	6	444,000	Galvanized Prefab
	4.2.3	Assemble & Ready Pumps for Installation on land	160	HRS	190	30,400	1 day/ea; 3 Mlwt, 1 Opr, 1 Lt Crane work onshore
	4.2.4	Manitowoc 555 Crane on Floats	80	HRS	500	40,000	Avg 2 sets per day
	4.2.5	Divers for Pump Installation	80	HRS	500	40,000	Diver, Tender, Stndby
	4.2.6	Add'l Diver Support	80	HRS	200	16,000	Air, boat, etc.
	4.2.7	Electrical Hookup for Pumps				0	Not Included
	4.3	Inland Tug for Pumping Plant Work	60	HRS	200	12,000	Draft Tug w/5 Man Crew
	4.4	Subtotal Pumping Plant			8,074,400		

BROWNLEE COLD WATER PUMPING PLANT ALTERNATIVE No. 3

IN RESERVOIR FLOATING PUMP STATION w/LLDPE DELIVERY PIPE TO INTAKE

COMPARATIVE RECONNAISSANCE LEVEL CONSTRUCTION COST ESTIMATE

(2011 Dollars)

Ref No.			Project Feature	Quant	Unit Meas	Unit Rate	Amount	Comments
5			Cable Anchors for Barge Positioning in Reservoir					
	5.1		Furn & Install Steel Cable					
		5.1.1	Rock Bolt Anchors, Underwater	6	EA	1,200	7,200	
		5.1.2	Steel Cable Material					
		5.1.3	1" Dia Galv Steel Cable	10,000	LF	7	70,000	Quote from US Cargo Control
		5.1.4	Hardware Fasteners (Turnbuckle)	6	EA	300	1,800	
		5.1.5	Support Labor for Installation	40	HRS	200	8,000	4 Lab @ $50/Crew hr
		5.1.6	Floating Crane Service	40	HRS	500	20,000	
		5.1.7	Diver & Tender Assist	20	HRS	500	10,000	
	5.2		Subtotal Cable Anchors		117,000			
6			F&I LLDPE Delivery Piping, 9' Dia, 60 mil thick in 200 Ft Lengths					
	6.1		Fabricate LLDPE Pipe at Project Site	42,000	LF	44	1,848,000	Quote from GSE
	6.2		Purchase FlexiFloats for Delivery Pipe	19	EA	50,000	950,000	Purch & Ship Quote 40'x10'x5'
	6.3		Fabricate Pipe Holding Steel Bands	190,000	LBS	6	1,140,000	Galvanized Prefab Steel
	6.4		Install Delvery Pipe to Permanent FlexiFloat Barge Supports					
		6.4.1	Assemble Pipe Sections on Temp Float (add temp21 floats rental)	420	HRS	1,450	609,000	12 Lab, 3 Opr, 3 Oilr; 3 - 50 mT Cranes; 1 hrs per 100 ' Length joints
		6.4.2	Rent 21 floats for pipe assembly & 6 for Transporting Land to FPS	1,418	Day	83	117,653	Assm = 120' long x 70' wide; Trans = 120'x20'
		6.4.3	Inland Tug for Pipe Work	11,340	HRS	200	2,268,000	Draft Tug w/5 Man Crew
	6.5		Subtotal LLDPE Delivery Pipe		6,932,653			
7			Power Supply for Pumping Plant					
	7.1		Furn & Install PowerCable	3,000	LF		0	Not Included
	7.2		Substation Mod's for Service to Pumping Plant				0	Not Included
	7.3		Switchgear and Disconnect Hardware				0	Not Included
	7.4		Subtotal Power Supply		0			
8			Instrumentation & Controls	1	LS	200,000	200,000	Input 40 Data Pts & 2 control Stas
9			Subtotal Direct				25,006,053	
10			Contingency @ 30%				7,501,948	
11			Construction Total				32,508,000	
12			Engineering, PM/CM, Other Owner Costs @ 20% +/-	1			6,502,000	Allowance
13			Project Total				39,010,000	
			Costs not Included:	Sales Tax				
				Loss of Power Generation during Construction Outage				
				Loss of Power Generation due to Head Loss in System				
				AFUDC				
				Start-up & Testing; and Electric Power Supply				

Flexifloat Preliminary Design Calculations - Alternative 3 with Geomembrane Pipe and FRP Suction Pipe

Weights

	Weight	Factor	Effective	
Weight of Hull (Flexifloats)	178	1.00	178	ton
Weight of Mobile Crane on barge	0	1.00	0	ton, no mobile crane will be operating on barge
Weight of Crane Hook Load	0	1.00	0	ton, no mobile crane will be operating on barge
Weight of Telescoping suction pipe	664	0.38	250	ton, FRP steel 4 - 9' & 4 - 16.5' Dia, assuming 4* thickness of steel pipe, 1.1 factor for overlapping
Weight of Delivery pipe	0	0.00	0	ton, Geomembrane LLDPE, weight slightly less than water, neglected
Transition Pipe/Plenum	121	0.38	45	ton, Segmented FRP
Weight of Pump Equipments	5	0.87	4	ton
Weight of Structural Framing	32	0.87	28	ton
Weight of Telescoping winches	40	1.00	40	ton, 4 winches
Weight of Telescoping Lifting Support	54	0.87	47	ton
Weight of Other Miscellaneous	5	1.00	5	ton
Total Weight			598	ton

Flexifloat Barge:

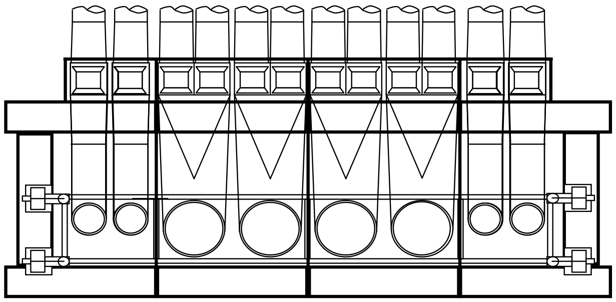
Flexifloat Type	No. of Units	Unit Area (sf)	Area (sf)	Unit Weight (lbs)	Unit Weight (lbs)
Quadrafloats - 30'x7.5'x3.8'	0	225.0	0	15500	0
Duofloats - 15'x7.5'x3.8'	0	112.5	0	8400	0
Quadrafloats - 40'x10'x5'	0	400.0	0	27000	0
Duofloats - 20'x10'x5'	0	200.0	0	14700	0
Quadrafloats - 40'x10'x7'	10	400.0	4000	35600	356000
Duofloats - 20'x10'x7'	0	200.0	0	18900	0
Total	10		4000		356000

Hull Depth $D_{hull} =$ 7 ft

Volume displacement $V_D =$ 19153 ft^3

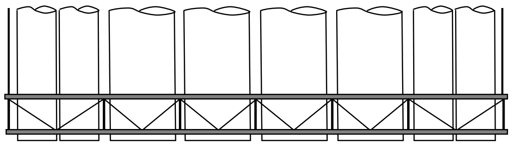
Draft $D = V_D/A =$ 4.79 ft

Free Board $FB = D_{hull} - D =$ 2.21 ft



Alternative 3, Pump and Suction Pipe Support Barge Plan

Not to Scale



Suction Pipe Bottom Support Elevation

Not to Scale

Approximate Barge Structural Framing QTO - Alternative 3 with Geomembrane Pipe and FRP Suction

Structural framing to secure pumps and pipe attachment

No of Pumps	20	
Pump diameter	8.0	ft
Clearance between pumps	1.0	ft
Structural Member	20	lb/ft
Approx. Structural Framing length	72	ft/per pump
Total Framing length	1440	ft
Weight of framing	14.4	ton

Structural framing to secure floating pipe

Structural Member	20	lb/ft
Approx. Structural Framing length	490.1	ft
Weight of framing	4.9	ton

Structural framing to secure telescoping pipe to barge

Structural Member	40	lb/ft
Approx. Structural Framing length	490.1	ft
Weight of framing	9.8	ton

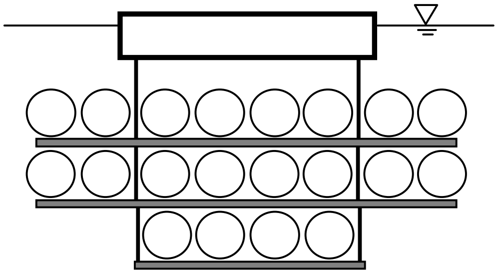
Total Weight

Total structural steel weight	29.1	ton
Connectors	2.9	ton
Total Weight	32	ton

Approx. Suction Pipe Bottom Support Steel Framing

Structural Member	100	lb/ft
Main Structural Framing length	700.0	ft
Factor (other members)	1.4	
Connector Factor	1.1	
Weight of framing	53.9	ton

Pipe Float Preliminary Design Calculations - Alternative 3 with LLDPE



LLDPE Pipe Supporting Floats

Not to Scale

Pipe Float Station Spacing

Float spacing	100	ft
Pipeline Length	2000	ft
Number of float stations	19	

Weights

Weight of Hull (Flexifloats)	14	ton
Weight of Pipe	0	ton, 20 LLDPE Pipes
Weight of Steel for securing pipe	5	ton
Total Weight	19	ton

Flexifloat Per Segment:

Flexifloat Type	No. of Units	Unit Area (sf)	Area (sf)	Unit Weight (lbs)	Unit Weight (lbs)
Quadrafloats - 30'x7.5'x3.8'	0	225.0	0	15500	0
Duofloats - 15'x7.5'x3.8'	0	112.5	0	8400	0
Quadrafloats - 40'x10'x5'	1	400.0	400	27000	27000
Duofloats - 20'x10'x5'	0	200.0	0	14700	0
Quadrafloats - 40'x10'x7'	0	400.0	0	35600	0
Duofloats - 20'x10'x7'	0	200.0	0	18900	0
Total	1		400		27000

Hull Depth	D_{hull} =	5	ft
Volume displacement	V_D =	598	ft^3
Draft	$D = V_D/A$ =	1.49	ft
Free Board	$FB = D_{hull} - D$ =	3.51	ft

Flexifloat for the pipeline:

Total Number of Flexifloat units	19

Steel Frame

Structural Member	30	lb/ft
Main Structural Framing length	240.0	ft
Factor (other members)	1.3	
Connector Factor	1.1	
Weight of framing	5.1	ton

Alternative 3 - Approximate Pipeline Headloss and QTO Estimates

With Steel Pipeline

Flow (cfs)	No. of Pipes	Diameter (ft)	Velocity (ft/s)	Length (ft)	Manning's Coeff n	Friction Loss (ft)	Velocity Head (ft)	Entrance Loss Coeff	Entrance Loss (ft)	Exit Loss Coeff	Exit Loss (ft)	Pump Loss (ft)	Minor Loss Coeff	Minor Loss (ft)	Total Loss (ft)	Minimum Thickness (in)	Weight (ton)	Weight (ton/ft)
250	1	9.00	3.9	2,250	0.013	0.91	0.240	0.3	0.072	0.8	0.192	0.15	1.0	0.240	1.6	0.32	416	0.18
250	1	8.50	4.4	2,250	0.013	1.23	0.301	0.3	0.090	0.8	0.241	0.16	1.0	0.301	2.0	0.31	374	0.17
250	1	8.00	5.0	2,250	0.013	1.70	0.384	0.3	0.115	0.8	0.307	0.18	1.0	0.384	2.7	0.29	335	0.15
250	1	7.50	5.7	2,250	0.013	2.40	0.497	0.3	0.149	0.8	0.398	0.20	1.0	0.497	3.6	0.28	298	0.13
250	1	7.00	6.5	2,250	0.013	3.46	0.655	0.3	0.197	0.8	0.524	0.23	1.0	0.655	5.1	0.26	263	0.12
250	1	6.50	7.5	2,250	0.013	5.14	0.881	0.3	0.264	0.8	0.705	0.28	1.0	0.881	7.3	0.25	230	0.10
5,000	4	18.00	4.9	2,250	0.013	0.56	0.375	0.3	0.112	0.8	0.300	0.17	1.0	0.375	1.5	0.59	6131	2.72
5,000	4	17.00	5.5	2,250	0.013	0.76	0.471	0.3	0.141	0.8	0.377	0.19	1.0	0.471	1.9	0.56	5496	2.44
5,000	4	16.00	6.2	2,250	0.013	1.06	0.600	0.3	0.180	0.8	0.480	0.22	1.0	0.600	2.5	0.53	4895	2.18
5,000	4	15.00	7.1	2,250	0.013	1.49	0.777	0.3	0.233	0.8	0.622	0.26	1.0	0.777	3.4	0.50	4330	1.92
5,000	4	14.00	8.1	2,250	0.013	2.15	1.024	0.3	0.307	0.8	0.819	0.30	1.0	1.024	4.6	0.47	3798	1.69
5,000	4	13.00	9.4	2,250	0.013	3.19	1.377	0.3	0.413	0.8	1.102	0.38	1.0	1.377	6.5	0.44	3302	1.47

With Smooth Geomembrane (LLDPE) Delivery Pipe and FRP Suction Pipe

Flow (cfs)	No. of Pipes	Diameter (ft)	Velocity (ft/s)	LLDPE Length (ft)	FRP Length (ft)	Manning's Coeff n	Friction Loss (ft)	Velocity Head (ft)	Entrance Loss Coeff	Entrance Loss (ft)	Exit Loss Coeff	Exit Loss (ft)	Pump Loss (ft)	Minor Loss Coeff	Minor Loss (ft)	Total Loss (ft)	LLDPE Area (sy)	FRP Min. Thick. (in)	FRP Weight (ton)	FRP Weight (ton/ft)	FRP Area (sy)
250	1	9.00	3.9	2,000	250	0.01	0.54	0.240	0.3	0.072	0.8	0.192	0.15	1.0	0.240	1.2	524	1.28	37	0.15	65
250	1	8.50	4.4	2,000	250	0.01	0.73	0.301	0.3	0.090	0.8	0.241	0.16	1.0	0.301	1.5	495	1.22	33	0.13	62
250	1	8.00	5.0	2,000	250	0.01	1.01	0.384	0.3	0.115	0.8	0.307	0.18	1.0	0.384	2.0	465	1.16	30	0.12	58
250	1	7.50	5.7	2,000	250	0.01	1.42	0.497	0.3	0.149	0.8	0.398	0.20	1.0	0.497	2.7	436	1.10	26	0.11	55
250	1	7.00	6.5	2,000	250	0.01	2.05	0.655	0.3	0.197	0.8	0.524	0.23	1.0	0.655	3.7	407	1.04	23	0.09	51
250	1	6.50	7.5	2,000	250	0.01	3.04	0.881	0.3	0.264	0.8	0.705	0.28	1.0	0.881	5.2	378	0.98	20	0.08	47
5,000	4	18.00	4.9	2,000	250	0.01	0.33	0.375	0.3	0.112	0.8	0.300	0.17	1.0	0.375	1.3	4189	2.36	545	2.18	524
5,000	4	17.00	5.5	2,000	250	0.01	0.45	0.471	0.3	0.141	0.8	0.377	0.19	1.0	0.471	1.6	3956	2.24	488	1.95	495
5,000	4	16.00	6.2	2,000	250	0.01	0.62	0.600	0.3	0.180	0.8	0.480	0.22	1.0	0.600	2.1	3723	2.12	435	1.74	465
5,000	4	15.00	7.1	2,000	250	0.01	0.88	0.777	0.3	0.233	0.8	0.622	0.26	1.0	0.777	2.8	3491	2.00	385	1.54	436
5,000	4	14.00	8.1	2,000	250	0.01	1.27	1.024	0.3	0.307	0.8	0.819	0.30	1.0	1.024	3.7	3258	1.88	338	1.35	407
5,000	4	13.00	9.4	2,000	250	0.01	1.89	1.377	0.3	0.413	0.8	1.102	0.38	1.0	1.377	5.2	3025	1.76	294	1.17	378

With Smooth FRP Pipeline

Flow (cfs)	No. of Pipes	Diameter (ft)	Velocity (ft/s)	Length (ft)	Manning's Coeff n	Friction Loss (ft)	Velocity Head (ft)	Entrance Loss Coeff	Entrance Loss (ft)	Exit Loss Coeff	Exit Loss (ft)	Pump Loss (ft)	Minor Loss Coeff	Minor Loss (ft)	Total Loss (ft)	FRP Min. Thick. (in)	FRP Weight (ton)	FRP Weight (ton/ft)	FRP Area (sy)
250	1	9.00	3.9	2,250	0.01	0.54	0.240	0.3	0.072	0.8	0.192	0.15	1.0	0.240	1.2	1.28	333	0.15	589
250	1	8.50	4.4	2,250	0.01	0.73	0.301	0.3	0.090	0.8	0.241	0.16	1.0	0.301	1.5	1.22	299	0.13	556
250	1	8.00	5.0	2,250	0.01	1.01	0.384	0.3	0.115	0.8	0.307	0.18	1.0	0.384	2.0	1.16	268	0.12	524
250	1	7.50	5.7	2,250	0.01	1.42	0.497	0.3	0.149	0.8	0.398	0.20	1.0	0.497	2.7	1.10	238	0.11	491
250	1	7.00	6.5	2,250	0.01	2.05	0.655	0.3	0.197	0.8	0.524	0.23	1.0	0.655	3.7	1.04	210	0.09	458
250	1	6.50	7.5	2,250	0.01	3.04	0.881	0.3	0.264	0.8	0.705	0.28	1.0	0.881	5.2	0.98	184	0.08	425
5,000	4	18.00	4.9	2,250	0.01	0.33	0.375	0.3	0.112	0.8	0.300	0.17	1.0	0.375	1.3	2.36	4904	2.18	4712
5,000	4	17.00	5.5	2,250	0.01	0.45	0.471	0.3	0.141	0.8	0.377	0.19	1.0	0.471	1.6	2.24	4396	1.95	4451
5,000	4	16.00	6.2	2,250	0.01	0.62	0.600	0.3	0.180	0.8	0.480	0.22	1.0	0.600	2.1	2.12	3916	1.74	4189
5,000	4	15.00	7.1	2,250	0.01	0.88	0.777	0.3	0.233	0.8	0.622	0.26	1.0	0.777	2.8	2.00	3464	1.54	3927
5,000	4	14.00	8.1	2,250	0.01	1.27	1.024	0.3	0.307	0.8	0.819	0.30	1.0	1.024	3.7	1.88	3039	1.35	3665
5,000	4	13.00	9.4	2,250	0.01	1.89	1.377	0.3	0.413	0.8	1.102	0.38	1.0	1.377	5.2	1.76	2642	1.17	3403

APPENDIX C

QUANTITY TAKEOFF for COLD WATER PUMPING PLAN – FLOATING PUMP STATION

Flexifloat Preliminary Design Calculations - Alternative 3 with Geomembrane Pipe and FRP Suction Pipe

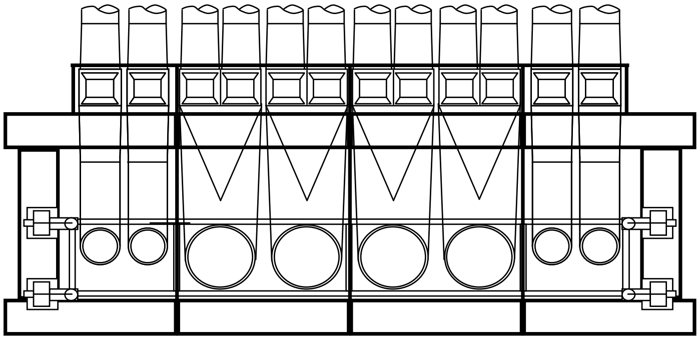
Weights

	Weight	Factor	Effective	
Weight of Hull (Flexifloats)	178	1.00	178	ton
Weight of Mobile Crane on barge	0	1.00	0	ton, no mobile crane will be operating on barge
Weight of Crane Hook Load	0	1.00	0	ton, no mobile crane will be operating on barge
Weight of Telescoping suction pipe	664	0.38	250	ton, FRP steel 4 - 9' & 4 - 16.5' Dia, assuming 4* thickness of steel pipe, 1.1 factor for overlapping
Weight of Delivery pipe	0	0.00	0	ton, Geomembrane LLDPE, weight slightly less than water, neglected
Transition Pipe/Plenum	121	0.38	45	ton, Segmented FRP
Weight of Pump Equipments	5	0.87	4	ton
Weight of Structural Framing	32	0.87	28	ton
Weight of Telescoping winches	40	1.00	40	ton, 4 winches
Weight of Telescoping Lifting Support	54	0.87	47	ton
Coldwater weight difference	25	1.00	25	ton
Weight of Other Miscellaneous	5	1.00	5	ton
Total Weight			623	ton

Flexifloat Barge:

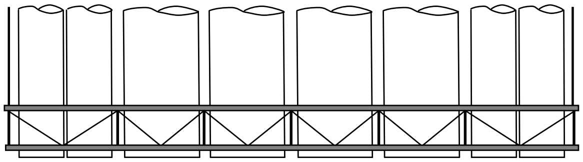
Flexifloat Type	No. of Units	Unit Area (sf)	Area (sf)	Unit Weight (lbs)	Unit Weight (lbs)
Quadrafloats - 30'x7.5'x3.8'	0	225.0	0	15,500	0
Duofloats - 15'x7.5'x3.8'	0	112.5	0	8,400	0
Quadrafloats - 40'x10'x5'	0	400.0	0	27,000	0
Duofloats - 20'x10'x5'	0	200.0	0	14,700	0
Quadrafloats - 40'x10'x7'	10	400.0	4000	35,600	356,000
Duofloats - 20'x10'x7'	0	200.0	0	18,900	0
Total	10		4000		356,000

Hull Depth	D_{hull} =	7	ft
Volume displacement	V_D =	19954	ft^3
Draft	$D = V_D/A$ =	4.99	ft
Free Board	$FB = D_{hull} - D$ =	2.01	ft



Alternative 3, Pump and Suction Pipe Support Barge Plan

Not to Scale



Suction Pipe Bottom Support Elevation

Not to Scale

Approximate Barge Structural Framing QTO - Alternative 3 with Geomembrane Pipe and FRP Suction Pipe

Structural framing to secure pumps and pipe attachmen

No of Pumps	20	
Pump diameter	8.0	ft
Clearance between pumps	1.0	ft
Structural Member	20	lb/ft
Approx. Structural Framing length	72	ft/per pump
Total Framing length	1440	ft
Weight of framing	14.4	ton

Structural framing to secure floating pip

Structural Member	20	lb/ft
Approx. Structural Framing length	490.1	ft
Weight of framing	4.9	ton

Structural framing to secure telescoping pipe to barg

Structural Member	40	lb/ft
Approx. Structural Framing length	490.1	ft
Weight of framing	9.8	ton

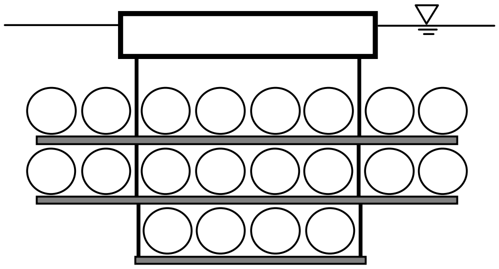
Total Weight

Total structural steel weight	29.1	ton
Connectors	2.9	ton
Total Weight	32	ton

Approx. Suction Pipe Bottom Support Steel Framing

Structural Member	100	lb/ft
Main Structural Framing length	700.0	ft
Factor (other members)	1.4	
Connector Factor	1.1	
Weight of framing	53.9	ton

Pipe Float Preliminary Design Calculations - Alternative 3 with LLDPE



LLDPE Pipe Supporting Floats
Not to Scale

Pipe Float Station Spacing

Float spacing	100	ft
Pipeline Length	2000	ft
Number of float stations	19	

Weights

Weight of Hull (Flexifloats)	14	ton
Weight of Pipe	0	ton, 20 LLDPE Pipes
Weight of Steel for securing pipe	5	ton
Coldwater weight difference	10	ton , assume 5°C vs 20°C
Total Weight	29	ton

Flexifloat Per Segment:

Flexifloat Type	No. of Units	Unit Area (sf)	Area (sf)	Unit Weight (lbs)	Unit Weight (lbs)
Quadrafloats - 30'x7.5'x3.8'	0	225.0	0	15,500	0
Duofloats - 15'x7.5'x3.8'	0	112.5	0	8,400	0
Quadrafloats - 40'x10'x5'	1	400.0	400	27,000	27,000
Duofloats - 20'x10'x5'	0	200.0	0	14,700	0
Quadrafloats - 40'x10'x7'	0	400.0	0	35,600	0
Duofloats - 20'x10'x7'	0	200.0	0	18,900	0
Total	1		400		27,000

Hull Depth	D_{hull} =	5	ft
Volume displacement	V_D =	918	ft^3
Draft	$D = V_D/A$ =	2.30	ft
Free Board	$FB = D_{hull} - D$ =	2.70	ft

Flexifloat for the pipeline:

Total Number of Flexifloat units	19

Steel Frame

Structural Member	30	lb/ft
Main Structural Framing length	240.0	ft
Factor (other members)	1.3	
Connector Factor	1.1	
Weight of framing	5.1	ton

Alternative 3 - Approximate Pipeline Headloss and QTO Estimates

With Steel Pipeline

Flow (cfs)	No. of Pipes	Diameter (ft)	Velocity (ft/s)	Length (ft)	Manning's Coeff n	Friction Loss (ft)	Velocity Head (ft)	Entrance Loss Coeff	Entrance Loss (ft)	Exit Loss Coeff	Exit Loss (ft)	Pump Loss (ft)	Minor Loss Coeff	Minor Loss (ft)	Total Loss (ft)	Minimum Thickness (in)	Weight (ton)	Weight (ton/ft)
250	1	9.00	3.9	2,250	0.013	0.91	0.240	0.3	0.072	0.8	0.192	0.15	1.0	0.240	1.6	0.32	416	0.18
250	1	8.50	4.4	2,250	0.013	1.23	0.301	0.3	0.090	0.8	0.241	0.16	1.0	0.301	2.0	0.31	374	0.17
250	1	8.00	5.0	2,250	0.013	1.70	0.384	0.3	0.115	0.8	0.307	0.18	1.0	0.384	2.7	0.29	335	0.15
250	1	7.50	5.7	2,250	0.013	2.40	0.497	0.3	0.149	0.8	0.398	0.20	1.0	0.497	3.6	0.28	298	0.13
250	1	7.00	6.5	2,250	0.013	3.46	0.655	0.3	0.197	0.8	0.524	0.23	1.0	0.655	5.1	0.26	263	0.12
250	1	6.50	7.5	2,250	0.013	5.14	0.881	0.3	0.264	0.8	0.705	0.28	1.0	0.881	7.3	0.25	230	0.10
5,000	4	18.00	4.9	2,250	0.013	0.56	0.375	0.3	0.112	0.8	0.300	0.17	1.0	0.375	1.5	0.59	6131	2.72
5,000	4	17.00	5.5	2,250	0.013	0.76	0.471	0.3	0.141	0.8	0.377	0.19	1.0	0.471	1.9	0.56	5496	2.44
5,000	4	16.00	6.2	2,250	0.013	1.06	0.600	0.3	0.180	0.8	0.480	0.22	1.0	0.600	2.5	0.53	4895	2.18
5,000	4	15.00	7.1	2,250	0.013	1.49	0.777	0.3	0.233	0.8	0.622	0.26	1.0	0.777	3.4	0.50	4330	1.92
5,000	4	14.00	8.1	2,250	0.013	2.15	1.024	0.3	0.307	0.8	0.819	0.30	1.0	1.024	4.6	0.47	3798	1.69
5,000	4	13.00	9.4	2,250	0.013	3.19	1.377	0.3	0.413	0.8	1.102	0.38	1.0	1.377	6.5	0.44	3302	1.47

With Smooth Geomembrane (LLDPE) Delivery Pipe and FRP Suction Pipe

Flow (cfs)	No. of Pipes	Diameter (ft)	Velocity (ft/s)	LLDPE Length (ft)	FRP Length (ft)	Manning's Coeff n	Friction Loss (ft)	Velocity Head (ft)	Entrance Loss Coeff	Entrance Loss (ft)	Exit Loss Coeff	Exit Loss (ft)	Pump Loss (ft)	Minor Loss Coeff	Minor Loss (ft)	Total Loss (ft)	LLDPE Area (sy)	FRP Min. Thick. (in)	FRP Weight (ton)	FRP Weight (ton/ft)	FRP Area (sy)
250	1	9.00	3.9	2,000	250	0.01	0.54	0.240	0.3	0.072	0.8	0.192	0.15	1.0	0.240	1.2	524	1.28	37	0.15	65
250	1	8.50	4.4	2,000	250	0.01	0.73	0.301	0.3	0.090	0.8	0.241	0.16	1.0	0.301	1.5	495	1.22	33	0.13	62
250	1	8.00	5.0	2,000	250	0.01	1.01	0.384	0.3	0.115	0.8	0.307	0.18	1.0	0.384	2.0	465	1.16	30	0.12	58
250	1	7.50	5.7	2,000	250	0.01	1.42	0.497	0.3	0.149	0.8	0.398	0.20	1.0	0.497	2.7	436	1.10	26	0.11	55
250	1	7.00	6.5	2,000	250	0.01	2.05	0.655	0.3	0.197	0.8	0.524	0.23	1.0	0.655	3.7	407	1.04	23	0.09	51
250	1	6.50	7.5	2,000	250	0.01	3.04	0.881	0.3	0.264	0.8	0.705	0.28	1.0	0.881	5.2	378	0.98	20	0.08	47
5,000	4	18.00	4.9	2,000	250	0.01	0.33	0.375	0.3	0.112	0.8	0.300	0.17	1.0	0.375	1.3	4189	2.36	545	2.18	524
5,000	4	17.00	5.5	2,000	250	0.01	0.45	0.471	0.3	0.141	0.8	0.377	0.19	1.0	0.471	1.6	3956	2.24	488	1.95	495
5,000	4	16.00	6.2	2,000	250	0.01	0.62	0.600	0.3	0.180	0.8	0.480	0.22	1.0	0.600	2.1	3723	2.12	435	1.74	465
5,000	4	15.00	7.1	2,000	250	0.01	0.88	0.777	0.3	0.233	0.8	0.622	0.26	1.0	0.777	2.8	3491	2.00	385	1.54	436
5,000	4	14.00	8.1	2,000	250	0.01	1.27	1.024	0.3	0.307	0.8	0.819	0.30	1.0	1.024	3.7	3258	1.88	338	1.35	407
5,000	4	13.00	9.4	2,000	250	0.01	1.89	1.377	0.3	0.413	0.8	1.102	0.38	1.0	1.377	5.2	3025	1.76	294	1.17	378

With Smooth FRP Pipeline

Flow (cfs)	No. of Pipes	Diameter (ft)	Velocity (ft/s)	Length (ft)	Manning's Coeff n	Friction Loss (ft)	Velocity Head (ft)	Entrance Loss Coeff	Entrance Loss (ft)	Exit Loss Coeff	Exit Loss (ft)	Pump Loss (ft)	Minor Loss Coeff	Minor Loss (ft)	Total Loss (ft)	FRP Min. Thick. (in)	FRP Weight (ton)	FRP Weight (ton/ft)	FRP Area (sy)
250	1	9.00	3.9	2,250	0.01	0.54	0.240	0.3	0.072	0.8	0.192	0.15	1.0	0.240	1.2	1.28	333	0.15	589
250	1	8.50	4.4	2,250	0.01	0.73	0.301	0.3	0.090	0.8	0.241	0.16	1.0	0.301	1.5	1.22	299	0.13	556
250	1	8.00	5.0	2,250	0.01	1.01	0.384	0.3	0.115	0.8	0.307	0.18	1.0	0.384	2.0	1.16	268	0.12	524
250	1	7.50	5.7	2,250	0.01	1.42	0.497	0.3	0.149	0.8	0.398	0.20	1.0	0.497	2.7	1.10	238	0.11	491
250	1	7.00	6.5	2,250	0.01	2.05	0.655	0.3	0.197	0.8	0.524	0.23	1.0	0.655	3.7	1.04	210	0.09	458
250	1	6.50	7.5	2,250	0.01	3.04	0.881	0.3	0.264	0.8	0.705	0.28	1.0	0.881	5.2	0.98	184	0.08	425
5,000	4	18.00	4.9	2,250	0.01	0.33	0.375	0.3	0.112	0.8	0.300	0.17	1.0	0.375	1.3	2.36	4904	2.18	4712
5,000	4	17.00	5.5	2,250	0.01	0.45	0.471	0.3	0.141	0.8	0.377	0.19	1.0	0.471	1.6	2.24	4396	1.95	4451
5,000	4	16.00	6.2	2,250	0.01	0.62	0.600	0.3	0.180	0.8	0.480	0.22	1.0	0.600	2.1	2.12	3916	1.74	4189
5,000	4	15.00	7.1	2,250	0.01	0.88	0.777	0.3	0.233	0.8	0.622	0.26	1.0	0.777	2.8	2.00	3464	1.54	3927
5,000	4	14.00	8.1	2,250	0.01	1.27	1.024	0.3	0.307	0.8	0.819	0.30	1.0	1.024	3.7	1.88	3039	1.35	3665
5,000	4	13.00	9.4	2,250	0.01	1.89	1.377	0.3	0.413	0.8	1.102	0.38	1.0	1.377	5.2	1.76	2642	1.17	3403

Approximate Additional Weight Due to Difference in Water Temperature

Water Weight Density	62.4	pcf
Assumed Bottom Temperature	5	°C
Assumed 5ft Deep Temperature	20	°C

Flow (cfs)	No. of Pipes	Diameter (ft)	Area (sf)	Length (ft)	Volume (cf)	Water Weight Diff.	Additional Weight (ton)
250	20	10.00	78.54	100	157,080	0.20%	9.80
250	20	9.00	63.62	100	127,235	0.20%	7.94
250	4	10.00	78.54	300	94,248	0.20%	5.88
250	4	9.00	63.62	300	76,341	0.20%	4.76
5,000	4	18.00	254.47	300	305,363	0.20%	19.05
5,000	4	16.00	201.06	300	241,274	0.20%	15.06
5,000	4	15.00	176.71	300	212,058	0.20%	13.23

APPENDIX D

CONSTRUCTION and ANNUAL OPERATION & MAINTENANCE COST ESTIMATES for FLOATING PUMP STATION

BROWNLEE COLD WATER PUMPING PLANT

IN RESERVOIR FLOATING PUMP STATION w/LLDPE DELIVERY PIPE TO INTAKE

CONCEPT LEVEL CONSTRUCTION COST ESTIMATE

(2011 Dollars)

Ref No.	Project Feature	Quant	Unit Meas	Unit Rate	Amount	Comments
1	Mobilization/Demob					
1.1	Prepare for On-Site FRP Manufacture		LS		100,000	Conc Pad, Warehouse, Elect
1.2	Prepare for On-Site LLDPE Pipe Manufacture		LS		100,000	Conc Pad, Warehouse, Elect
1.3	Erect 136 mT Crawler Crane (555) for Handling Pipe & Floats				160,000	Mob, Demob, Assmbl & Disasm
1.4	Mobilize Marine Equipment & Crane Flexi-Float				300,000	Marine Equip (3 Crane Set-ups
1.5	F&I Log Boom	3000	LF	50	150,000	Allowance
1.6	Demob from Site				300,000	Marine Equip
1.7	Subtotal Mob/Demob for Site Work			1,110,000		
2	Fab & Install Permanent FlexiFloat Barge for Floating Pump Station					
2.1	Purchase FlexiFloats S-70 for Barge	10	EA	60,000	600,000	Purch & Ship Quote 40'x10'x7'
2.2	Assemble & Outfit FlexiFloats					
2.2.1	Manitowoc 555 Crane on Floats	100	HRS	500	50,000	10 hrs per ea
2.2.2	F&I four Winches for Telecope Pipe	4	EA	50,000	200,000	Allowance for Hvy Duty Equip & Hvy Cables
2.2.3	F&I four Winches for Locating Barge during Operation	4	EA	30,000	120,000	Allowance for large drum winches
2.2.4	Inland Tug for Pipe Work	100	HRS	300	30,000	Draft Tug w/5 Man Crew
2.3	Subtotal Floating Pump Station Floats			1,000,000		
3	New Suction Piping, 4 - 22' Max Dia Reinforced Fiberglass Pipes (RFP) and 4 - 16.5' Max Dia RFP					
3.1	Fabricate 22' Dia RFP @ Site	1,000	LF	4,104	4,104,000	Ershigs Quote
3.2	Fabricate 16.5' Dia RFP @Site	1,000	LF	2,742	2,742,000	Ershigs Quote
3.3	Fabricate Pipe Lifting Beams	108,000	LBS	6	648,000	Galvanized Prefab Steel
3.4	Assemble Pipe Sections on floats	40	EA	500	20,000	2 hr per spool, 50' Lengths
3.5	Install Lifting Beams &Telescoping Pipe to Permanent FlexiFloat Barge					
3.5.1	Manitowoc 555 Crane on Floats	160	HRS	500	80,000	Crane & Crew on Rental Flexi-Floats, 4 hr/pipe
3.5.2	Additional Barges for Pipe	40	HRS	100	4,000	2 Temp Barges for pipe
3.5.3	Inland Tug for Pipe Work	160	HRS	300	48,000	Draft Tug w/5 Man Crew
3.6	Subtotal RFP Suction Pipe			7,646,000		
4	Pumping Plant on Permanent FlexiFloat Barge					
4.1	Steel Transition RFP to Pumps					
4.1.1	Prefab Steel Transition Structures	242,000	LBS	6	1,452,000	Galvanized Prefab
4.1.2	Manitowoc 555 Crane on Floats	40	HRS	500	20,000	Handle & Hold Transitions
4.1.3	Additional Barge for Transition Sectio	40	HRS	100	4,000	Hold Structures
4.1.4	Divers for Pipe Connect to Transitions	40	HRS	584	23,360	Diver, Tender, Stndby
4.1.5	Add'l Diver Support	40	HRS	200	8,000	Air, boat, etc.
4.2	Furnish & Install 250 cfs Pumps					
4.2.1	Purchase 250 cfs Pumps	20	EA	238,000	4,760,000	Flygt 8' Dia Axial Flow Pump
4.2.2	Steel Framework for Housing Pumps	74,000	LBS	6	444,000	Galvanized Prefab
4.2.3	Assemble & Ready Pumps for Installation on land	160	HRS	190	30,400	1 day/ea; 3 Mlwt, 1 Opr, 1 Lt Crane work onshore
4.2.4	Manitowoc 555 Crane on Floats	80	HRS	500	40,000	Avg 2 sets per day
4.2.5	Divers for Pump Installation	80	HRS	584	46,720	Diver, Tender, Stndby
4.2.6	Add'l Diver Support	80	HRS	200	16,000	Air, boat, etc.
4.2.7	Electrical Hookup for Pumps				0	See 7.12 & 7.13
4.3	Inland Tug for Pumping Plant Work	60	HRS	300	18,000	Draft Tug w/5 Man Crew
4.4	Subtotal Pumping Plant			6,844,480		

BROWNLEE COLD WATER PUMPING PLANT

IN RESERVOIR FLOATING PUMP STATION w/LLDPE DELIVERY PIPE TO INTAKE

CONCEPT LEVEL CONSTRUCTION COST ESTIMATE

(2011 Dollars)

Ref No.	Project Feature	Quant	Unit Meas	Unit Rate	Amount	Comments
5	Cable Anchors for Barge Positioning in Reservoir					
5.1	Furn & Install Steel Cable					
5.1.1	Rock Bolt Anchors, Underwater	8	EA	1,200	9,600	
5.1.2	Steel Cable Material					
5.1.3	1" Dia Galv Steel Cable	10,000	LF	7	70,000	Quote from US Cargo Control
5.1.4	Hardware Fasteners (Turnbuckle)	8	EA	300	2,400	
5.1.5	Support Labor for Installation	40	HRS	200	8,000	4 Lab @ $50/hr each
5.1.6	Floating Crane Service	40	HRS	500	20,000	
5.1.7	Diver & Tender Assist	20	HRS	584	11,680	
5.2	Subtotal Cable Anchors		121,680			
6	F&I LLDPE Delivery Piping, 9' Dia, 60 mil thick in 200 Ft Lengths					
6.1	Fabricate LLDPE Pipe at Project Site	42,000	LF	44	1,848,000	Quote from GSE
6.2	Purchase FlexiFloats for Delivery Pipe	19	EA	50,000	950,000	Purch & Ship Quote 40'x10'x5'
6.3	Fabricate Pipe Holding Steel Bands	190,000	LBS	6	1,140,000	Galvanized Prefab Steel
6.4	Install Delvery Pipe to Permanent FlexiFloat Barge Supports					
6.4.1	Assemble Pipe Sections on Temp Float (add temp21 floats rental)	420	HRS	1,450	609,000	12 Lab, 3 Opr, 3 Oilr; 3 - 50 mT Cranes; 1 hrs per 100 ' Length joints
6.4.2	Rent 21 floats for pipe assembly & 6 for Transporting Land to FPS	1,418	Day	83	117,653	Assm = 120' long x 70' wide; Trans = 120'x20'
6.4.3	Inland Tug for Pipe Work	11,340	HRS	300	3,402,000	Draft Tug w/5 Man Crew
6.5	Subtotal LLDPE Delivery Pipe		8,066,653			
7	Power Supply for Pumping Plant					
7.1	F&I 12.47 kV Ovrhd Distribution Line	3,000	LF	15	45,000	Assume 3,000' in rocky terrain
7.2	Shore Terminal - Protection, Plug, dead-end, grounding, arresters	1	EA	85,000	85,000	w/PLM 15kV plug and receptacle
7.3	Power and Ground Conductor to Barge w/ surface floats	1	LS	75,000	75,000	Messenger with corrugated armored cable
7.4	Reservior Bank cable protective chute	1	LS	7,000	7,000	Messenger w/ corrugated armored cable
7.5	Communications/Controls conductors to barge w/surface floats	1	LS	15,000	15,000	
7.6	Commel connectors, shore and barge	1	LS	4,000	4,000	
7.7	Barge Terminal - Plug and dead-end	1	LS	30,000	30,000	w/PLM 15kV plug & recept
7.8	Barge Unit Substation	1	LS	389,000	389,000	Primary switch, 3,000kVA xfmr, 2 output CB's
7.9	MCC w/ (10) 125hp FVNR Starters	2	EA	88,000	176,000	
7.10	MCC Feeders	2	EA	10,000	20,000	
7.11	Low voltage barge/float power and lighting allowance	1	LS	45,000	45,000	Add CB's to MCC's to feed xfmr and panels
7.12	SCADA and wiring	1	LS	225,000	225,000	
7.13	Motor Feeders	20	EA	3,500	70,000	
7.14	Barge Grounding	1	LS	5,000	5,000	
7.15	Power Cable Reel on Trailer	1	EA	12,000	12,000	Order cable with non-returnable oversize steel
7.16	Commel/Controls Cable Reel on Trailer	1	EA	3,000	3,000	
7.17	Pre-fab Electrical Building for Barge	1	LS	120,000	120,000	
7.18	System Start-up & Testing	100	HRS			Excludes Equip Rep's
7.18.1	Technician Labor	140	HRS	300	42,000	2 Elect, 2 Mlwrt, 2 Labr @ $50/hr ea; avg 5 hr/pump + 40 hrs
7.18.2	Inland Tug for Startup & Testing	140	HRS	300	42,000	Draft Tug w/5 Man Crew
7.19	Subtotal Power Supply		1,326,000			

BROWNLEE COLD WATER PUMPING PLANT

IN RESERVOIR FLOATING PUMP STATION w/LLDPE DELIVERY PIPE TO INTAKE

CONCEPT LEVEL CONSTRUCTION COST ESTIMATE

(2011 Dollars)

Ref No.	Project Feature	Quant	Unit Meas	Unit Rate	Amount	Comments
8	Subtotal Direct				26,216,813	
9	Contingency @ 25% +/-				6,554,188	
10	Construction Total				32,771,000	
11	Engineering, PM/CM, Other Owner Costs @ 20% +/-	1			6,554,000	Allowance
12	Project Total				39,325,000	
	Costs not Included:	Sales Tax				
		Loss of Power Generation during Construction Outage				
		Loss of Power Generation due to Head Loss in System				
		AFUDC				

BROWNLEE COLD WATER PUMPING PLANT

IN RESERVOIR FLOATING PUMP STATION w/LLDPE DELIVERY PIPE TO INTAKE

ANNUAL OPERATION & MAINTANENCE COST ESTIMATE

(2011 Dollars)

Ref No.	Project Feature	Quant	Unit Meas	Unit Rate	Amount	Comments
1	Mobilization/Demob					
1.1	Mobilize Marine Equipment & Inland Tug				20,000	Draft Tug w/5 Man Crew
1.2	Demob from Site				20,000	Marine Equip
1.3	Subtotal Mob/Demob for Site Work		40,000			
2	Ready FPS for Operation					
2.1	Tug to Extend/Adjust Cable Anchors	32	HRS	300	9,600	Draft Tug w/5 Man Crew
2.2	Install Power/Communication Cables					
2.2.1	Retreve Cables from Storage	1	LS	1,000	1,000	10 hrs
2.2.2	Unreel Cables & Afix Floats	4	HRS	150	600	3 Labr @$50 ea
2.2.3	Attach Plugs to Land and FPS	4	HRS	180	720	3 Elect @ $60 ea
2.2.4	Inland Tug for Power Cable Work	8	HRS	300	2,400	Draft Tug w/5 Man Crew
2.2.5	Check Circuits & Comm Links	20	HRS	180	3,600	3 Elect @ $60 ea
2.3	Position FPS over cold water source	10	HRS	300	3,000	Draft Tug w/5 Man Crew
2.4	Lower Suction Pipes to Depth	2	HRS	60	120	1 Opr @$60 ea
2.5	Visually Inspect Delivery Pipes	8	HRS	140	1,120	2 Opr @$60 ea; Pwr Motor Boat
2.6	Work Boat for Access to FPS	30	HRS	100	3,000	Skif w/30 Hp Motor & Opr
2.7	Subtotal Ready FPS for Opn		25,160			
3	Operate FPS for 5 Weeks					
3.1	Start Pumps	2	HRS	60	120	1 Opr @$60 ea
3.2	P/T Operator to Check Pumps	70	HRS	60	4,200	1 Opr @$60 ea; 2 hr/day
3.3	Operate at 2MW for 5 Weeks	840	HRS	200	168,000	Elect Rate $.10/kWH
3.4	Subtotal RFP Suction Pipe		172,320			
4	Ready FPS for Storage/Non-operation					
4.1	Visually Inspect Delivery Pipes	8	HRS	140	1,120	2 Opr @$60 ea; Pwr Motor Boat
4.2	Raise Suction Pipes	2	HRS	60	120	1 Opr @$60 ea
4.3	Move FPS toward Shore	10	HRS	300	3,000	Draft Tug w/5 Man Crew
4.4	Remove Power/Communication Cables					
4.4.1	Inland Tug for Power Cable Work	8	HRS	300	2,400	Draft Tug w/5 Man Crew
4.4.2	Detach Plugs at Land and FPS	4	HRS	180	720	3 Elect @ $60 ea
4.4.3	Reel up Cables & Remove Floats	4	HRS	150	600	3 Labr @$50 ea
4.4.4	Return Cables to Storage	1	LS	1,000	1,000	10 hrs
4.5	Work Boat for Access to FPS	26	HRS	100	2,600	Skif w/30 Hp Motor & Opr
4.6	Subtotal Shutdown FPS		11,560			
5	Maint of Pumps Every Other Month (6 times/year)					
5.1	Temp Power for Turnover of Pumps	120	HRS	50	6,000	200 kW Generator
5.2	Operator to Start/Stop Pumps	120	HRS	60	7,200	1 Opr @$60 ea; 1 hr/pump
5.3	Work Boat for Pump Maint	120	HRS	100	12,000	Skif w/30 Hp Motor & Opr
5.4	Subtotal Maint of Pumps		25,200			
6	Maint Contract w/ Flygt					
6.1	Annual Periodic Maint by Manufacturer	1	LS	60,000	60,000	Rough Est in Conversation w/Flygt
6.2	Subtotal LLDPE Delivery Pipe		60,000			
7	Subtotal Direct				334,240	
8	Contingency @ 20% +/-				66,760	
9	Annual O&M Total				401,000	
	Costs not Included:	Sales Tax				
		Loss of Power Generation during Construction Outage				

Exhibit 7.1-10

March 11, 2011 Idaho Power Company’s responses to the Oregon Department of Environmental Quality (ODEQ) additional information request

Responses to ODEQ Additional Information Request

Hells Canyon Project
FERC No. P-1971-079

March 11, 2011

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INTRODUCTION

This document is being submitted to Oregon Department of Environmental Quality (ODEQ) in response to an additional information request (AIR) sent to Idaho Power Company (IPC) on December 6, 2010. The request was prompted by ODEQ's review of IPC's 401 Certification Application for the Hells Canyon Complex (HCC) submitted September 2010. IPC has responded to each question in the AIR. The responses vary from general background information to detailed responses based upon ongoing analyses and modeling. Many responses include information that was already provided to ODEQ from previous HCC 401 applications or Federal Energy Regulatory commission (FERC) information requests in which ODEQ was a consulted agency. These previously submitted documents, which are being provided as attachments to this AIR response, contain technical information that address ODEQ's latest request. Attachments for this AIR were obtained from the following sources:

- Snake River-Hells Canyon Total Maximum Daily Load (SR-HC TMDL) Process (Attachment 3)
- FERC License Application Appendices (Attachments 2 and 10)
- FERC AIR responses (Attachments 5, 6, 15)
- Idaho Department of Environmental Quality (IDEQ) (Attachment 11)
- ODEQ process to evaluate IPC's Site Specific Criteria application (Attachments 7, 12, 13)
- Information not previously presented (Attachments 4, 8, 9, 14).

The HCC 401 certification process has occurred over an extended period in part because of the physical scale of the HCC, and the complexities associated with environmental analyses and the regulatory process. This process began with IPC initiating water quality data collection in the early 1990's. In addition to extensive data collection, IPC then initiated a water quality modeling program in 1995 that developed a number of state of the art water quality models, spanning all 220 miles of river and reservoirs addressed in the Snake River-Hells Canyon TMDL. The Brownlee Reservoir model went through two peer review processes, one arranged by IPC and the other by Oregon and Idaho DEQ. The Brownlee Reservoir model was subsequently used by the ODEQ and IDEQ to support the Snake River nutrient and dissolved oxygen load allocations, approved by EPA in 2004.

During the process to prepare the HCC FERC license application (submitted in July 2003), much of the water quality data, analyses and modeling was provided within the framework of a "Collaborative Team" process. This team was composed of stakeholders, including state and federal agencies, environmental groups, Native American tribes, and customer groups. The teams met regularly to discuss ongoing studies and provide broad input. Subsequent to that, IPC and the stakeholders convened a Settlement Work Group that functioned to review and discuss ongoing efforts to address outstanding issues relative to the licensing of the HCC. A substantial issue was water quality, specifically the need and value of temperature manipulation within the HCC. These efforts resulted in large advances in the understanding of the nature and dynamics of water quality associated with the HCC.

In working with the DEQs to process its 401 applications since 2003, IPC has consistently taken a collaborative approach to its data, analyses and modeling efforts with the view that discussion leading to consensus between analysts and decision makers is critical. Because water quality analyses and modeling was key to understanding and addressing issues in this 401 certification process, IPC met regularly with ODEQ and IDEQ throughout development of its successive 401 applications. In fact, this process of informally meeting with ODEQ and IDEQ to review and discuss water quality data, analyses and modeling efforts began prior to the 401 process during the development of the SR-HC TMDL. In 2005, after completion of the TMDL, similar 401 technical meetings were initiated. These meetings were working sessions to review and comment on preliminary technical supporting information, and thus, notes and minutes were not formalized. However, IPC relied on these technical meetings to help guide and direct continual development of the technical supporting information found throughout much of the 401 applications. It was also clear to IPC that ODEQ was using these working sessions to understand and evaluate the HCC 401 applications.

It has become equally clear that ODEQ is not applying or recognizing these valuable information exchanges and discussions in its evaluation of IPC's current application. IPC is concerned that much of the understanding gained through working directly with ODEQ over many years has been lost. Specific examples range from ODEQ's request for information to support the validity of 13.3°C as the appropriate temperature target for evaluation of modeling results, to the request regarding accumulated thermal units under alternative scenarios. Both these items were the subject of past technical discussions and based on those discussions have been used and presented in multiple previous applications. The temperature target is based on the Snake River-Hells Canyon TMDL target and application of Oregon's water quality standards after TMDLs are approved. ODEQ's requests for additional modeling to assess alternative scenarios, such as increased winter and spring warming to accelerate fall Chinook development and emergence, has already been done and evaluated by stakeholders in the FERC licensing process. Specific to the potential value of a temperature control structure in Brownlee Reservoir, NOAA and other resource agencies concluded several years ago that there was no potential for substantially accelerating fall Chinook development or emergence.

IPC realizes that the 401 certification has been a long and complex process, and understands that ODEQ staff currently assigned to the HCC 401 certification were not present during most of the licensing and certification processes and associated meetings. It is also important to understand that full and complete written responses to many of the AIR questions would be a costly and time consuming effort, covering questions previously raised without an associated process to reach a common understanding or identify the more significant issues. With this in mind, IPC submits the following response to ODEQ's AIR request.

ODEQ REQUEST #1

The equation does not address the possible attenuation of cold water as it moves through the Hells Canyon complex. In order for ODEQ to evaluate the potential for the HPS to attain water quality standards, IPC must provide an analysis of the temperature expected below the Hells Canyon dam.

For the proposed HPS please provide a detailed evaluation of the potential effectiveness of the system to meet the 13°C criterion as allocated in the Snake River TMDL. The modeling should simulate the flow of water as it moves through the three dam complex and address the possible attenuation of the cold water as it moves through the complex. The temperature of water discharged from Hells Canyon reservoir should be modeled for representative flow years.

IPC RESPONSE

Numerical modeling using CE-QUAL-W2 models of Brownlee Reservoir and the HCC was applied to address potential attenuation of cool water as it moves through the HCC, and to evaluate the potential of the HPS to attain the 13 °C salmonid spawning criterion downstream of HC Dam. CE-QUAL-W2 is a two dimensional (longitudinal and vertical, laterally averaged) model that has been applied extensively to the HCC.

CE-QUAL W2 Modeling

In order to model the HPS, IPCs Version 3.1 CE-QUAL W2 models were upgraded to Version 3.7 and customized by Scott Wells (Environmental Engineering). The custom coding allows water to be withdrawn at a point in the hypolimnion of Brownlee and placed in the turbine intake channel. Version 3.7 includes numerous upgrades and changes to the basic model package available with the Version 3.1 model. Using the Version 3.7 model package without adjustment of any previous (Version 3.1) coefficients produced temperature simulation that was very similar to the optimized Version 3.1 models (Attachment 1). Attachment 1 presents selected model uncertainty statistics for the Version 3.1 models and briefly outlines applications and revisions of IPC's CE-QUAL-W2 models. While focused on previous versions of the models, general information relative to model set-up and optimization can be found in Attachment 2 and Attachment 3.

Throughout the years of HCC water quality modeling, numerous applications, versions, years, and customizations of CE-QUAL-W2 have been developed. These include modeling for SR HC TMDL phosphorus and dissolved oxygen, FERC final license application modeling, FERC AIRs, and §401 water quality certification applications. Throughout these model applications, six years have been developed to represent a range of flow conditions: 1992, 1994, 1995, 1997, 1999 and 2002. For this HPS modeling, four years were used: 1992, 1995, 1999 and 2002. These years are appropriate for this model application because:

- These models represent the range of water year types including low (i.e. 1992, 2002), medium (i.e. 1995), and high (i.e. 1999).
- These models do not include the very high water year of 1997 because the 13 °C salmonid spawning criterion was met in that year with a measured value of 13.3 °C 7-day average maximum on October 29 below Hells Canyon Dam (13.3 °C represents the criterion plus the human use allowance of 0.3 °C)
- These models include only years where actual historical measured turbine operations were applied. For the 1994 model (not used for this HPS modeling) only Proposed Operations (Attachment 2) were applied. Proposed Operations were developed for the FERC final license application and do not include elements outlined in the FERC Final Environmental Impact Statement for the HCC. In addition, Proposed Operations include a modeled approximation of Brownlee outflow. Actual historical operations may better represent daily variability in Brownlee outflow that may occur in the future, which are more appropriate to consider when evaluating the HPS.

The model design, inputs and results for the selected years specific to the potential effectiveness of the HPS are presented below.

Boundary Conditions

Boundary conditions for the selected model years were based on measured data from various locations. In some cases the raw data could be used but in many cases the boundary conditions were developed through transformations or relationships with the measured data (Table 1).

Table 1. Description of boundary conditions used in the 1992, 1995, 1999 and 2002, Brownlee, Oxbow and Hells Canyon Reservoir CE-QUAL-W2 Models.

Boundary condition	**Boundary Condition Description**			
	1992	**1995**	**1999**	**2002**
Brownlee Reservoir				
Snake River inflow rate	Historical Snake River at Weiser gage 7-day “centered” average	Historical Snake River at Weiser gage 7-day “centered” average	Historical Snake River at Weiser gage 7-day “centered” average	Historical Snake River at Weiser gage 7-day “centered” average
Snake River inflow temperature	Measured at Swan Falls Dam approximately every 2 hours	Measured at Brownlee inflow (RM 340) every two weeks	Measured at Brownlee inflow (RM 345.6) hourly or every two weeks to fill gaps	Measured at Brownlee inflow (RM 345.6) every 10 minutes or RM 340 every two weeks to fill gaps
Snake River dissolved oxygen	Measured in profile and averaged at Brownlee inflow (RM 335 or 330) approximately every two weeks	1995 Lower Snake River Model output till 10/16 (extent of LSR model) then measured at RM 340 every two weeks	Measured at Brownlee inflow (RM 340) every two weeks	Measured at Brownlee inflow (RM 345.6) every 10 minutes or RM 340 every two weeks to fill gaps
Snake River inflow water quality[1]	Measured (grab sample) at Brownlee inflow (RM 335 or 330) approximately every two weeks	1995 Lower Snake River Model output till 10/16 (extent of LSR model) then measured at RM 340 every two weeks	Measured at Brownlee inflow (RM 340) every two weeks	Algae (as chlorophylla) measured at Brownlee inflow (RM 345.6) every 10 minutes other measured at RM 340 approximately every two weeks
Powder River inflow rate	Measured daily average Powder River near Richland plus Eagle Creek near New Bridge	Measured daily average Powder River near Richland plus Eagle Creek near New Bridge	Measured daily average Powder River near Richland plus Eagle Creek near New Bridge	Measured hourly average Powder River near Richland plus Eagle Creek near New Bridge
Powder River inflow temperature	1999 measured near Powder River mouth hourly	1999 measured near Powder River mouth hourly	1999 measured near Powder River mouth hourly	2002 measured hourly near Powder River mouth
Powder River inflow DO	1999-2000 measured near Powder River mouth approximately monthly	1999-2000 measured near Powder River mouth approximately monthly	1999-2000 measured near Powder River mouth approximately monthly	1999-2000 measured near Powder River mouth approximately monthly
Powder River inflow Water Quality	1999-2000 measured near Powder River mouth approximately monthly	1999-2000 measured near Powder River mouth approximately monthly	1999-2000 measured near Powder River mouth approximately monthly	1999-2000 measured near Powder River mouth approximately monthly and relationships with Snake River data
Burnt River inflow rate	Measured daily average Burnt River	Measured daily average Burnt River	Measured daily average Burnt River near	Measured hourly Burnt River near Huntington
Burnt River inflow temperature	1999 measured near Powder River mouth hourly	1999 measured near Powder River mouth hourly	1999 measured near Powder River mouth hourly	2002 measured near Powder River mouth hourly
Burnt River inflow DO	1999-2000 measured near Burnt River mouth approximately monthly	1999-2000 measured near Burnt River mouth approximately monthly	1999-2000 measured near Burnt River mouth approximately monthly	1999-2000 measured near Burnt River mouth approximately monthly
Burnt River inflow Water Quality	1999-2000 measured near Burnt River mouth approximately monthly	1999-2000 measured near Burnt River mouth approximately monthly	1999-2000 measured near Burnt River mouth approximately monthly	1999-2000 measured near Burnt River mouth approximately monthly
Meterological conditions	Transformed 1992 measured data from Parma, Idaho based on 2002 Lake Station relationships	Transformed 1995 measured data from Parma, Idaho based on 2002 Lake Station relationships	Transformed 1999 measured data from Parma, Idaho based on 2002 Lake Station relationships	Measured data from Lake Stations, Brownlee Dam, Boise, Idaho or transformed measured wind data from Parma, Idaho
Turbine outflow rate	IPC measured Brownlee turbine flows hourly	IPC measured Brownlee turbine flows hourly	IPC measured Brownlee turbine flows hourly	IPC measured Brownlee turbine flows hourly
Spill outflow rate	IPC measured Brownlee spill flow	IPC measured Brownlee spill flow hourly	IPC measured Brownlee spill flow hourly	IPC measured Brownlee spill flow hourly

Boundary condition	**Boundary Condition Description**			
	1992	**1995**	**1999**	**2002**
Oxbow Reservoir				
Snake River inflow rate	Combined measured Brownlee turbine plus spill outflow hourly	Combined measured Brownlee turbine plus spill outflow hourly	Combined measured Brownlee turbine plus spill outflow hourly	Combined measured Brownlee turbine plus spill outflow hourly
Snake River inflow temperature	Flow weighted turbine and spill outflow temperature from Brownlee model	Flow weighted turbine and spill outflow temperature from Brownlee model	Flow weighted turbine and spill outflow temperature from Brownlee model	Flow weighted turbine and spill outflow temperature from Brownlee model
Snake River inflow DO	Flow weighted turbine and spill outflow DO from Brownlee model	Flow weighted turbine and spill outflow DO from Brownlee model	Flow weighted turbine and spill outflow DO from Brownlee model	Flow weighted turbine and spill outflow DO from Brownlee model
Snake River inflow water quality	Flow weighted turbine and spill outflow constituents from Brownlee model	Flow weighted turbine and spill outflow constituents from Brownlee model	Flow weighted turbine and spill outflow constituents from Brownlee model	Flow weighted turbine and spill outflow constituents from Brownlee model
Wildhorse River inflow rate	Water balance generated through CHEOPS model	1995 measured near Wildhorse River mouth hourly	Water balance generated through CHEOPS model	2002 measured near Wildhorse River mouth hourly
Wildhorse River inflow temperature	1999 measured near Wildhorse River mouth hourly	1999 measured near Wildhorse River mouth hourly	1999 measured near Wildhorse River mouth hourly	2002 Measured near Wildhorse River mouth hourly
Wildhorse River inflow DO	1999-2000 measured near Wildhorse River mouth approximately monthly	1999-2000 measured near Wildhorse River mouth approximately monthly	1999-2000 measured near Wildhorse River mouth approximately monthly	1999-2000 measured near Wildhorse River mouth approximately monthly
Wildhorse River inflow Water Quality	1999-2000 measured near Wildhorse River mouth approximately monthly	1999-2000 measured near Wildhorse River mouth approximately monthly	1999-2000 measured near Wildhorse River mouth approximately monthly	1999-2000 measured near Wildhorse River mouth approximately monthly
Meterological conditions	Same as applied to Brownlee model waterbody 3 (closest to Dam)	Same as applied to Brownlee model waterbody 3 (closest to Dam)	Same as applied to Brownlee model waterbody 3 (closest to Dam)	Same as applied to Brownlee model waterbody 3 (closest to Dam)
Turbine outflow rate	IPC measured Oxbow turbine outflows hourly	IPC measured Oxbow turbine outflows hourly	IPC measured Oxbow turbine outflows hourly	IPC measured Oxbow turbine outflows hourly
Spill outflow rate	IPC measured Oxbow spill flow hourly	IPC measured Oxbow spill flow hourly	IPC measured Oxbow spill flow hourly	IPC measured Oxbow spill flow hourly
Hells Canyon Reservoir				
Snake River inflow rate	IPC measured Oxbow turbine flows hourly and measured Oxbow spill flow hourly (two separate inputs)	IPC measured Oxbow turbine flows hourly and measured Oxbow spill flow hourly (two separate inputs)	IPC measured Oxbow turbine flows hourly and measured Oxbow spill flow hourly (two separate inputs)	IPC measured Oxbow turbine flows hourly and measured Oxbow spill flow hourly (two separate inputs)
Snake River inflow temperature	Oxbow model output turbine outflow temperature and spill outflow temperature hourly (two separate inputs)	Oxbow model output turbine outflow temperature and spill outflow temperature hourly (two separate inputs)	Oxbow model output turbine outflow temperature and spill outflow temperature hourly (two separate inputs)	Oxbow model output turbine outflow temperature and spill outflow temperature hourly (two separate inputs)
Snake River inflow DO	Oxbow model output turbine outflow DO and spill outflow DO hourly (two separate inputs)	Oxbow model output turbine outflow DO and spill outflow DO hourly (two separate inputs)	Oxbow model output turbine outflow DO and spill outflow DO hourly (two separate inputs)	Oxbow model output turbine outflow DO and spill outflow DO hourly (two separate inputs)
Snake River inflow water quality	Oxbow model output turbine outflow DO and spill outflow DO hourly (two separate inputs)	Oxbow model output turbine outflow DO and spill outflow DO hourly (two separate inputs)	Oxbow model output turbine outflow DO and spill outflow DO hourly (two separate inputs)	Oxbow model output turbine outflow DO and spill outflow DO hourly (two separate inputs)

Boundary condition	Boundary Condition Description			
	1992	**1995**	**1999**	**2002**
Pine Creek inflow rate	Water balance generated through CHEOPS model	Water balance generated through CHEOPS model	Water balance generated through CHEOPS model	2002 measured Pine Creek near Oxbow hourly
Pine Creek inflow temperature	1999 measured near Pine Creek mouth hourly	1999 measured near Pine Creek mouth hourly	1999 measured near Pine Creek mouth hourly	1999 measured near Pine Creek mouth hourly
Pine Creek inflow DO	1999-2000 measured near Pine Creek mouth approximately monthly	1999-2000 measured near Pine Creek mouth approximately monthly	1999-2000 measured near Pine Creek mouth approximately monthly	1999-2000 measured near Pine Creek mouth approximately monthly
Pine Creek inflow Water Quality	1999-2000 measured near Pine Creek mouth approximately monthly	1999-2000 measured near Pine Creek mouth approximately monthly	1999-2000 measured near Pine Creek mouth approximately monthly	1999-2000 measured near Pine Creek mouth approximately monthly
Meterological conditions	Same as applied to Brownlee model waterbody 3 (closest to Dam)	Same as applied to Brownlee model waterbody 3 (closest to Dam)	Same as applied to Brownlee model waterbody 3 (closest to Dam)	Same as applied to Brownlee model waterbody 3 (closest to Dam)
Turbine outflow rate	IPC measured Hells Canyon turbine ouflow hourly	IPC measured Hells Canyon turbine ouflow hourly	IPC measured Hells Canyon turbine ouflow hourly	IPC measured Hells Canyon turbine ouflow hourly
Spill outflow rate	IPC measured Hells Canyon spill outflow rate	IPC measured Hells Canyon spill outflow rate	IPC measured Hells Canyon spill outflow rate	IPC measured Hells Canyon spill outflow rate

Notes: [1]Organic matter compartments were calculated differently for each year depending on available data.

Model Grid and HPS Configuration and Operation

Topographic data from IPC's geographical information system (GIS), along with detailed bathymetry surveys were used to generate the model grid for all three HCC reservoirs. Overall, the Brownlee Reservoir model grid includes the Snake River from the Brownlee Dam (RM 284.6) to the head of Brownlee Reservoir (RM 343), a separate grid for the Powder River arm (entering at RM 296) and a separate grid for the turbine intake channel (Table 2). The Brownlee Reservoir grid was divided into three waterbodies to allow for spatially variable meterological conditions and other kinetic coefficients to be applied to each waterbody. The Oxbow and Hells Canyon Reservoir model grids are relatively simple with variable segment lengths based on orientation, width and depth of the reservoirs (Table 2).

Table 2. Description of Hells Canyon Complex CE-QUAL-W2 model grid for the 1995, 1999 and 2002 models.

Reservoir	Waterbody	Branches within waterbody	Description	Model segments	Segment length/layer height
Brownlee	1	Branch 1	Brownlee Reservoir Main Branch,	2-41	1004.84 m long. 1.52 m high
Brownlee	2	Branch 2	Brownlee Reservoir Main Branch,	44-70	1004.84 m long. 1.52 m high
Brownlee	3	Branch 3	Brownlee Reservoir Main Branch,	73-93	1004.84 m long. 1.52 m high
Brownlee	3	Branch 4	Powder River Branch connects to Brownlee Reservoir at River Mile 296	96-109	1071.14 m long. 1.52 m high
Brownlee	3	Branch 5	Brownlee Turbine Intake Channel	112-116	43.57 m long. 1.52 m high
Oxbow	1	Branch 1	Oxbow Reservoir Main Branch	2-33	Variable from 222.77-1039.45 m long. 2.0 m high
Hells Canyon	1	Branch 1	Hells Canyon Reservoir Main Branch	2-59	Variable from 121.7-1294.1 m long. 2.0 m high

Note: The 1992 model grid is similar but begins at a location further downstream due to Brownlee Reservoir inflow boundary conditions being collected further downstream in 1992. This results in less segments overall for the 1992 model grid.

Using the customized pump coding, the HPS was simulated as a point withdrawal near the bottom of the most downstream segment in Brownlee Reservoir. The configuration is shown in Figure 1 and includes:

- One point withdrawal in the hypolimnion with centerline at 558.6 m elevation to simulate a 25 ft diameter intake pipe with bottom of pipe approximately 30 ft off the bottom. The withdrawal type was set to lateral with a withdrawal zone extending from the bottom to the top of the reservoir. Internal algorithms in CE-QUAL-W2 determine the water that is actually drawn from the reservoir based on flow rate and thermal structure (density).
- Withdrawn hypolimnetic water was placed in the intake channel segment just upstream of the last segment (Figure 1). The pipe discharge was set to be equally distributed between elevation 1936 ft (590.0 m) and 1961 (597.7 m) simulating 25 ft diameter pipe openings.

HPS operations were simulated to investigate the feasibility of meeting the salmonid spawning criterion below Hells Canyon Dam of a 7-day average maximum of 13.3 °C on October 29. The pumping was simulated as a variable flow rate, meaning the pump rate was calculated by the custom CE-QUAL-W2 coding based on a temperature target for the modeled Brownlee outflow and the turbine outflow rate. In addition, when turbine outflow was zero the pump rate was zero.

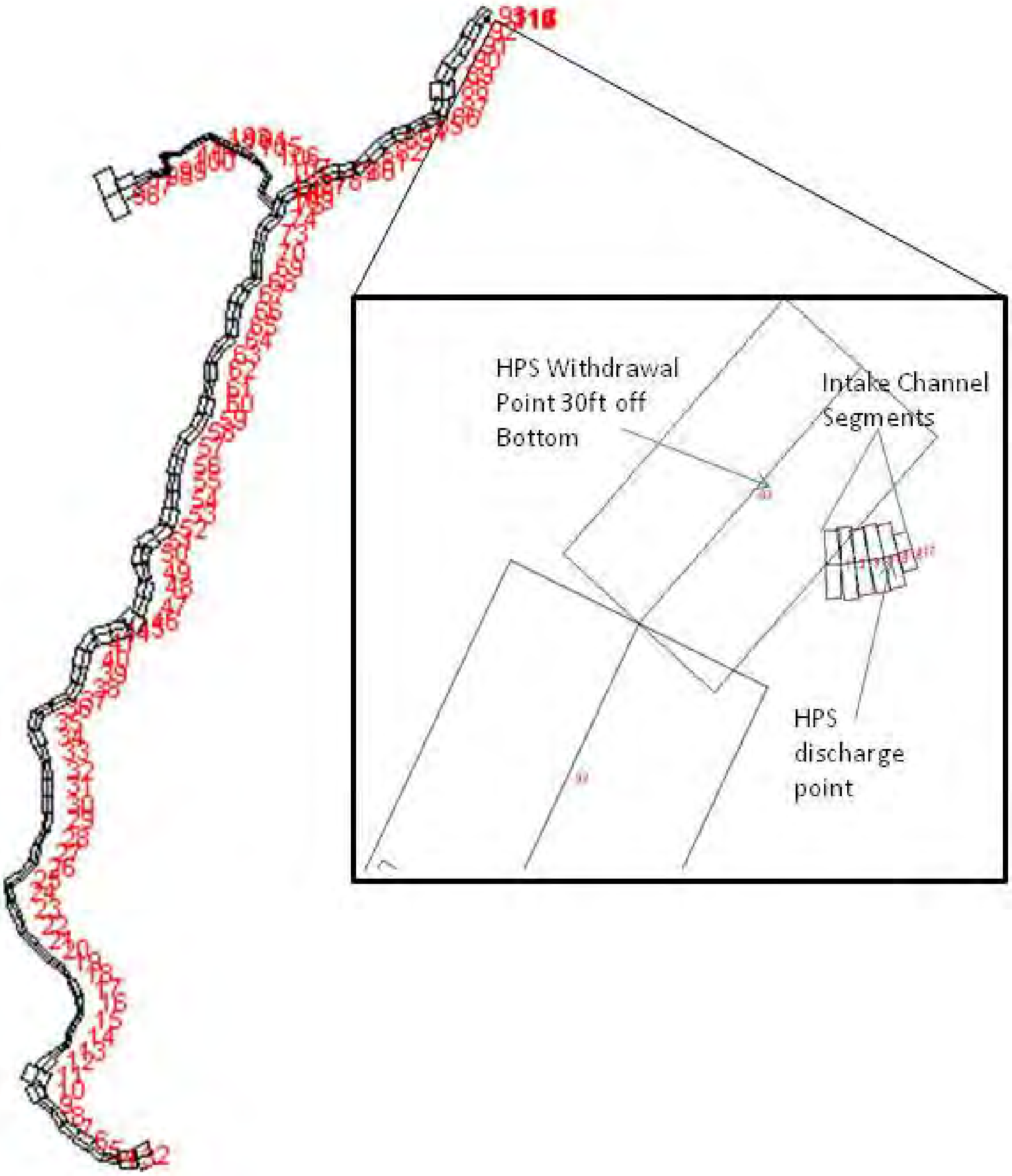

Figure 1. Brownlee Reservoir CE-QUAL-W2 model grid schematic showing configuration of the HPS. Red numbers correspond to the model segment numbers for the 1995, 2002, and 1999 models.

HPS CE-QUAL-W2 Modeling Results

Results of the HPS modeling indicate that the criterion can likely be achieved with the proposed HPS (Table 3 and Figures 1-5). Calculated 7-day average maximums on October 29 using hourly Hells Canyon modeled outflow temperature were at or below 13.3 °C for all years except 1999 which was at 13.6 °C (Table 3). Results for 1999 (and all years) should be evaluated in the context of model uncertainty and specific conditions (e.g. meteorological and hydrological) unique to that year. In both 2002 and 1995 a Brownlee outflow temperature target of 12.8 °C resulted in output that was cooler than the 13.3 °C criterion at Hells Canyon outflow. In 1992, the translation was not as direct and water did appear to warm and/or attenuate slightly as it moved through Oxbow and Hells Canyon Reservoirs. Overall, the modeling confirms the capacity of the proposed HPS in Brownlee Reservoir to achieve the necessary cooling to meet the criterion at Hells Canyon outflow in a broad range of water years (Figure 2, 3, 4 and 5). These results are similar to the results of mass balance analyses provided in Table7.1-2 of the 401 application.

Table 3. Modeled Hells Canyon outflow temperature results as 7-day average maximum on October 29 for the 4 model years.

Model Year	Baseline, no HPS (7-day average maximum °C)	HPS, variable flow (7-day average maximum °C)	Average pump flow rate for HPS variable (cfs)
1992	15.5	13.3	3395
1995	14.0	12.8	1865
1999	14.5	13.6	4292
2002	14.2	12.9	1476

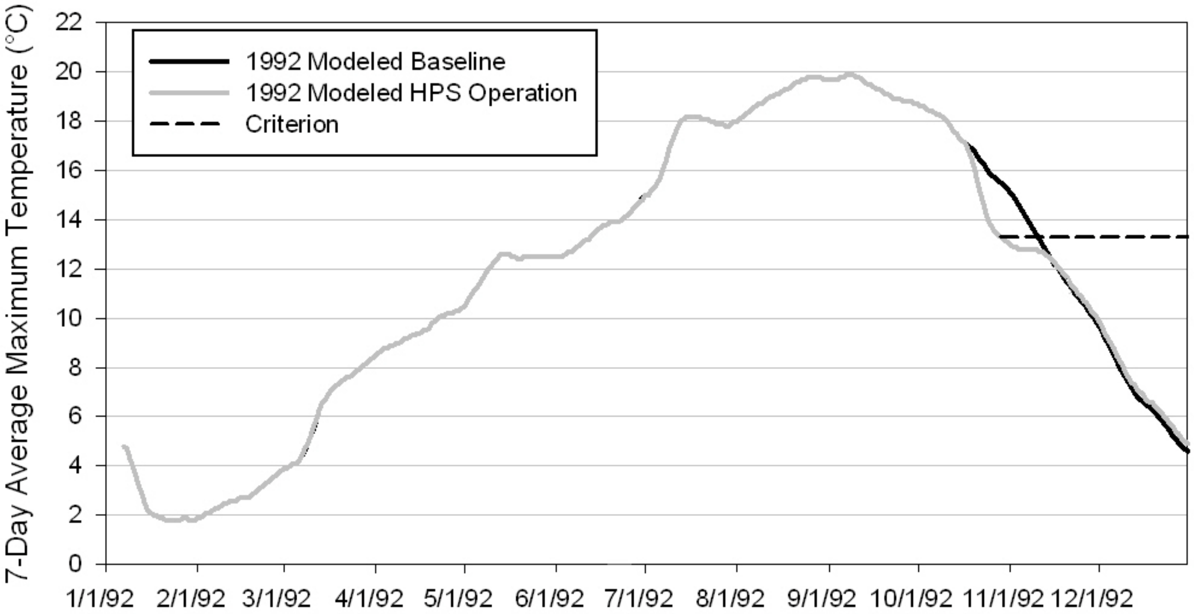

Figure 2. Modeled 1992 Hells Canyon outflow 7-day average maximum temperature for Baseline (no HPS) and HPS operation with CE-QUAL-W2 calculated pump flow rate.

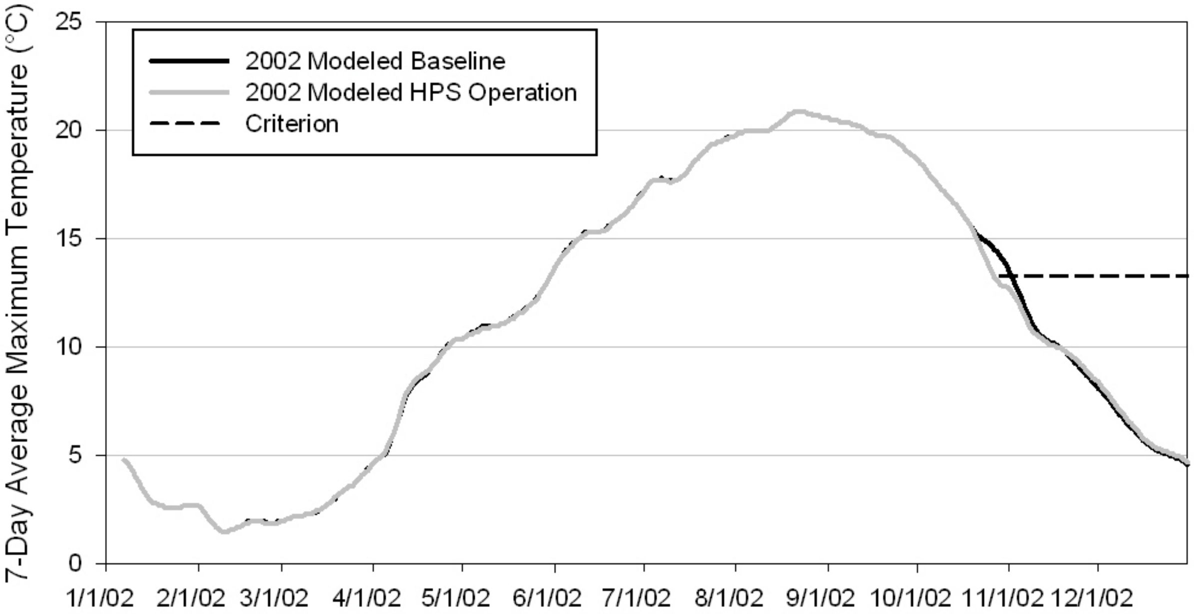

Figure 3. Modeled 2002 Hells Canyon outflow 7-day average maximum temperature for Baseline (no HPS) and HPS operation with CE-QUAL-W2 calculated pump flow rate.

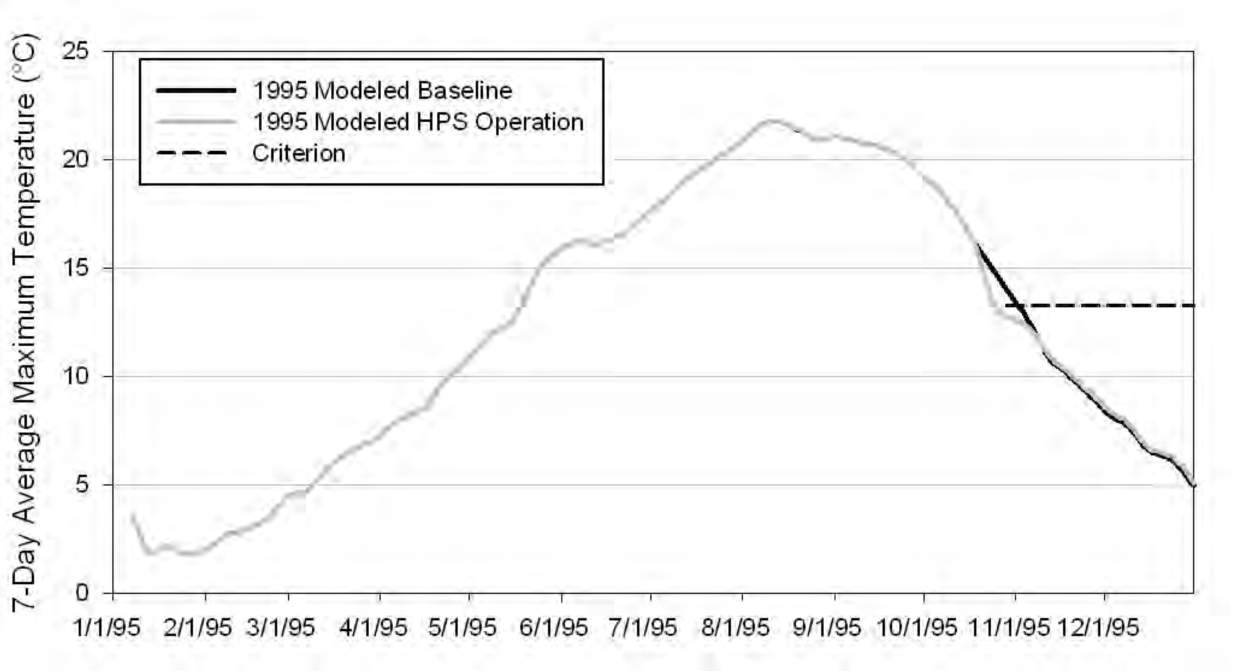

Figure 4. Modeled 1995 Hells Canyon outflow 7-day average maximum temperature for Baseline (no HPS) and HPS operation with CE-QUAL-W2 calculated pump flow rate.

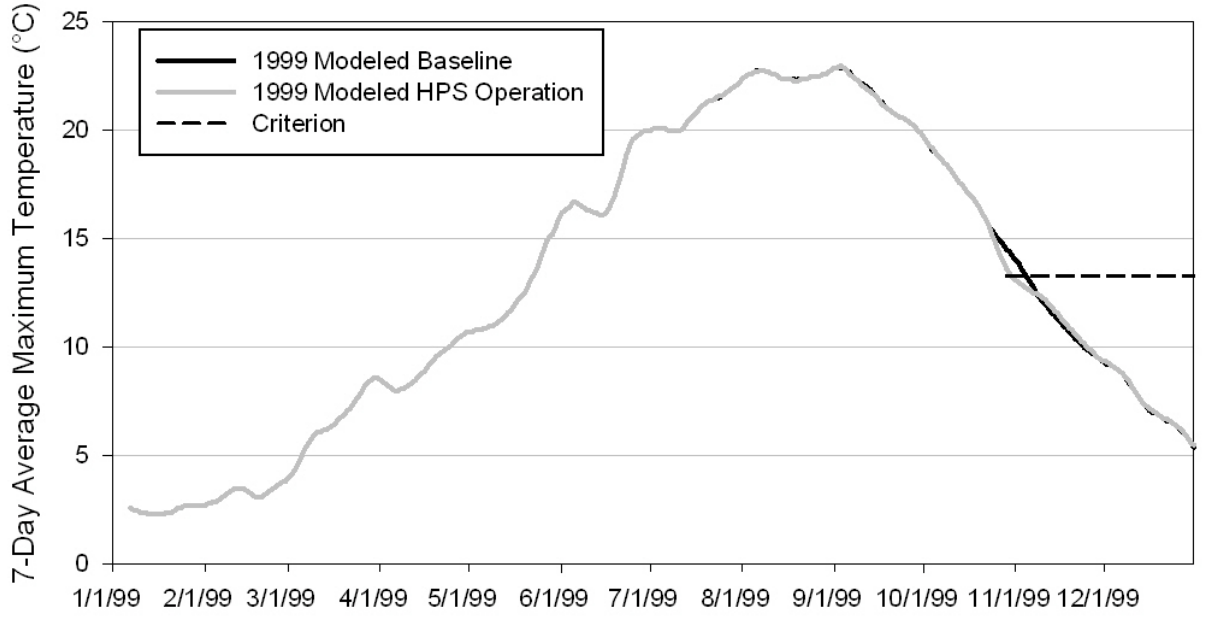

Figure 5. Modeled 1999 Hells Canyon outflow 7-day average maximum temperature for Baseline (no HPS) and HPS operation with CE-QUAL-W2 calculated pump flow rate.

ODEQ Request #2

1. *What is the point of maximum temperature impact of HCC? Show longitudinal plots of predicted change in temperature from 'current project operations' to 'without project.' In the longitudinal plots please include locations corresponding to the inflow and outflow of each reservoir, the location representative of 12 hours travel time downstream, and at the Oregon/Washington border. See Khangaonkar and Yang (Khangaonkar, T. and Yang, Z. 200S. Dynamic Response of Stream Temperatures to Boundary and Inflow Perturbation Due to Reservoir Operations. River Research and Applications. 24(4): 420 -433) and DEQ's Mainstem Willamette TMDL (http://www.deq.state.or.us/wq/tmdls/docs/willamettebasin/willamette/chpt4temp.pdf) for discussion. Please include discussion of whether the point of maximum impact is expected to change under different flow regimes or under different project operations.*

IPC RESPONSE

This request includes a modeling analysis comparing “current project operations” and “without project” scenarios at multiple points (Dam locations, 12 hour travel time below HC Dam, Oregon/Washington border) to determine where the largest temperature difference is seen. IPC has not developed a “without project” model similar to the CE_QUAL-W2 models it developed to represent existing and potential future conditions. Development of that capability is not practical within the required ODEQ timeframe for response to this AIR.

However, IPC conducted analyses on Snake River temperature data as guided by the references provided by ODEQ to address the point of maximum impact question. The basic issue with the point of maximum impact appears to be that temperature of outflowing water from large reservoirs lacks a natural daily cycle. This is true for the Hells Canyon Dam outflow. As water flows downstream from the dam the daily cycle returns, which can potentially create a daily maximum condition downstream that is warmer than the daily maximum condition measured at the dam (Figure 6). However, the daily minimums also become cooler. The development of this cycle occurs relatively quickly (within 17 miles downstream) meaning that fish are also exposed to cooler temperature, for a period every day, than that measured at Hells Canyon Dam. Overall warming or cooling can also occur as water moves downstream (Figure 6). Previous analyses of the temperature conditions downstream of Hells Canyon Dam have focused on the immediate outflow based on data that shows an overall cooling pattern in the fall (in most years) as water moves downstream (Attachment 2).

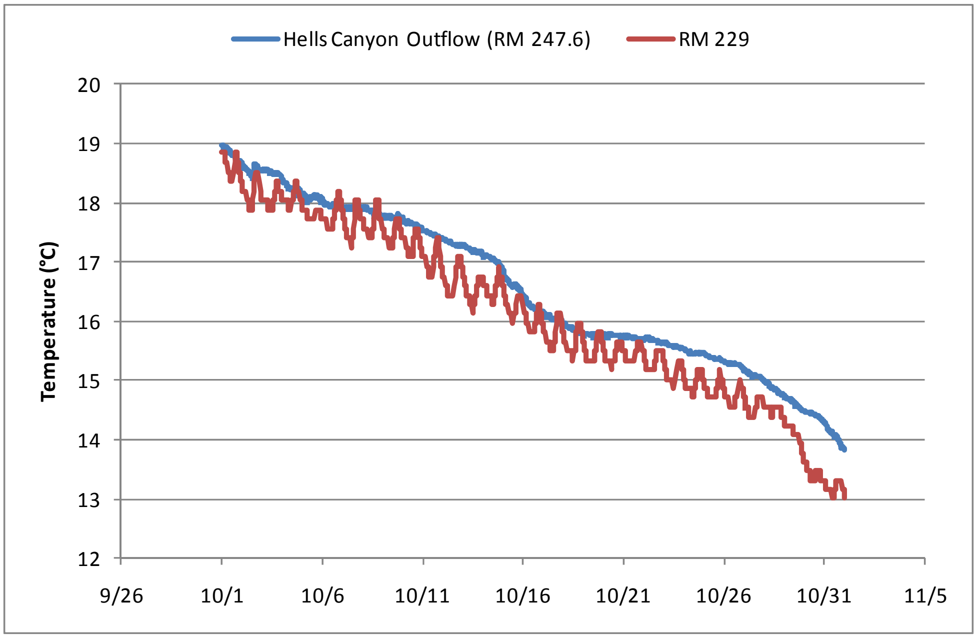

Figure 6. Snake River temperature during October 2002 compared between Hells Canyon Dam outflow and a point approximately 18 miles downstream of the dam.

ODEQ specifies in the AIR letter that the point of maximum impact evaluation should include comparison of temperature at Hells Canyon Dam outflow and a location representative of 12 hours travel time downstream and at the Oregon/Washington border. IPC's Mike 11 for the Snake River downstream of Hells Canyon Dam indicates a 12 hour travel time for releases from Hells Canyon Dam (RM 247) at outflows of 8,500 and 30,500 cfs corresponds to RM 225 and RM 201, respectively. IPC has monitored temperature at RM 229.8, which is nearby the location of a 12 hour travel time at 8,500 cfs(Figure 7).

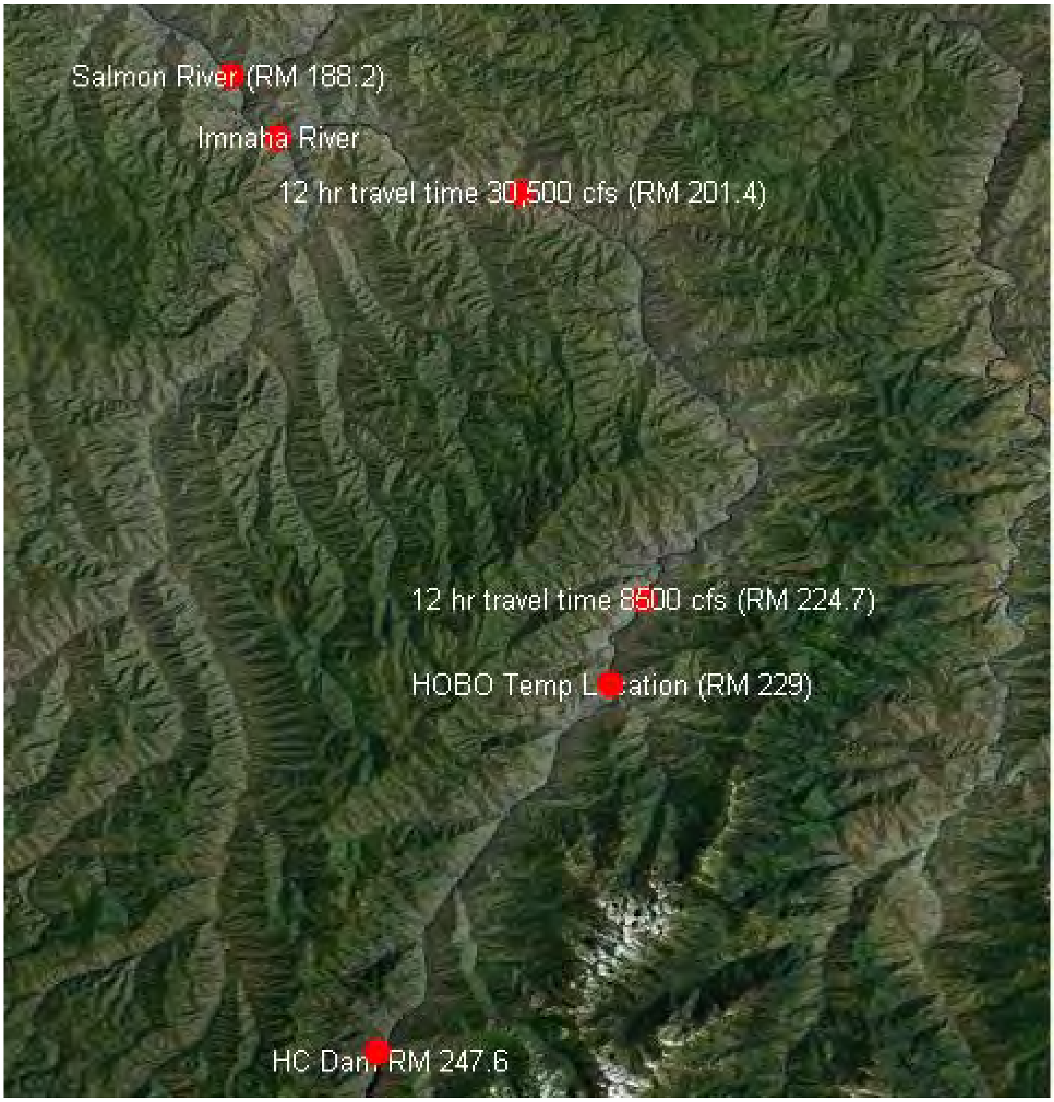

Figure 7. Map showing the Snake River from Hells Canyon Dam to the Salmon River confluence and locations corresponding to 12 hour travel time at 8,500 and 30,500 cfs. Also shown is a temperature monitoring location at RM 229.8.

Data collected at RM 229.8 were compared to Hells Canyon Dam data (Attachment 4) to investigate if daily maximum temperature conditions were different. Specifically, the difference was calculated between the 7-day average maximum temperature at the two points for days when there was seven previous days of data available for both locations. The comparison (Table 4) shows:

1. On October 29 warmer or cooler daily maximum conditions can occur 12 hours (approx.) downstream. When there were warmer maximums the difference was small (i.e. 0.2°C or less). This is equal to or less than the manufacturer's stated accuracy for the temperature sensor.
2. Warming or cooling was negligible (i.e. -0.04°C), on average for October 29. A paired t-test on the 7-day average maximums at Hells Canyon Dam and RM 229.8 data showed no significant differences (p=0.58).

Table 4. Differences between 7-day average maximum temperature (°C) at Hells Canyon Dam and RM 229.8, approximately 12 hour travel time downstream (at 8,500 cfs). Positive numbers indicate warmer conditions downstream and negative numbers cooler.

Year	October 29	Oct. Average	Nov. Average
1996	-0.1	-0.2	-0.1
1997	0.1	0.1	-0.1
1998	0.2	0.2	-0.5
1999	Na	Na	Na
2000	-0.2	-0.2	-0.4
2001	Na	Na	Na
2002	-0.4	-0.2	-0.3
2003	0.1	0	-0.2
2004	-0.2	0	-0.2
2005	0.1	0.2	0
2006	Na	0.2	0
2007	0.2	0.2	0
2008	0.1	-0.1	0.1
2009	-0.3	-0.2	-0.2
2010	Na	Na	Na
Average	-0.04	0	-0.16

Existing data suggest that a modeling effort to determine point of maximum impact may reveal negligible differences in 7-day average maximum temperature between the Hells Canyon Dam outflow and a location 12 hours downstream (i.e. 0.2°C or less). This appears true for the October time frame and specifically October 29 when salmonid spawning criteria begin. Other considerations include:

- Differences in October were clearly variable depending on year due to variable flow rates, meteorological conditions etc.
- Changing Hells Canyon Dam outflow rates can change 12 hour travel time location up to 23 miles at flows from 8,500 to 30,500 cfs.
- Differences consistently increased moving from October back to July. The largest average difference seen was during July in 2002 and 2003.
- During the majority of the year (except October/Nov fall Chinook flows), with daily load following, it will be difficult to pinpoint an appropriate location as a 12 hour travel time for the comparisons.

ODEQ Request #3

2. *What is the predicted temperature at the point of maximum impact for the entire year compared to 'current project operations' and 'no project'? Plot temperature of outflow from Hells Canyon reservoir. Plot simulated seven day moving average of the daily maximum temperature from Hells Canyon outflow. Model these temperatures over the representative flow years used in the FLA (1992, 1994, 1995, 1999 and 1997) (time series plots).*

IPC RESPONSE

Analysis conducted relative to the point of maximum impact, discussed above, indicates that additional modeling efforts to determine point of maximum impact would likely reveal negligible differences in 7-day average maximum temperature between the Hells Canyon Dam outflow and a location 12 hours downstream (i.e. 0.2°C or less). IPC respectfully suggests that this issue could be resolved through a technical meeting with ODEQ, IDEQ, and IPC staff to discuss the results of analyses conducted and presented as part of this AIR response.

ODEQ Request #4

3. *How is the 13.3 °C (as a 7-day average of the daily maximum) target derived? Please provide additional justification for the target. The SR-HC TMDL indicates a spawning target of 13.0 °C minus a 10% safety factor applied to the difference between the criteria and the upstream temperature.*

IPC RESPONSE

Derivation of the 13.3°C target is based on the ODEQ water quality standards, the SR-HC TMDL, and guidance and confirmation by IDEQ and ODEQ during informal consultation and technical meetings. It is simply the 13°C standard plus the 0.3°C human use allowance identified under the standard. This has been the target consistently identified and used throughout numerous analyses and discussion with ODEQ and IDEQ technical staff when comparing model output to the numeric salmonid spawning target. It is also consistent with the SR-HC TMDL.

The 10% safety factor was not among the compliance parameters previously discussed with ODEQ and IDEQ during development of 401 applications because it does not affect compliance with the numeric criteria. The 10% safety factor referenced in the SR-HC TMDL was part of a nominal calculation of excess thermal load during times when temperatures measured at RM 345 exceed the 13°C numeric standard, which rarely occurs. It was not applied to the numeric standard itself. The TMDL also provides:

"Specific compliance parameters for meeting this load allocation [to the HCC] will be defined as part of the 401 Certification process." (SR-HC TMDL at 469).

ODEQ Request #5

4. *What is the predictive uncertainty? Please discuss sources of uncertainty. See U.S EPA's 2009 Guidance on the Development, Evaluation, and Application of Regulatory Environmental Models for additional information.*

IPC RESPONSE

The referenced EPA guidance document (EPA/100k-09/003) describes predictive uncertainty as "How closely does the model approximate the real system of interest?" The guidance further states that "modelers and decision makers should consider what degree of uncertainty is acceptable within the context of a specific model application." EPA proposes three approaches to understand the uncertainties underlying a model.

1. Model corroboration (Section 4.2.3.2), which includes all quantitative and qualitative methods for evaluating the degree to which a model corresponds to reality.
2. Sensitivity analysis (Section 4.2.3.3), which involves studying how changes in a model's input values or assumptions affect its output or response.
3. Uncertainty analysis (Section 4.2.3.3), which investigates how a model might be affected by the lack of knowledge about a certain population or the real value of model parameters.

In past applications IPC has used CE-QUAL-W2 as a modeling tool. We typically used analyses relative to measured conditions as a means for indicating how closely the model corresponds to reality. Unfortunately, relative to evaluating a temperature control device that would operate in Brownlee Reservoir, there is no method to evaluate how well the model corresponds to reality because the modeled condition is proposed and will not be "testable" against reality until the device is installed and operational. However, IPC routinely conducts sensitivity analyses associated with model predictions.

Much of the value of uncertainty analysis relates to "transparency" of the model. The EPA guidance states it as:

> "Effective uncertainty communication requires a high level of interaction with the relevant decision makers to ensure that they have the necessary information about the nature and sources of uncertainty and their consequences. Thus, performing uncertainty analysis for environmental regulatory activities requires extensive discussion between analysts and decision makers."

IPC has consistently approached modeling with the view that discussion leading to consensus between analysts and decision makers is critical. The water quality modeling developed and conducted during preparation of the FERC license application was done within the framework of the Collaborative Team. This was a stakeholder group that was assembled and met regularly to discuss ongoing studies. Subsequent to that, IPC and the parties to the FERC proceeding convened a Settlement Work Group that functioned to review and discuss ongoing efforts to address outstanding issues relative to the licensing of the HCC. A substantial issue was water quality, specifically the need and value of temperature manipulation within the HCC.

In addition, because modeling was a key component of addressing issues in the 401 certification process, IPC has met regularly with ODEQ and IDEQ technical staff throughout development of several 401 applications since 2003. Because these were informal working meetings between IPC and the DEQs, formal notes and minutes were not maintained. We understand that ODEQ staff currently assigned to the HCC 401 certification was not present during most of these meetings and we would be pleased to provide a detailed briefing of areas of agreement with the DEQs. Since the same IDEQ staff member that attended the working meetings still is involved, we recommend that the briefing for ODEQ include IDEQ.

Specific examples include ODEQ's request for information to support the validity of 13.3°C as the appropriate target for evaluation of modeling results and the request for additional modeling to evaluate the potential for increased winter and spring warming to accelerate fall Chinook development and emergence. Both these items were the subject of technical discussions and based on those discussions have been used and presented in multiple previous 401 applications. Moreover, ODEQ's additional modeling request has already been done and evaluated by stakeholders, including ODEQ, in the FERC licensing process. Based on earlier modeling in which agencies including ODEQ were involved, NOAA concluded several years ago that there was no potential for significant winter and springtime warming relative to fall Chinook from manipulation of Brownlee Reservoir release temperatures.

ODEQ Request #6

1. *Model release of cold water to shift maximum temperature outflow from Hells Canyon dam. Plot annual thermal pattern with cold water releases to move summer peak closer to that represented by pre-dam data at river mile 273. Plot the seasonal thermal pattern below Hells Canyon dam and at the Oregon/Washington border.*

IPC RESPONSE

This request is similar to an AIR request issued by FERC as part of the licensing process, and responded to by IPC on February 3, 2005. The FERC AIR response (WQ-2(a)) contains model runs simulating various temperature control devices in Brownlee Reservoir. The temperature manipulation targets were developed in consultation with resource agencies and stakeholders in the HCC licensing process. Specific objectives for downstream temperature manipulation that IPC evaluated included springtime warming, summer/early fall cooling, and cooling to meet the numeric fall Chinook spawning standard. Summer cooling objectives that were evaluated relate directly to ODEQ's request for model runs that move the summer peak closer to pre-dam conditions. The summer peak would occur earlier in the summer with cool water supplementation because the current late summer peak would be lowered. IPC submits FERC AIR WQ-2(b) to address the ODEQ request (Attachment 5).

ODEQ Request #7

2. *Based on these modeling results, determine whether there is sufficient cold water in Brownlee to meet the spawning criterion and shift the thermal pattern as described in item #1.*

IPC RESPONSE

Similar to item #1, IPC submits FERC AIR response WQ-2(b) to address questions regarding the availability of cool water to shift the summer thermal pattern (Attachment 5).

ODEQ Request #8

3. *If there is insufficient cold water to increase fall cooling and attain the 13°C spawning criterion, please demonstrate what downstream cooling can be achieved with the HPS and available cold water from the hypolimnion in Brownlee Reservoir.*

IPC RESPONSE

Modeling of expected conditions with operation of the HPS indicates sufficient fall cooling could be attained to meet the 13.3°C spawning target (IPC response to ODEQ Request #1). In some years, cool water in addition to what the models indicate may be necessary for meeting the fall target will remain stored in Brownlee Reservoir. This additional cool water provides further reasonable assurance that the applicable target will be met. IPC is not proposing to move cold water from the hypolimnion in Brownlee Reservoir downstream for any purpose other than meeting the applicable fall target.

ODEQ Request #9

4. *Does Figure 6.1-11 assume that spawning occurs on the same date for each location? Provide data, model, assumptions and supporting information used to derive Figure 6.1-11 on page 53.*

IPC RESPONSE

This analysis of emergence timing at different locations in the Snake River does assume that the spawning distributions for the different historic spawning areas are the same as that observed today in the Snake River below Hells Canyon Dam. The rationale, supporting information and basis for this assumption is explained in the 2nd complete paragraph on page 52 of the application:

> "The spawning period for fall Chinook salmon observed present-day and when it was observed in reaches upstream of the HCC historically do not greatly differ. Surveys were not conducted at the level of detail as those in Hells Canyon over the last 20 years (weekly flights of the entire spawning area), so definitive historic start and end dates for comparison are difficult to determine. Today, some of the earliest spawning observed in the Snake River is during the second week of October. The peak spawning period (the median distribution of redd observations for the years 1993 through 2009) is November 4. The latest spawning observations are generally near the second week in December. Evermann (1896) reported the observations of ripe and spent fall Chinook salmon in a fishery at Millet Island in 1894. The fishery began on October 1 and extended through October 31. Their first observed spent female in the fishery was on October 10, which comports well with present day observations. Ripe fish were still being captured at the close of the fishery, suggesting that spawning at least continued past November 1. An observation reported by Evermann from an interview with a seine fisherman near Glenns Ferry (RM 539) reported observing carcasses through the first half of November. Similarly, below Swan Falls Dam, Zimmer (1950) reported 3 redds observed in the first week of October in 1947, with a peak number of redds counted on the November 6 flight and that spawning was generally completed by the end of the first week of December. These observations comport very well with what is observed today. With this information, for purposes of comparing emergence timing among historic and present-day reaches of river, application of the present-day spawning distribution to the various thermal regimes to estimate differences in emergence timing among those locations is reasonable.
>
> Emergence timing reflects the different thermal patterns of the Snake River and demonstrates a negative linear relationship with river mile (Figure 6.1-11)."

This analysis is based on the observed spawning distribution below Hells Canyon Dam. Figure 6.1-11 is estimating median emergence dates for the various historic reaches and the present day contemporary reach below Hells Canyon Dam using the median spawn date observed below Hells Canyon Dam. The median spawn date for the period of 1991 -2009 is November 4 (see Figure 1 below). The simplest way to calculate estimated emergence dates for the various historic and contemporary spawning reaches is to use the temperature data from each reach and accumulate thermal units beginning with November 4. As discussed in the application, on page 51, first complete paragraph, the accumulated thermal units (ATU's) to emergence for fall Chinook salmon used in the analysis is 944 ATU's based on the finding of Geist et al. (2006). Further discussion on the basis and rationale for this analysis can be found in Attachment 6.

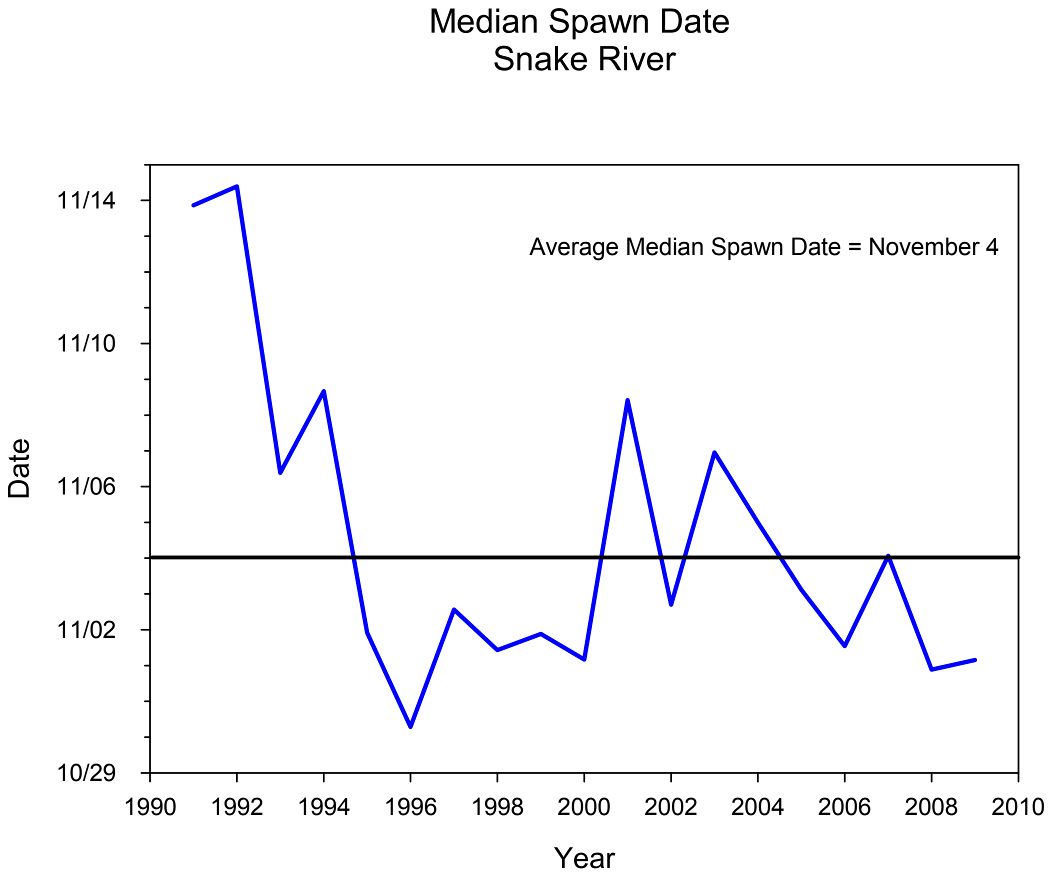

Figure – The average of the median spawn dates for the years 1991 through 2009.

ODEQ Request #10

5. *What are the accumulated thermal units and predicted accumulated thermal units for other possible thermal regimes? Please consider scenarios where IPC uses available water to provide warmer water earlier in the spring, warmer water throughout winter, and no warming or cooling relative to upstream temperature.*

IPC RESPONSE

The requested information is similar to requests made by FERC. IPC submits the FERC AIR WQ-2(c) response as Attachment 7. The conclusion of the modeling was that manipulative warming of winter and spring release flows did not have potential for meaningfully benefiting fall Chinook recruitment success. NOAA supported this conclusion in its 11/03/06 comments to the DEIS. Specifically, NOAA stated it had worked extensively with IPC to investigate several temperature control structures and related strategies, and concluded a temperature control structure would not provide the benefits NOAA had envisioned to incubating, rearing, migrating or spawning fall Chinook.

ODEQ Request #11

What is the impact of proposed changes related to the migration criteria? Although the Hells Canyon complex has not been determined to be a source of impairment impacting the migration use, please provide documentation and graphs showing that proposed changes will not adversely cause or contribute to an exceedence of the migration criteria. Please use the questions related to spawning use to direct your response.

IPC RESPONSE

The HPS is being proposed for limited use during the specific time period necessary to achieve the salmonid spawning standard. During this time, releases from Hells Canyon Dam are below 20°C, and operation of the HPS would not contribute any warming to the releases. Similarly, because the HPS is only proposed to operation for short periods during naturally cooling fall conditions, depletion of the cool hypolimnetic water in Brownlee Reservoir will have no potential for resulting in a warmer system later in the year, as could be the situation if the HPS was being proposed for summer-time operation.

ODEQ Request #12

The § 401 application does not contain a section on reasonable assurance to meet the temperature load allocation or a temperature monitoring plan. Please provide these sections. Please propose a compliance point or points that will allow for data collection through the Hells Canyon reach to determine attainment of the temperature load allocation, and NSTP during the applicable seasons.

IPC RESPONSE

IPC is submitting modeling details relative to potential operation of an HPS that provides technical support for reasonable assurance that the temperature load allocation will be met. In addition, IPC submits a temperature compliance monitoring plan (Attachment 8), that when implemented, will document compliance of the releases from Hells Canyon Dam with the SR-HC TMDL temperature load allocation assigned to the HCC. The location of the proposed temperature monitoring site was selected in consideration of FERC FEIS recommended guidelines for an operational compliance monitoring site, point of maximum impact analysis provided in this AIR response, and logistics.

ODEQ Request #13

Conceptual project risk assessment
IPC describes the potential risks of operating the HPS as primarily related to discharge of low dissolved oxygen water with elevated levels of toxics. IPC must describe what water quality conditions, throughout the project, could be exacerbated by the discharge of water from Brownlee Reservoir's hypolimnion. IPC must discuss all available data indicating these risks and define data gaps. IPC must also propose mitigation measures for these possible impacts. Issues of concern include the possible effects of ammonia toxicity downstream of the complex, biochemical oxygen demand increase, release of pesticides from sediment and the methylation of mercury.

IPC RESPONSE

IPC is submitting a technical report containing information regarding toxics levels in the hypolimnetic water of Brownlee Reservoir (Attachment 9). In addition, Attachment 10 contains information on pollutant transport and processing (including ammonia, metals, and pesticides).

The strong stratification that develops in Brownlee Reservoir during the summer is an important process relative to toxics in the HCC. Toxics occur in Brownlee Reservoir due to Snake River and tributary inflows and in-reservoir conversion of materials into more toxic forms as decomposition of dead algae, organic sediments, and other organic matter depletes oxygen. This results in production of anaerobic by-products including methane, sulfides, dissolved nutrients, methylmercury and dissolved inorganics. Under current operations, the toxics and anaerobic by-products in the hypolimnion during the summer stratification are transported within or downstream of the HCC, especially during the fall, when breakdown of the thermal stratification in Brownlee Reservoir mobilizes toxics that are isolated to the hypolimnion during the summer stratification.

Operation of the proposed HPS would likely modify the timing of transport of toxics that are temporarily isolated in the hypolimnion during summer stratification. Cool water being pumped from the hypolimnion would be moved downstream earlier and potentially in greater volumes than under current operations. In October, the cold water in the hypolimnion of Brownlee Reservoir is anoxic and pumping this water to the intake channel to be drawn through the turbines will correspondingly result in reduced DO immediately downstream of Brownlee Reservoir and at the HCC outflow. Increased levels of methane, sulfides, dissolved nutrients, methylmercury and other dissolved inorganics associated with the anoxic conditions in the hypolimnion of Brownlee Reservoir may also be released downstream. Some of these products (e.g., methane, sulfides) are oxidized when oxygen is added to the water and can create additional oxygen demand. Others, such as methylmercury, are a concern due to aquatic toxicity.

Aeration actions proposed to be implemented as mitigation for the lower dissolved oxygen levels in Brownlee Reservoir releases will limit additional transport with HPS operation. Similarly, the operation of the proposed HPS would be restricted to the minimum amount of time and flow volumes necessary to meet the downstream criteria. This action is important to minimize the potential, and actual, downstream transport of toxics.

The presence of toxic materials in hypolimnetic waters of Brownlee Reservoir has received limited study focus throughout the HCC licensing process. Proposal of the HPS has resulted in increased concerns and need for information. Toxic materials can include both inorganic (e.g., trace metals) and organic (e.g., pesticides) substances.

IPC retained HyQual, P.A. (HyQual) and Landau Associates to assist with screening-level water quality sampling within Brownlee Reservoir in an effort to understand the potential for increased levels of toxic inorganics in the discharge from the HCC during operation of the HPS.

The toxics assessment sampling was directed at the potential presence of inorganic toxics as identified in Idaho's and Oregon's water quality standards (IDAPA and OAR, respectively). The specific objectives were to 1) identify what, if any, inorganic toxic constituents are detectable in the water column, 2) compare concentrations of any detected toxics to Oregon and Idaho state water quality criteria, and 3) use data and procedures to guide design of a more detailed future sampling plan, if needed.

Detailed methods and results are presented in Attachment 8. Of the parameters analyzed, only the cyanide concentration exceeded a state water quality criterion. This exceedance occurred in only one of the epilimnion samples (RM286EPI1) at the location near the dam. Levels of cadmium, silver, zinc, arsenic, chromium, and nickel were below criteria at all locations.

In general, results of water samples collected from the hypolimnion appear to be similar to results from the other locations (e.g., epilimnion, riverine, and discharge). Based on the preliminary results, it appears that levels of chromium and nickel could increase slightly during operation of an HSP. However, levels would still be well below criteria.

Mercury has been a consistent concern throughout the HCC. The SR HC TMDL identified the primary sources of mercury as legacy mining and natural loading; both are associated with geological deposits within the Owyhee and Weiser river watersheds. Based on mercury levels in fillets of fish from Brownlee Reservoir, both Oregon and Idaho have issued fish consumption advisoriesA primary concern is the methylation of mercury (IDEQ and ODEQ 2004). Low DO and the presence of substantial amounts of organic matter near the sediment and water interface can result in higher levels of methylmercury. . Based on these and other information, a mercury TMDL is planned, but the effort has not been formally initiated.

Mercury was not analyzed as part of the study reported in Attachment 8 due to the need for an increased level of quality assurance/quality control (QA/QC) for this parameter. However, in 2007 IDEQ sampled Brownlee Reservoir on a monthly basis from May through November (Attachment 11). The samples were collected in multiple locations and composited for sample analyses, and thus results provide an average for the reservoir. Mercury levels in the water of Brownlee Reservoir average 4.8 ng/L , with highest levels in September and lowest levels in June (i.e., 8.0 and 2.7 ng/L, respectively). All results were below Oregon's chronic aquatic life water column total mercury criterion of 12 ng/L.

Oxygen demand from reduced substances such as labile organic matter, ammonia, methane and sulfides can also occur in the hypolimnion of Brownlee Reservoir. Oxidation of these materials can consume oxygen over various periods and some require weeks for complete oxidation. These materials are present in Brownlee Reservoir hypolimnion in October (Attachment 9). The laboratory testing for biochemical oxygen demand (BOD) in the hypolimnion water indicates that 1 to 2.5 mg/L of oxygen was consumed in the first 3 days following addition of oxygen. After 30 days 3.3 to 9.8 mg/L of oxygen was consumed.

ODEQ Request #14

Antidegradation

IPC notes that blending of cooler water from Brownlee Reservoir may further degrade downstream conditions and have an effect on beneficial uses downstream (pg. 146). In order to complete its review of the § 401 application, ODEQ will need to complete an antidegradation review. Please describe specifically how water quality within Brownlee Reservoir and downstream water quality and beneficial uses will be affected by the blending of cooler water from Brownlee Reservoir.

IPC RESPONSE

Available data and analyses have shown pumping of cool water from the hypolimnion of Brownlee Reservoir to address the TMDL temperature allocation will change the timing and level of the downstream transport of lower DO waters with associated anaerobic byproducts. This change in water quality (e.g., a decrease in DO, and a slight, but potentially measureable increase in biological oxygen demand, ammonia, nickel or chromium) could occur during the relatively short period of HPS operation (i.e. , generally less than 2 weeks). IPC's HPS proposal also includes turbine aeration of the Brownlee releases, which is intended to address these water quality concerns and should be factored into any assessment of potential degradation. With the capacity for operation of aeration equipment in the summer and well into the fall, the potential for improved of water quality over an extended period of time should be considered in any process that compares economic and social benefits with environmental costs.

It is our understanding that initial stages of antidegradation review, as presented in the Oregon's Antidegradation Policy Internal Management Directive (ODEQ 2001), include:

1. The permit writer determines if the proposed activity requires an Antidegradation Review.
2. If an Antidegradation Review is required, the permit writer determines if a significant lowering of water quality is likely to occur.
3. If a lowering of water quality is likely to occur, then the permit writer determines how the classification of the waterbody receiving the discharge will further affect the review process.

The policy also indicates that the process for assessing activities should include consideration of existing TMDLs, non-point source load and point source wasteload allocations, and associated implementation plans. However, based on previous discussions with ODEQ, IPC is uncertain how existing TMDLs and water quality improvement efforts are considered.

With the previous applications, extensive discussions and meetings with the DEQs, and this AIR response, IPC has provided considerable data, analyses and supporting information that should allow

ODEQ the ability to initiate the antidegradation decision-making process. As the ODEQ proceeds with its review and provides clarification on initial steps, IPC can then respond to information requested.

ODEQ Request #15

Biocriteria

Under water quality criteria designed to protect biological integrity (biocriteria -OAR 340-041-0011) waters must be of "sufficient quality to support aquatic species without detrimental changes in the resident biological communities." Please describe how the HPS may affect the resident biological communities within and downstream of Brownlee Reservoir, including the lower reservoirs and Snake River downstream of the complex.

IPC RESPONSE

Attachments 12 and 13 are additional information related to the potential effects of the HPS on downstream biological communities that has become available since IPC submitted its 401 application. IPC continues to assess and develop information relative to the potential effects of the HPS on downstream biological communities.

ODEQ Request #16

The proposed HPS will alter the hydrodynamics of Brownlee Reservoir and impact the dissolved oxygen concentration and algae population. Under the proposed HPS and aeration scenario, please predict the dissolved oxygen concentration in the metalimnion and transition zone in Brownlee Reservoir and the chlorophyll a concentration in the epilimnion. Please provide the same predictions under the HPS and phosphorus trading scenario.

IPC RESPONSE

Information provided by IPC earlier in this AIR response contains all temperature and dissolved oxygen information available at this time relative to the modeling of water quality conditions in Brownlee Reservoir under operation of the proposed HPS. Model results specific to the reservoir could not be completed within the time frame of this AIR. IPC's current Version 3.7 CE-QUAL-W2 models have not been reviewed relative to the ability to reliably predict algae levels. In addition, modeling changes in algal population types is not a capability of IPC's CE-QUAL-W2 models at this time.

ODEQ Request #17

IPC notes that installation and operation of the HPS at Brownlee will affect outflow dissolved oxygen. The application states that aerating runners designed for Brownlee turbines may be capable of increasing dissolved oxygen concentrations by 2.5 mg/L for 5,000 cfs flows. The modeling was conducted based on an incoming dissolved oxygen concentration of 2.0 mg/L and water temperatures of 23 0 C. However, the data provided with the application show that incoming dissolved oxygen concentrations at the time of HPS operation are likely to be below 1.0 mg/L. The application also acknowledges the likely presence of anoxic products in the pumped water, but the oxygen demand of these products was not accounted for. Please model the affect of the aeration runners using boundary conditions based on data collected in the reservoir. Also, please provide an estimate of the affect of the aeration runners on the TDG levels below Brownlee Reservoir.

IPC RESPONSE

IPC is submitting a report developed by Voith, the company that developed and manufactures aerating turbines (Attachment 14) which provides aeration information developed to date relative to the function of aerating runners. The report addresses both dissolved oxygen and TDG.

ODEQ Request #18

1. *How was a SOD level of 0.1 g 02/m2/day chosen? Please provide a justification for this value, or provide a sensitivity analysis for the SOD parameter.*

IPC RESPONSE

This value was the result of consensus reached between IPC, ODEQ, and IDEQ technical staff over several years of discussion. Because these were informal working meetings between IPC and the DEQs, formal notes and minutes were not maintained. We understand that ODEQ staff currently assigned to the HCC 401 Certification was not present during these meetings and we would be pleased to provide a detailed briefing of areas of agreement with the DEQs. Since the same IDEQ staff member that attended the working meetings still is involved, we recommend that the briefing for ODEQ include IDEQ.

ODEQ Request #19

2. *Why were only the first five dates of IGDO data used to develop the water column*

dissolved oxygen target?

IPC RESPONSE

This value was the topic of technical discussions with ODEQ and IDEQ staff during development of previous 401 applications. It is IPC's understanding that this value was the result of consensus reached between IPC, ODEQ, and IDEQ technical staff over several years of discussion. Because these were informal working meetings between IPC and the DEQs, formal notes and minutes were not maintained. We understand that ODEQ staff currently assigned to the HCC 401 Certification was not present during these meetings and we would be pleased to provide a detailed briefing of areas of agreement with the DEQs. Since the same IDEQ staff member that attended the working meetings still is involved, we recommend that the briefing for ODEQ include IDEQ.

ODEQ Request #20

3. *What is the impact of assumed boundary conditions (i.e. SOD and algae concentrations) on the calculated load?*

IPC RESPONSE

IPC is providing the response to FERC AIR WQ-1 in response to this information request (Attachment 15). In that AIR, modeling was conducted that evaluates the effects of altered boundary conditions expected under implementation of the SR-HC TMDL, as well as the effects of transition zone aeration, turbine venting, and a turbine oxygen injection system.

ODEQ Request #21

IPC notes that the Brownlee Reservoir aeration system will increase DO levels in the vicinity of the diffuser. In low water years, however, modeling indicates that some anoxia can occur upstream of the diffusers. IPC notes that in extreme cases these conditions could extend to the surface (pg. 168). In the dissolved oxygen monitoring plan section, IPC proposes to document the injection of 1,125 tons per year of dissolved oxygen to Brownlee Reservoir. Please propose a compliance point or points which will allow for data collection to determine attainment of the applicable dissolved oxygen criterion within the metalimnion of Brownlee Reservoir.

IPC RESPONSE

In this AIR response, IPC is withdrawing the alternative of installing an oxygen injection system in the transition zone of Brownlee Reservoir to comply with the dissolved oxygen load allocation assigned to Brownlee Reservoir in the SR-HC TMDL. In the application, IPC proposed that if a willing upstream participant could not be identified within one year of issuance of the 401 certification, IPC would implement in-reservoir aeration. In February, IPC executed a contractual agreement with Riverside Irrigation District relative to nutrient reduction activities to be implemented within the next 2 years. Based on this agreement, IPC has concluded that the in-reservoir aeration option is no longer necessary for 401 certification. IPC is developing a more complete explanation and analysis for review by the Oregon and Idaho DEQs.

ODEQ Request #22

IPC has at its disposal a calibrated water quality model (CE-QUAL-W2) that can be used to evaluate the impact of proposed HPS on temperature, dissolved oxygen and other parameters of concern.

ODEQ would like to evaluate the model runs, including model input and model design. ODEQ requests IPC provide documentation of the model calibration and scenarios used to evaluate the proposed mitigation measures.

IPC RESPONSE

Attachment 3 contains model documentation and peer review information for the initial CE-QUAL-W2 models developed for the HCC. Subsequent to that review, IPC has continued to develop the models to accommodate new scenarios, proposals, and version. IPC is submitting available documentation specific to model runs related to proposed HPS operations conducted in response to this AIR (see IPC response to ODEQ request #1).

Exhibit 7.1-11

July 2011 3D modeling of a hypolimnetic pump system in Brownlee Reservoir

3D MODELING OF A HYPOLIMNETIC PUMP SYSTEM IN BROWNLEE RESERVOIR

by

Marcela Politano, Antonio Arenas Amado, and Larry J. Weber

Submitted to
Idaho Power Company

Limited Distribution Report No. 372

IIHR – Hydroscience & Engineering
College of Engineering
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July 2011

Executive Summary

The goal of this study was to develop a 3-dimensional Computational Fluid Dynamics (CFD) numerical model capable of simulating the hydrodynamics and temperature dynamics in Brownlee Reservoir. The specific objective was to evaluate the stability of the thermocline during operation of a hypolimnetic pump system (HPS) and the ability of the HPS to draw cold hypolimnetic water without disturbing the thermocline and accessing warmer layers of the reservoir. Two different stratification conditions (i.e. strong and relatively weaker) were simulated to bracket the range of historical conditions seen in Brownlee Reservoir.

Two conditions observed in 1999 and 2002, were simulated. In 2002, low spring runoff and a shallow drawdown of Brownlee Reservoir for flood control resulted in strong stratification and cold hypolimnion temperatures. River inflows also remained low in the fall in 2002. In contrast, 1999 had high spring runoff and a deep drawdown of Brownlee Reservoir for flood control which resulted in relatively weak stratification and relatively warm hypolimnion temperatures. Also, river flow rates remained high in the fall in 1999. Temperature profiles at the upstream end of the model were provided by Idaho Power Company. The model was used to run fourteen days at the end of October, with and without the HPS. Predicted temperatures at turbine #5 were compared against measured data collected in the right channel downstream of the bridge. Good agreement was found between predicted and measured temperature during the simulated period.

The model was used to evaluate the reservoir hydrodynamics and temperature dynamics to assess the effects of the HPS operation on the thermocline. Also, intake channel hydrodynamics and outflow temperature reductions are presented. As the HPS is operating the amount of available cold water decreases with time. In 2002, the thermocline remained stable throughout the HPS operation. However, as the thermocline was lowered closer to the HPS intakes the temperature of the pumped water did increase from 5.0 to 9.0 ^{o}C. In 1999, weaker stratification conditions combined with the elevation of the HPS intakes resulted in water being drawn from the hypolimnion and warmer layers of the metalimnion. However, the pumped water was cooler than baseline (i.e., no HPS) outflow for the majority of the time period.

Acknowledgements

This numerical model study was conducted for, and sponsored by, Idaho Power, Company. The authors are grateful to Mr. Kelvin Anderson, Mr. Jesse Naymik, and Mr. Ralph Myers of Idaho Power Company for their support and cooperation.

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1. INTRODUCTION AND BACKGROUND

Brownlee Reservoir is a narrow and deep pool on the Snake River upstream of Brownlee Dam at RM 285. Figure 1-1 shows approximately 1.4 miles of the reservoir with bathymetric information in the NGVD29 coordinate system. Full pool water depth varies between approximately 300 ft at the deepest region to about 120 ft at the intake channel.

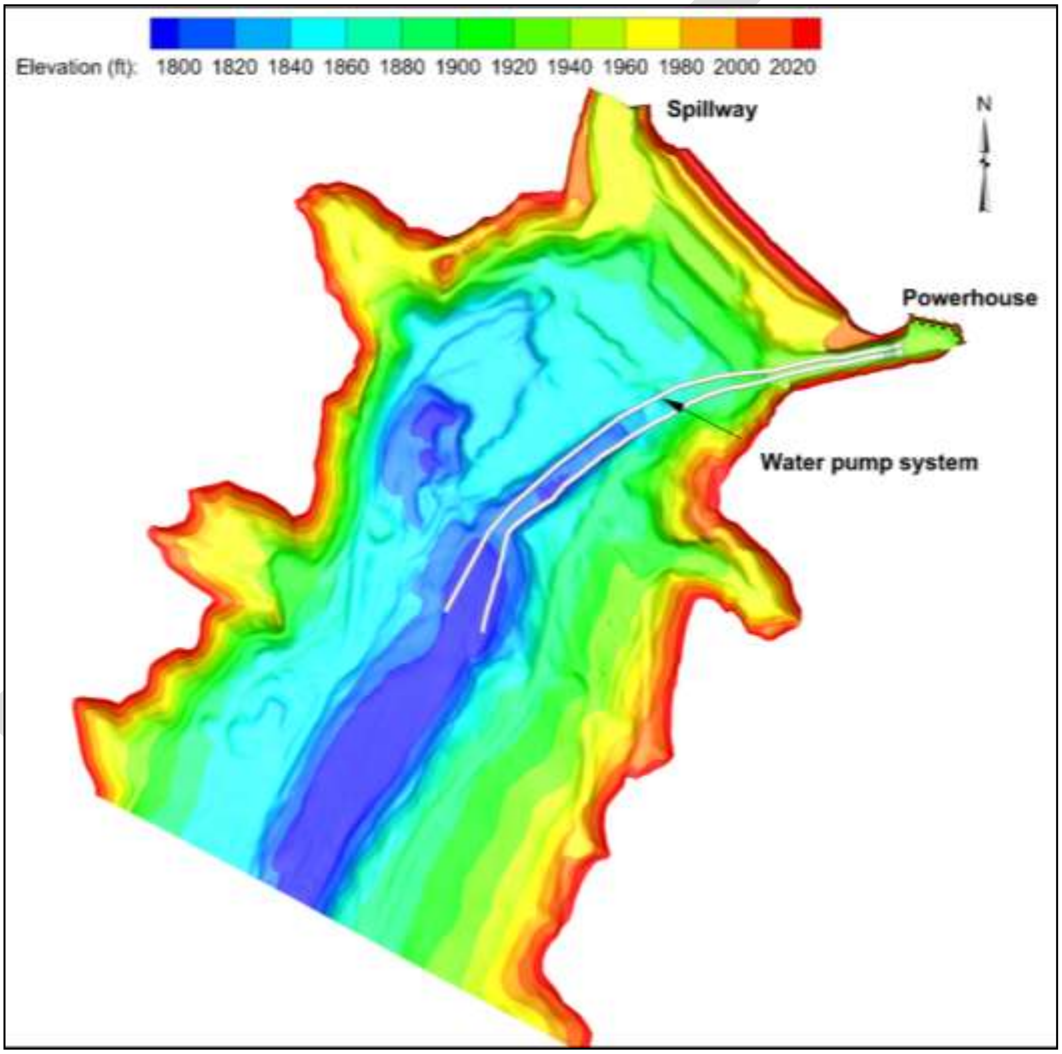

Figure 1-1. Bathymetry of Brownlee Reservoir.

During late spring to late fall, thermal stratification occurs in Brownlee Reservoir. The level of stratification in the reservoir depends on meteorological conditions and river flows especially spring runoff flows and the level of mandated spring drawdown of Brownlee for flood control. Low flow conditions increase the stratification as a result of longer residence time and more exposure to solar radiation. In addition, turbulence is less at low velocities, decreasing thermal mixing and thermal exchange across the metalimnion.

Figure 1-2 shows a typical temperature profile (thermocline) observed during a low flow condition in Brownlee Reservoir. The epilimnion is the layer closer to the free surface with the highest temperature and least density as a result of heat exchanges with the atmosphere. This zone has more turbulent mixing as a result of the wind action. The epilimnion is characterized by higher dissolved oxygen and greater biological activity. The hypolimnion is the denser and colder layer found near the bottom of the reservoir. These deep waters are isolated from energy and shear stresses imparted at the free surface. The boundary between these two layers is the metalimnion that is characterized by a rapid change in temperature with depth. Exchange of dissolved substances between the epilimnion and hypolimnion is limited due to the low level of mixing in the metalimnion.

DRAFT

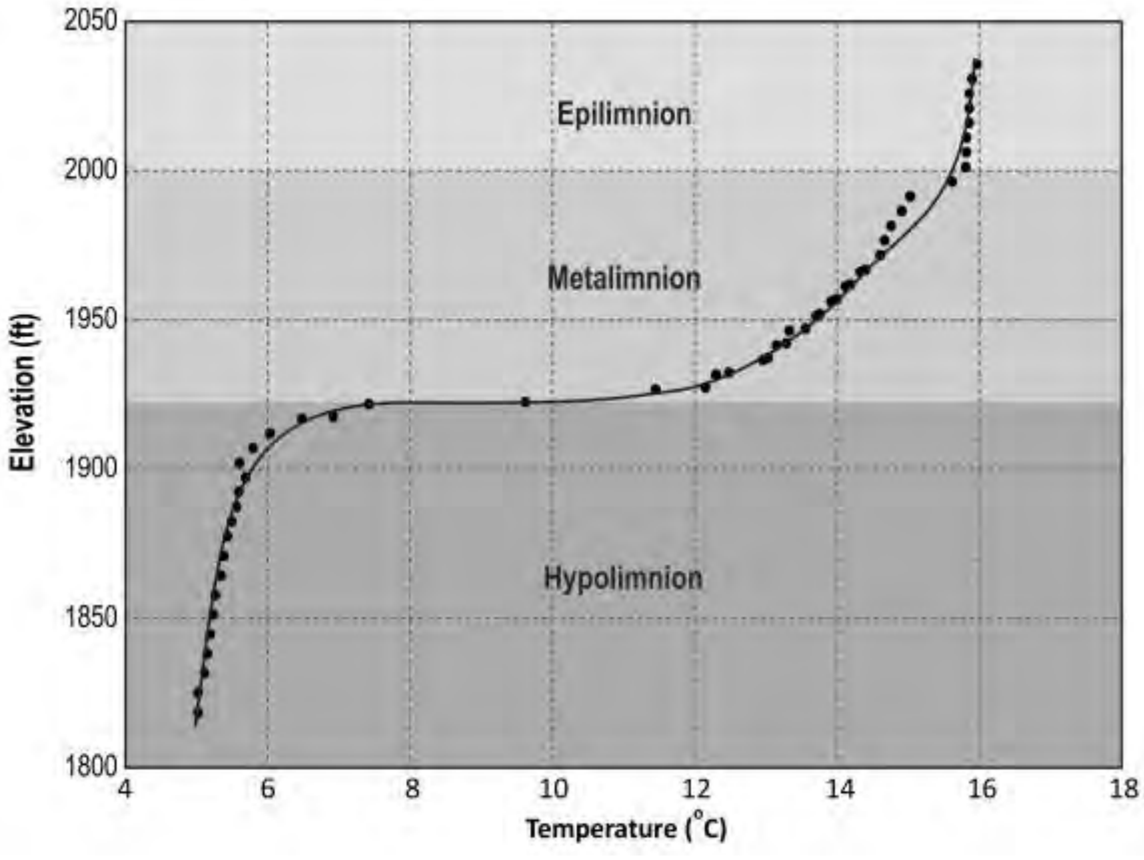

Figure 1-2. Thermocline in Brownlee Reservoir for a low river flow condition.

The stratification in Brownlee Reservoir can be strong in late fall. The temperature difference between the epilimnion and hypolimnion layers can be on the order of 10-20 °C. The intake channel is located in a relatively shallow region and therefore receives water from the epilimnion and metalimnion. In the fall, this water is usually warmer than downstream Oregon and Idaho numeric criteria. As a result, the outflow of Brownlee Reservoir (and the Hells Canyon Complex) has potential to exceed these criteria for temperature during the salmonid spawning period stated by the Snake River Total Maximum Daily Load (TMDL).

Idaho Power is developing a plan to comply with water quality standards including the numeric criteria for temperature. The project proposed by Idaho Power to reduce temperatures downstream of Brownlee Reservoir consists of a Hypolimnetic Pump System (HPS) that would draw and transport cold water from the hypolimnion to the intake channel. The system, as modeled in this study, comprises two 25 ft diameter pipes, approximately 2,200 ft long each with the capacity to draw 2,500 cfs (Figure 1-1). Figure 1-3 shows details of the HPS. The entrance of the pipes is located in the deepest region of the reservoir. The pipes, as modeled in this effort, are separated by approximately 180 ft in order to minimize possibility of thermocline disruption. The inlet end of the pipes are 30 ft from the bottom. The outlet end of the pipes is at the bottom of the powerhouse intake channel. Upstream of the intake channel, the pipes have a constant slope. This is a conceptual configuration of the system based on engineering design work completed at this time and is only applicable to this modeling effort. In this study the pipes were operated at 2,500 cfs each for a total pumped flow of 5,000 cfs. This flow rate was not based on a rate needed to cool outflows a specific amount. Rather, the maximum flow was modeled to observe the maximum potential changes to Brownlee Reservoir hydrodynamics, temperature dynamics and thermocline stability.

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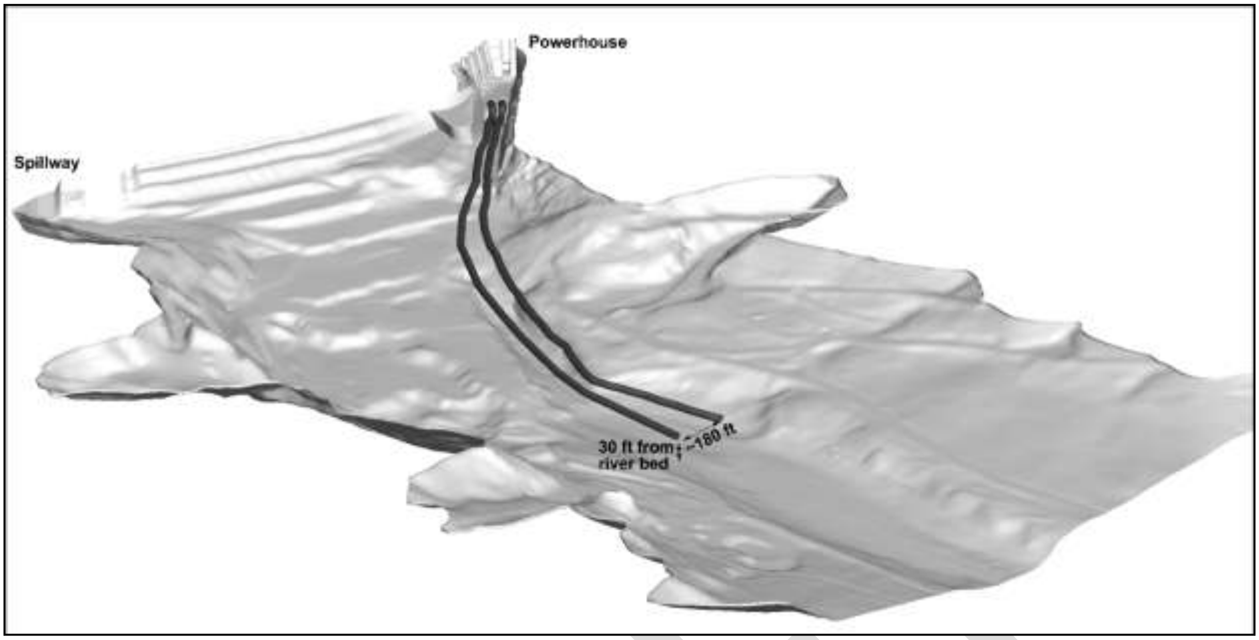

Figure 1-3. Hypolimnetic pump system in Brownlee Reservoir.

2. GOALS AND OBJECTIVES

The goal of this study was to develop a 3D numerical model capable of simulating the hydrodynamics and temperature dynamics in Brownlee Reservoir. The specific objective was to evaluate the stability of the thermocline during HPS operation and the ability of the HPS to draw cold hypolimnetic water without disturbing the thermocline and accessing warmer layers of the reservoir. Two different stratification conditions (i.e. strong and relatively weaker) were simulated to bracket the range of historical conditions seen in Brownlee Reservoir.

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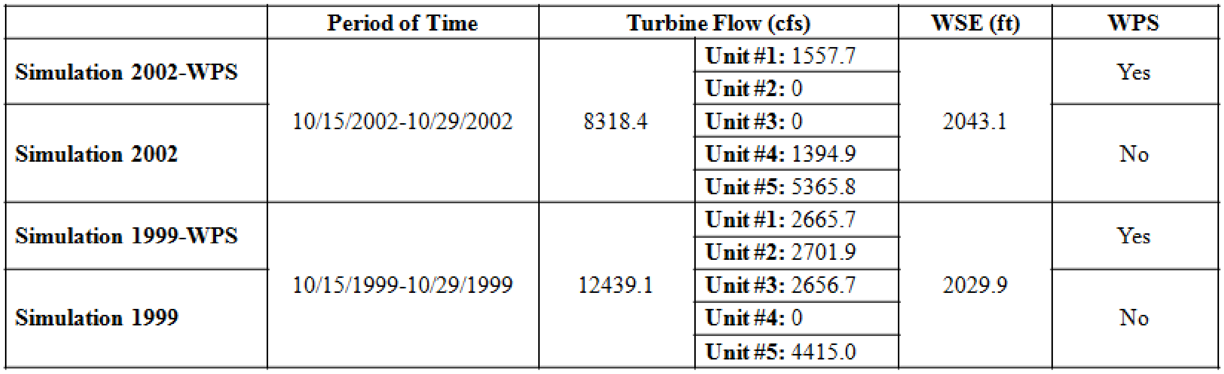
3. SIMULATION CONDITIONS

Two river conditions at low flow rate/strong stratification and high flow rates/weaker stratification, with and without the HPS, were simulated. In 2002, low spring runoff and a shallow drawdown of Brownlee Reservoir for flood control resulted in strong stratification and cold hypolimnion temperature. In contrast, 1999 had high spring runoff and deep drawdown of Brownlee Reservoir for flood control which resulted in relatively weak stratification and relatively warm hypolimnion temperature. Also river flow rates remained high in the fall in 1999 and low in 2002. The average turbine flows and water surface elevation (WSE) observed between October 15 and October 29 were used. Table 3-1 describes the simulation conditions. Measured solar radiation and air temperature were imposed to the model to compute heat fluxes at the water surface.

Table 3-1. Simulation Conditions



	Period of Time	Turbine Flow (cfs)		WSE (ft)	WPS
Simulation 2002-WPS	10/15/2002-10/29/2002	8318.4	**Unit #1:** 1557.7	2043.1	Yes
			Unit #2: 0		
Simulation 2002			**Unit #3:** 0		No
			Unit #4: 1394.9		
			Unit #5: 5365.8		
Simulation 1999-WPS	10/15/1999-10/29/1999	12439.1	**Unit #1:** 2665.7	2029.9	Yes
			Unit #2: 2701.9		
Simulation 1999			**Unit #3:** 2656.7		No
			Unit #4: 0		
			Unit #5: 4415.0		

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4. MODEL OVERVIEW

A grid sensitivity study was first performed to identify the discretization needed to capture the measured temperature profiles. A small channel that includes the deepest region of the forebay without the water pump system was used for this study. Three days using the atmospheric conditions observed in October 15, 2002 were simulated until a stable, periodic condition was reached. The initial condition was the measured temperature profile at 0.5 miles upstream of the dam. Refining the grid from 45 to 70 nodes in the vertical direction did not improve the prediction of the temperature profiles and therefore the Brownlee model grids were constructed with 45 nodes in the vertical direction.

The temperature profiles at the upstream end of the model were computed by Idaho Power with the 2D CEQUAL model. The model includes the entire reservoir, approximately 50 miles. The model was used to evaluate the availability of cold water during 14 days. A withdrawal drawing the same amount of water as the two pipes in the 3D model was included. The 2D model cannot evaluate if the thermocline is disturbed by the HPS since the pipe velocity is not the same. However, under a stable thermocline, it can be used to analyze if cold water will be available using mass and energy conservation principles and the process dynamics.

The effect of the HPS on the temperature distribution in the forebay was studied with two 3D models: 1) a refined comprehensive model containing most of the details of the forebay and HPS and 2) a simplified model to speed up the simulation run time.

The 3D comprehensive model includes the entire HPS and details of the forebay near the banklines, earth embankment, and spillway. This model is the most accurate for simulating the temperature dynamics in the forebay and intake channel. However, model size impedes its use to evaluate different configurations or operational conditions during several days with current IIHR computer capabilities.

A simplified 3D model was created to speed up the simulations. The model includes the pipe entrance of the water pump system and the pipes at the intake channel. The volume of water near the banklines and pipes in the middle of the forebay were removed to reduce grid size and improve grid aspect ratio and skewness. The initial condition for the simulations was the periodic condition obtained imposing the profile predicted in October 15, 2002.

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All grids were generated using the commercial grid generator Gridgen. Grid points were concentrated near the free surface, where the heat flux is important, and close to the river bottom to capture the bed shear stress. The grids were constructed nearly orthogonal in the vicinity of the free surface to improve convergence.

4.1 Mathematical Model

In order to evaluate the importance of the buoyancy in the reservoir, the Richardson and Rayleigh numbers were calculated. The Richardson number expresses the importance of buoyancy relative to forced convection:

$$Ri = \frac{g\,\beta\,\Delta T\,L}{|\vec{u}|^2} \tag{1}$$

where $\vec{u}$ is velocity, β thermal expansion coefficient, g acceleration due to gravity, T temperature, and L characteristic length. If $Ri > 10$ forced convection is negligible. In the Brownlee reservoir, L is the depth, which is approximately 300 ft in the deepest region. In October 2002, the reservoir was stratified and the average temperature difference between epilimnion and metalimnion was approximately $\Delta T = 10$ $^{\circ}$C. In 1999, river flows were higher and mixing was more important decreasing the temperature difference to about $\Delta T = 5$. The average velocities on 2002 and 1999 were $|\vec{u}| = 0.015$ fps and $|\vec{u}| = 0.046$ fps, respectively.

The Richardson numbers in the deepest region of the reservoir are of the order of $Ri \approx 10^4$ and $Ri \approx 10^3$, for 2002 and 1999, indicating that buoyancy is the dominant process. When the pump system is included, the Richardson numbers, using the predicted fluid velocity near the pipes, is $Ri \approx 50$ and the buoyant force is still very important.

The Rayleigh number is used to evaluate the importance of the natural convection caused by the buoyancy of the fluid:

$$Ra = \frac{g\,\beta\,\Delta T\,L^3}{\nu\,\alpha} \tag{2}$$

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where ν is the kinematic viscosity and α the thermal diffusivity. In most of the engineering applications, the Rayleigh number is between 10^6 and 10^8. At the deepest region of the reservoir, $Ra \approx 10^{16}$ and currents due to natural convection originated by temperature perturbations are expected to be strong.

Numerical simulation of the thermal dynamics in Brownlee Reservoir is challenging due to the strong Richardson and Rayleigh numbers. The hydrodynamic, turbulence and temperature are solved with coupled non-linear partial differential equations (PDEs). Buoyancy affects momentum, turbulence, and therefore the resulting temperature distribution. Numerical methods to solve the PDEs need to minimize any numerical perturbations that can originate strong convective currents and results in numerical divergence or unphysical results. In addition, time step needs to be small enough to guarantee convergence.

The general purpose computational fluid dynamics code FLUENT was used in this study. A rigid-lid model with fixed water surface elevation was used. The flow field was solved with the incompressible RANS equations using the Boussinesq approach:

$$\nabla \cdot \vec{u} = 0 \tag{3}$$

$$\rho_o \frac{\partial \vec{u}}{\partial t} + \rho_o \nabla \cdot (\vec{u}\,\vec{u}) = -\nabla p + \rho_o \vec{g}\left[1 + \beta(T - T_o)\right] + \nabla \cdot \left[\mu_{eff}\left(\nabla \vec{u} + \nabla \vec{u}^T\right)\right] \tag{4}$$

where p pressure, and $\mu_{eff} = \mu + \mu_t$ is the effective viscosity, with μ and μ_t denoting molecular and eddy viscosity, respectively. ρ_o represents water density at the average temperature.

The turbulence was modeled with a standard $\kappa - \varepsilon$ model with wall functions. The kinetic energy κ and the turbulent dissipation rate ε are obtained from:

$$\frac{\partial \kappa}{\partial t} + \nabla \cdot \left(\vec{u}\,\kappa\right) = \nabla\left[\left(\nu + \frac{\nu_t}{\sigma_k}\right)\nabla \kappa\right] + \nu_t\left[\left(\nabla \vec{u} + \nabla \vec{u}^{T}\right)\right] : \nabla \vec{u} - \varepsilon + \beta \vec{g}\,\frac{\nu_t}{\mathrm{Pr}_t}\nabla T \tag{5}$$

$$\frac{\partial \varepsilon}{\partial t} + \nabla \cdot \left(\vec{u}\,\varepsilon\right) = \nabla\left[\left(\nu + \frac{\nu_t}{\sigma_k}\right)\nabla \varepsilon\right] + C_{\varepsilon 1} S_\kappa \frac{\varepsilon}{\kappa} - C_{\varepsilon 2}\frac{\varepsilon^2}{\kappa} \tag{6}$$

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where the kinematic turbulent viscosity is given by $\nu_t = C_\mu \frac{\kappa^2}{\varepsilon}$. The default $\kappa-\varepsilon$ model constants were used. The last term on the RHS of Eq. (5) represents the buoyancy effects on the turbulence. A turbulent Prandtl number of $\Pr_t = 0.85$ was used.

The temperature was calculated from the energy conservation equation for incompressible flows:

$$\rho_o C_p \frac{\partial T}{\partial t} + \rho_o C_p \nabla \cdot \left(\vec{u}\, T\right) = \nabla \cdot k_{eff} \nabla T + S \tag{7}$$

where C_p is specific heat, S is the solar radiation, and $k_{eff} = k + k_t$ is effective thermal conductivity, with k and k_t, molecular and turbulent thermal conductivity, respectively.

The radiation S was modeled considering the attenuation of solar radiation with depth given by the Beer's law:

$$S = S_o \varphi \exp(-\varphi z^*) \tag{8}$$

where S_o is incident radiation, z^* is distance from the free surface and φ is the absorption coefficient, which is a function of water turbidity, wavelength and temperature. Usually a single mean spectral value is reported and used. φ ranges between 0.02 and 2 m-1 (Megard et al. 1979, Smith and Baker (1981) . For this study, an absorption coefficient $\varphi = 0.3 m^{-1}$ was used. This value corresponds to the absorption coefficient of clear water at room temperature and it was used to model the temperature dynamics in another reservoir in the Columbia River (Politano et al. 2008).

The incident radiation S_o was modeled as a quadratic sinusoidal function:

$$S_0 = \begin{cases} A\left(\sin \frac{2\pi}{C}(t-B)\right)^2 & \text{if } \mathrm{t_o} < t < \mathrm{t_f} \\ 0 & \text{if } \mathrm{t_f} < t \text{ or } t < \mathrm{t_o} \end{cases} \tag{9}$$

where *t* is time in *h*. The coefficients used in Eq. (9) were selected to adjust the measured solar radiation on 2002 and 1999. The coefficient values are given in Table 4-1 and Table 4-2,

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respectively. Figures 4-1 and 4-2 respectively show measured data together with the adjusted solar radiation function on 2002 and 1999.

Table 4-1. Coefficients of solar radiation function on 2002

Date	t_o	t_f	***A***	***B***	***C***
10/15/2002	8.3	18.8	610.2	71.6	25.9
10/16/2002	32.0	42.8	611.9	81.9	25.4
10/17/2002	56.3	66.8	624.3	106.0	25.6
10/18/2002	80.3	90.5	610.5	131.0	26.1
10/19/2002	104.3	114.5	610.2	149.4	22.9
10/20/2002	128.3	138.5	579.8	171.7	22.2
10/21/2002	152.5	162.8	509.9	194.5	21.0
10/22/2002	176.5	186.5	558.0	225.6	25.3
10/23/2002	200.5	210.5	562.0	251.0	26.1
10/24/2002	224.5	234.5	563.3	272.1	24.5
10/25/2002	248.5	258.5	560.5	294.0	23.4
10/26/2002	272.5	282.5	566.3	331.8	24.3
10/27/2002	295.8	305.5	544.0	352.7	23.3
10/28/2002	319.8	329.5	633.0	375.3	22.6
10/29/2002	345.6	353.3	179.0	379.5	16.9

Table 4-2. Coefficients of solar radiation function on 1999

Date	t_o	t_f	***A***	***B***	***C***
10/15/2002	8.0	19.3	660.7	114.4	26.9
10/16/2002	32.0	43.5	660.7	84.3	26.7
10/17/2002	56.3	67.3	652.8	108.2	26.6
10/18/2002	79.8	91.3	635.7	131.8	26.3
10/19/2002	104.3	115.3	639.4	155.6	26.2
10/20/2002	128.3	139.3	623.6	179.3	26.1
10/21/2002	152.3	163.8	617.5	202.7	25.7
10/22/2002	176.3	187.3	602.3	226.4	25.6
10/23/2002	200.3	211.0	651.0	247.8	24.0
10/24/2002	224.0	235.3	588.8	269.9	22.9
10/25/2002	248.3	259.0	588.8	296.7	24.7
10/26/2002	272.3	281.0	574.2	319.7	19.0
10/27/2002	296.3	304.8	535.0	341.7	18.3
10/28/2002	320.5	329.3	577.2	366.5	18.5
10/29/2002	344.3	353.0	579.1	394.1	25.4

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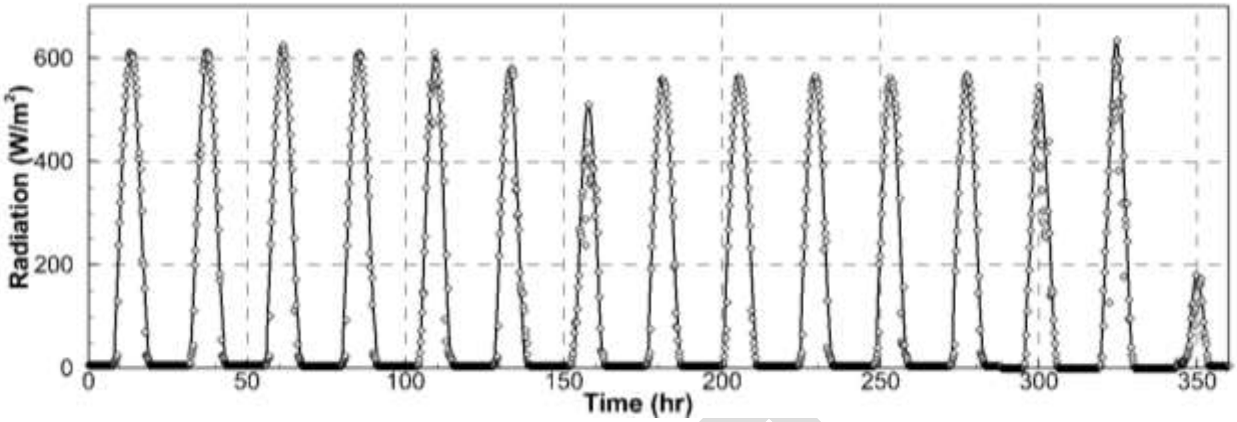

Figure 4-1. Solar radiation in 2002. Symbols: measured data and line: adjusted function.

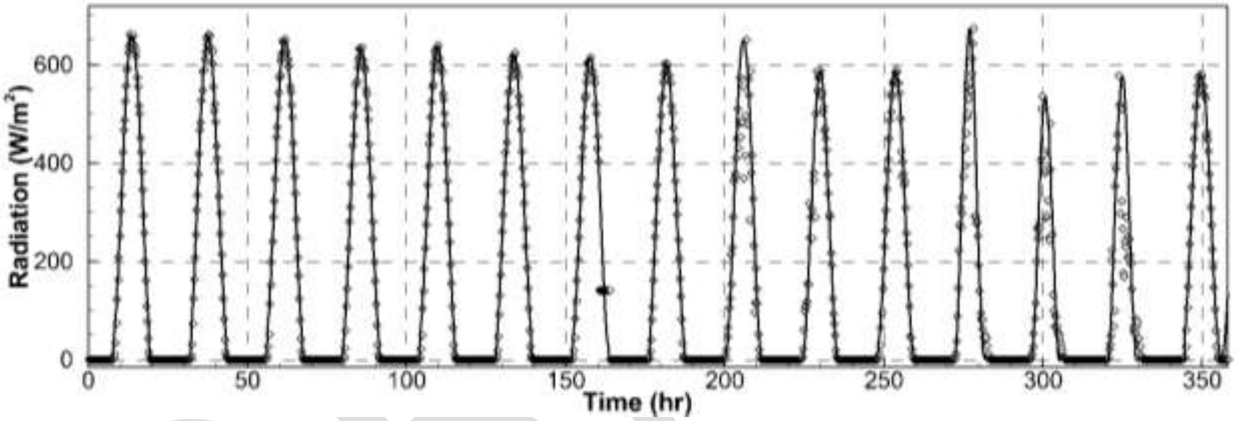

Figure 4-2. Solar radiation in 1999. Symbols: measured data and line: adjusted function.

Boundary Conditions

Top Surface: the free surface is modeled using a rigid-lid approximation imposing a shear stress calculated with the average measured wind between October 15 and October 29 as proposed in Politano et al. (2008).

The heat flux at the free surface is a linear function of the difference between water and air temperatures (Edinger et al. 1968):

$$q_c = C\, f(W)\,(T - T_{air}) \tag{10}$$

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The Bowen coefficient, $C = 0.62$ mb/^{o}C, relates the wind effect on sensible heat flux to that of latent heat flux. Many expressions are found in the literature for the wind speed function, $f(W)$ (Edinger et al. 1968, Shanahan 1984, Thomann and Mueller 1987, Kim and Chapra 1997). A discussion on modeling this term is found in Ahsan and Blumberg (1999). The correlation used by Ahsan and Blumberg (1999) was used in this study:

$$f(W) = 6.9 + 0.345\left|\vec{W}\right|^{2} \tag{11}$$

with $f(W)$ in W/(mb m^{2}) and the wind velocity W in m/s . The air temperature measured during October 15 and October 29, was used in Eq. (8). Figure 4-3 and 4-4 respectively show the air temperature during the simulated period on 2002 and 1999.

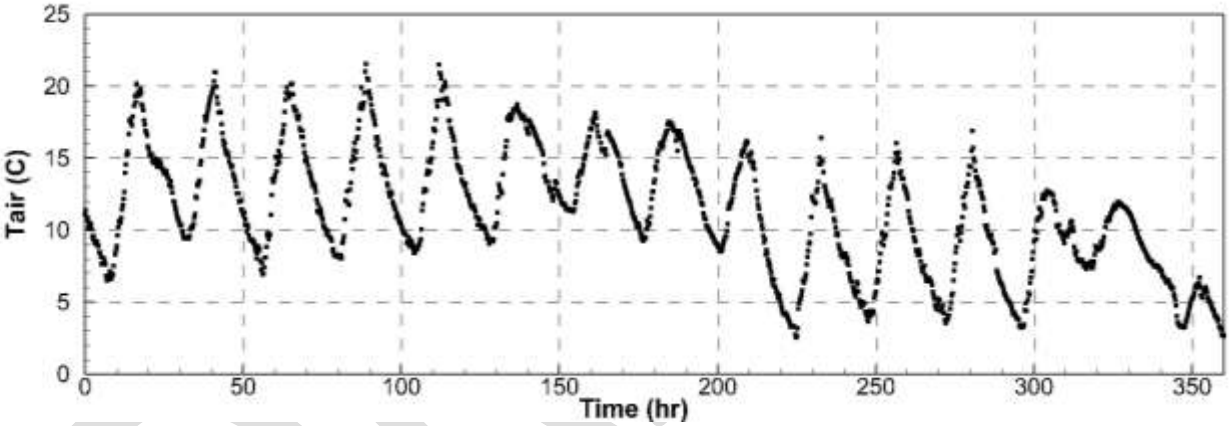

Figure 4-3. Measured air temperature in 2002

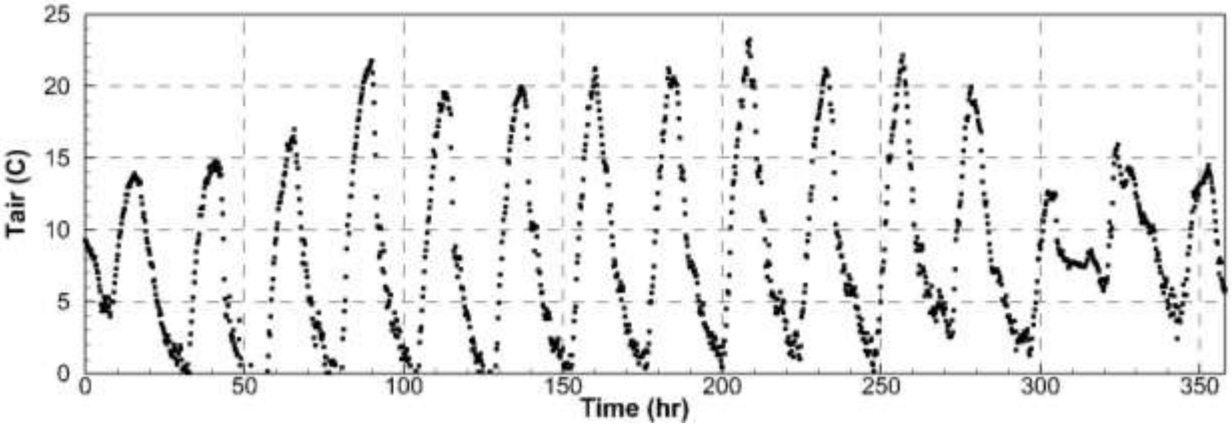

Figure 4-4. Measured air temperature in 1999

Inlet: the average turbine flow rate during the latest fourteen days in October was used at the inlet of the model. The turbulent variables are assumed zero at the upstream end.

Predicted temperature profiles with the CEQUAL model were provided by Idaho Power. Figures 4-5 and 4-6 show temperature profiles at 0.5 miles upstream of the dam on 2002 with and without the HPS, respectively. The temperature of the hypolimnion increases with time when the HPS is operating due to the withdrawal of cold water by the pumps. Temperature profiles used for the 1999 simulations are shown in Figures 4-7 and 4-8.

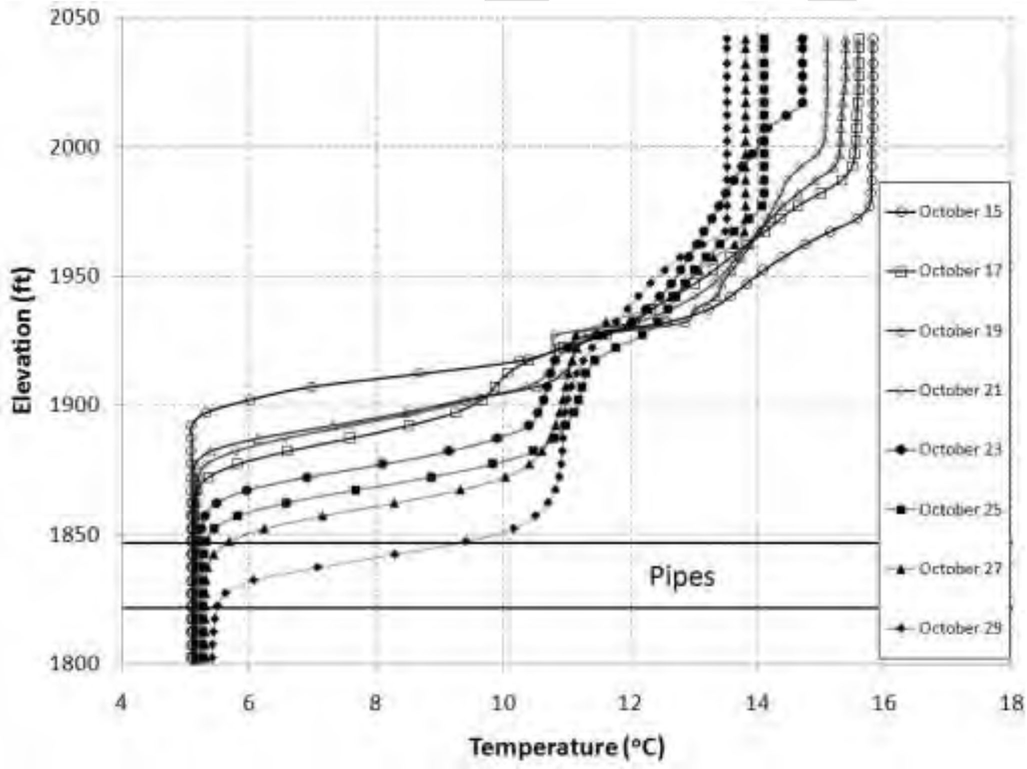

Figure 4-5. CE-QUAL modeled temperature profiles with HPS for 2002

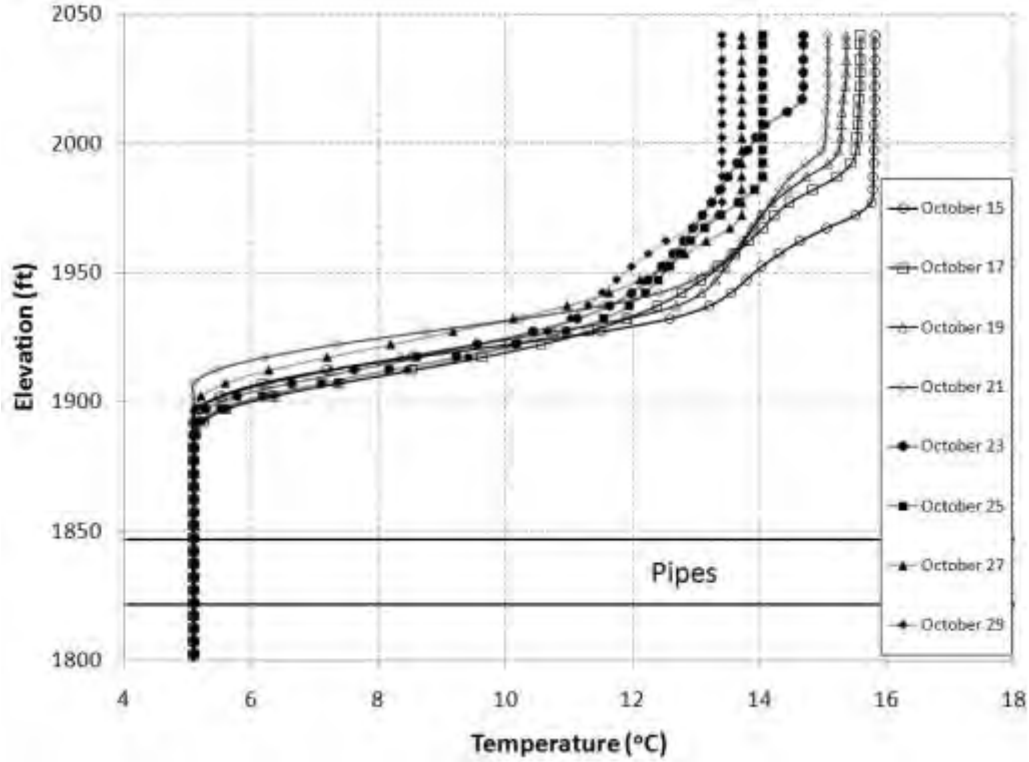

Figure 4-6. CE-QUAL modeled temperature profiles without HPS for 2002

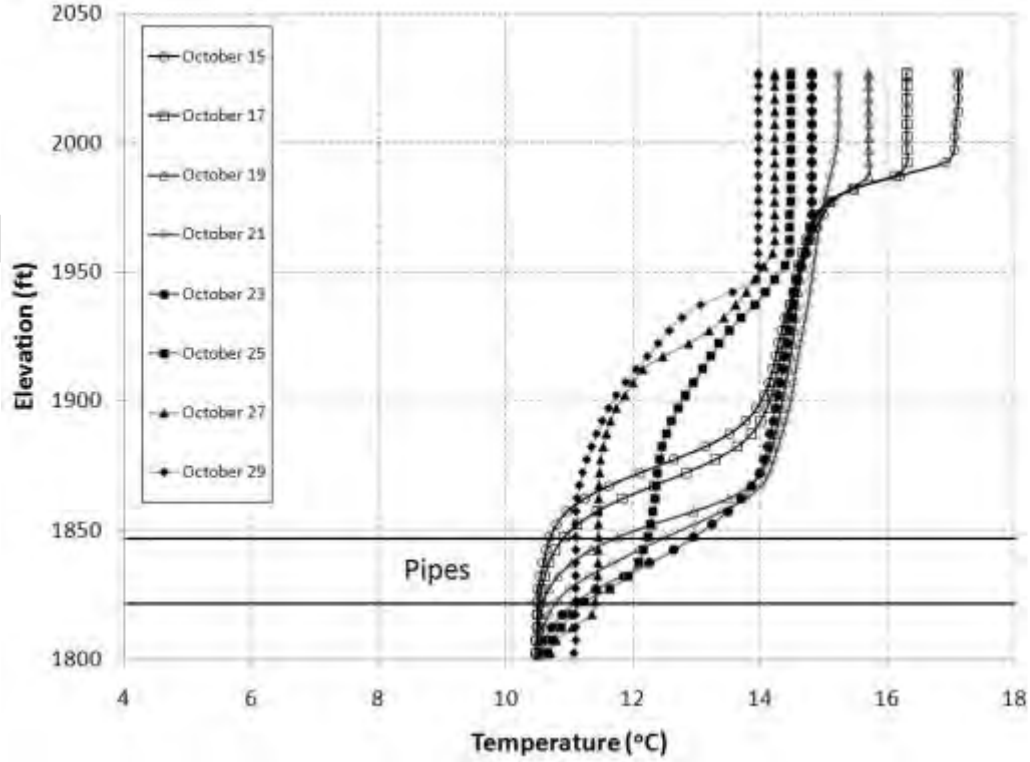

Figure 4-7. CE-QUAL modeled temperature profiles with HPS for 1999

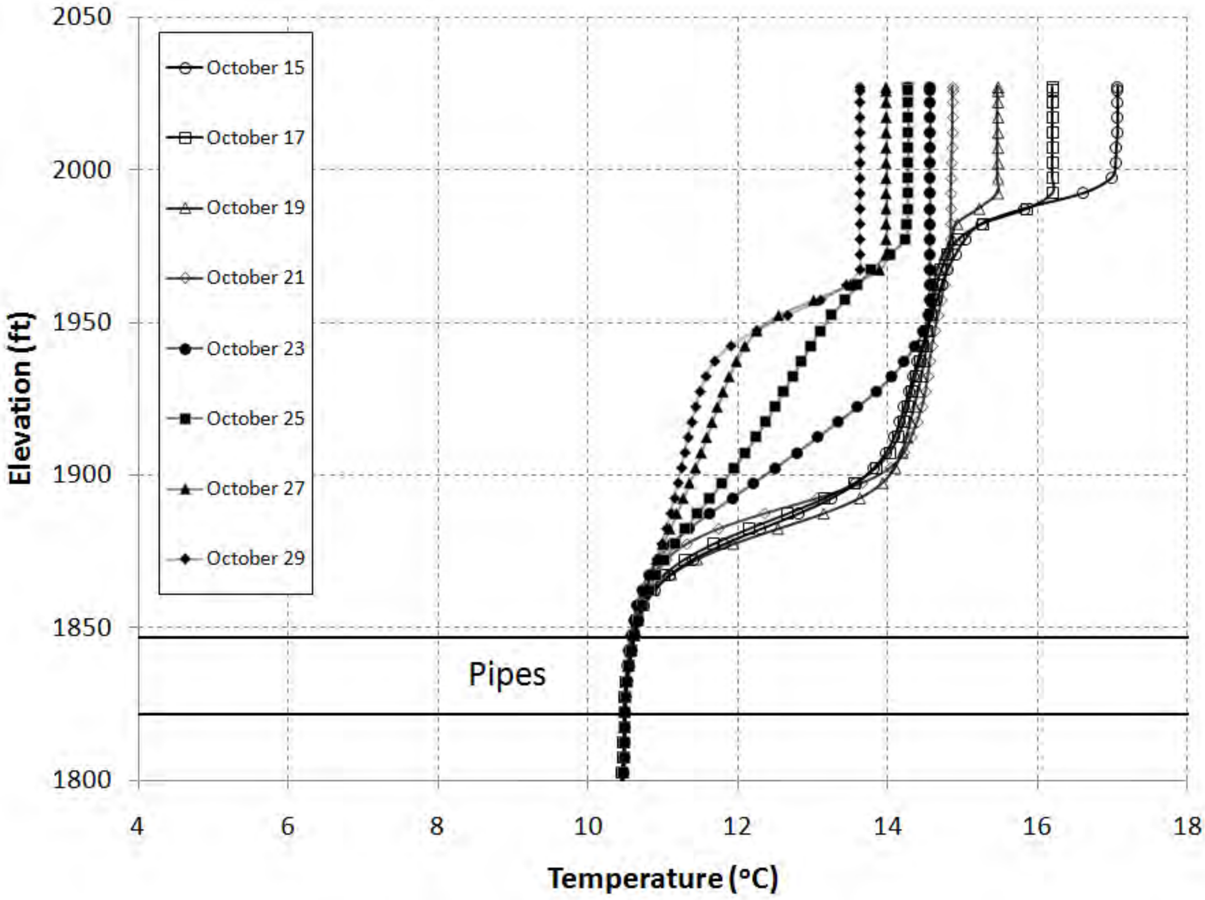

Figure 4-8. CE-QUAL modeled temperature profiles without HPS for 1999

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Walls and River Bed: a no-slip condition and zero heat flux were imposed on all walls and forebay bed.

Exits: the turbines are defined as outflows with a specific discharge. An average turbine discharge during October 15 and October 29 was used (Table 3-1). Turbines only operate above a minimum flow value. The minimum value for turbines #1 through #4 is about 700 cfs and turbine #5 is approximately 1100 cfs. Therefore, if the average flow in a turbine resulted in a value below the minimum, the turbine was closed and the flow from this turbine was distributed among the other opened turbines to make sure all the operating units are above the minimum.

Numerical Scheme

The pressure at the faces was obtained using a body force weighted scheme. The continuity equation was enforced using a Semi-Implicit Method for Pressure-Linked (SIMPLE) algorithm. A second order upwind scheme was used for the turbulent quantities. The energy equation was solved with a third-order MUSCL scheme.

Unsteady solutions were obtained using variable time-step between 0.1 to 0.5 seconds. Typically, two to three nonlinear iterations were needed within each time step to converge all variables to a L2 norm of the error $< 10^{-3}$.

Zero velocities and turbulence were used as initial conditions for the entire domain. The measured or modeled temperature profiles used at the inlet (Figures 4-5 and 4-6) were imposed in the entire domain at time zero.

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5. 2002 SIMULATIONS

5.1 Simulation 2002-HPS

3D Comprehensive Model

A 3D model, considering all the features of the forebay and pump system, was constructed to study the possibility of thermocline disruption due to the HPS and to evaluate the resulting temperature at the turbine penstocks.

Figure 5-1 shows views of the grid used. The grid contains only hexahedral elements. Non-conformal faces between some blocks (red lines) were used to reduce grid size and improve grid quality. The model includes approximately 0.7 miles of the forebay. The total number of nodes was approximately $2.7x10^6$. The size of typical cells in the forebay and intake channel were approximately (12 ft, 11 ft, 5 ft) and (2.3 ft, 13 ft, 3 ft), respectively. The vertical length of cells near the free surface and bed was significantly reduced.

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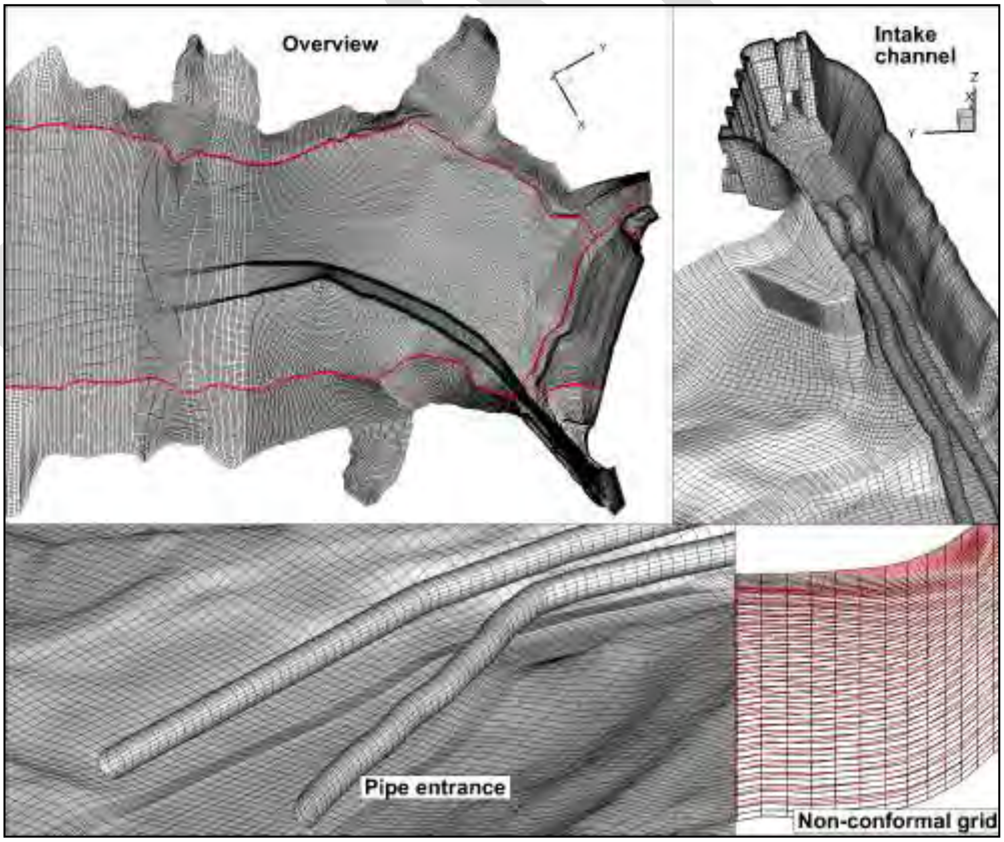

Figure 5-1. Views of the grid used in the comprehensive 3D model

Figure 5-2 shows 3D views with temperature distribution in the forebay on October 17, 2002. Details on the top show the temperature in the river bed and bank lines (left) and a close-up view near the intake channel (right). The detail on the bottom shows a vertical slice through one of the pipes. Warmer temperatures are observed at shallow regions near the forebay banks. According to the model, the thermocline was slightly disturbed by the pipes during the simulation time. The water pump system is capable of transporting cold water from the hypolimnion to the intake channel, decreasing the temperature in the turbine penstocks. Temperature distribution changes during time as a result of unsteady atmospheric and inflow conditions. However, the flow pattern is fairly steady. An animated version of this figure is at Figure5-2.AVI in the attached DVD.

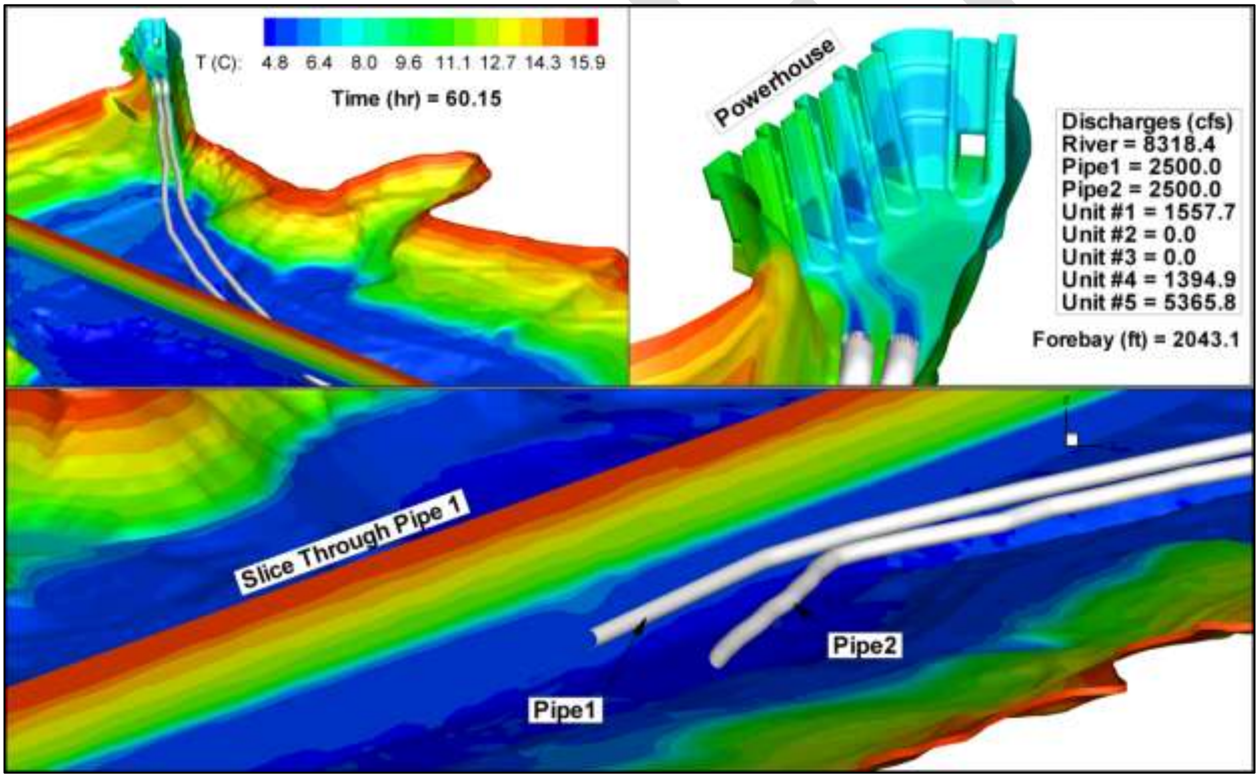

Figure 5-2. Temperature contours with the 3D comprehensive model on October 17, 2002 with the HPS

Figure 5-3 shows velocity vectors and temperature distribution in the intake channel at horizontal slices at 33, 66, and 82 ft from the water surface. The HPS creates a big eddy in the eastern region of the intake channel. The model predicts that cold water released by the pipes in the intake channel does not draw back to the forebay. Most of the cold water flowing in the pipes is directed to units #3, #4 and #5.

3D streamlines colored by temperature are shown in Figure 5-4 on October 17, 2002. According to the model, the eddy causes an important temperature mixing upstream of the turbines. An animation of this figure is available at Figure5-9.AVI in the attached DVD.

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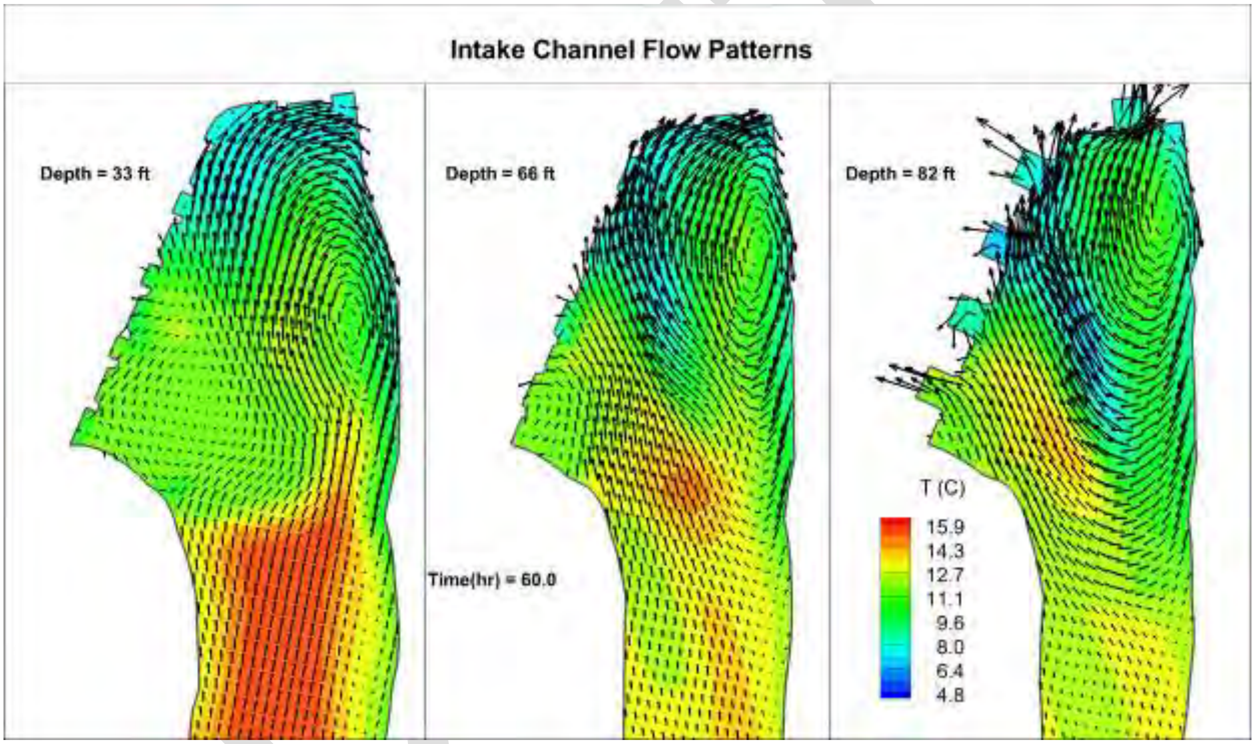

Figure 5-3. Velocity vectors and temperature contours with the 3D comprehensive model on October 17, 2002 with the HPS

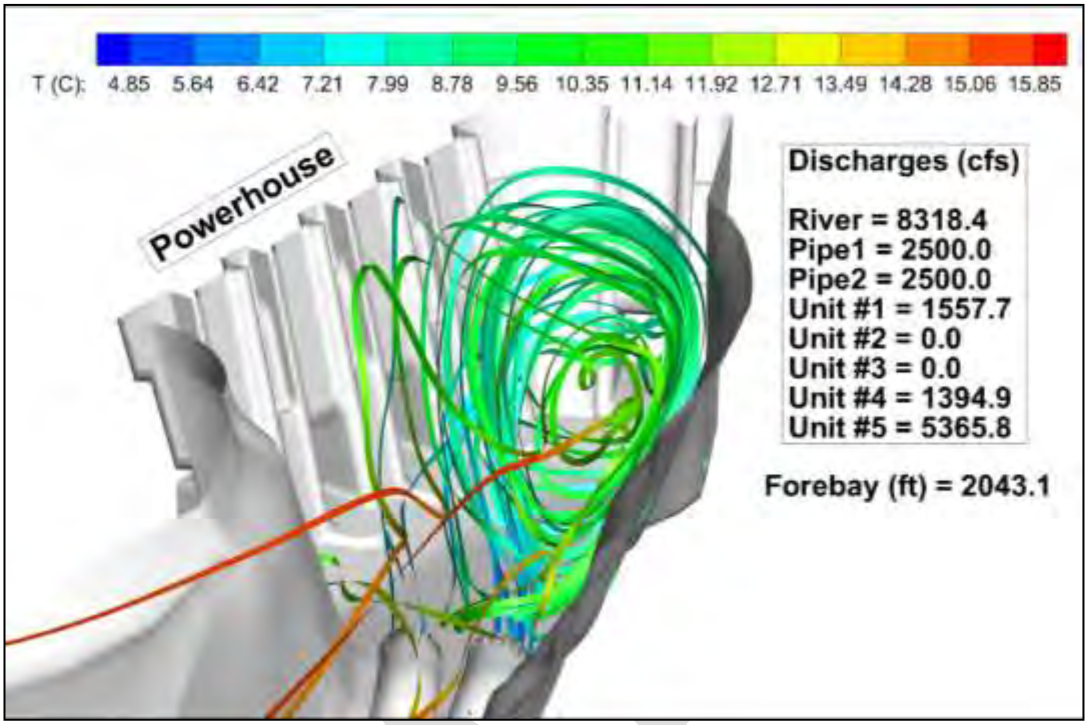

Figure 5-4. Streamlines colored by temperature at the intake channel with the 3D comprehensive model on October 17, 2002

The evolution of water temperature at the HPS entrances and turbine penstocks is shown in Figure 5-5. During the simulated 72 hours, the pipes draw cold water at about 5.5 ^{o}C. The flowrate weighted average temperature of the turbine is about 9 ^{o}C. The model indicates that unit #1 is drawing water relatively warm at about 12 ^{o}C. Improvement of the resulting averaged powerhouse temperature could be possible with a different orientation of the eastern pipe.

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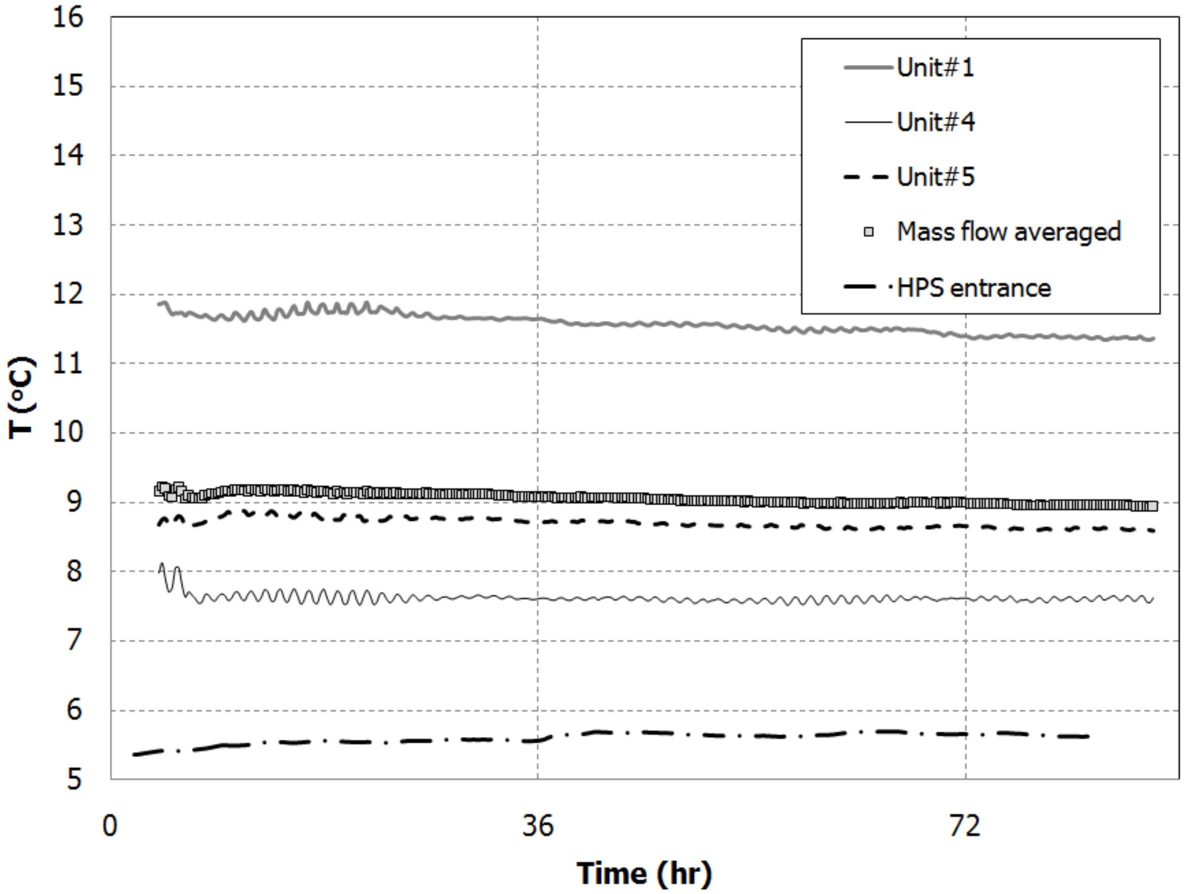

Figure 5-5. Evolution of the temperature at the pipe entrance and turbine penstocks with the 3D comprehensive model on 2002 with the HPS

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As explained earlier, high order resolution schemes were required to capture the measured temperature profiles. In addition, a small time step is needed for appropriate modeling of the temperature perturbations caused by the pump system under a strong buoyancy force. The above requirements resulted in a slow model with capabilities of running one day in about 5 days of computational time using a 4 socket 8 core Intel(R) Xeon(R) CPU X7560 at 2.27GHz, 32 cores total, with 128GB of RAM.

3D Simplified Model

A simplified model, with the basic forebay and pump system geometries, was constructed to speed up the simulation run time. The model includes 0.7 miles of the forebay. Conformal faces between all blocks were used to avoid interpolations. Figures 5-6 shows the grid and geometry of the simplified model. The geometry of intake channel and powerhouse intakes was respected. The water volume near banks and earth embankment was removed to reduce grid size and improve quality. All volumes behind the non-conformal faces (red lines in Figure 5-1) near the river bank were removed. The pump system was modeled as two short pipe entrances drawing the same amount of water as the two full pipes. The volume of the pipes in the forebay was considered negligible. However, the volume of the pipes cannot be ignored in the intake channel and therefore they were included in the model. In the intake channel, the space between pipes was neglected to improve grid quality. The flow area of the two joined pipes is the same as the sum of each separated pipe area. The spillway and earth embankment area was simplified. The grid discretization was reduced in the lateral and longitudinal direction, resulting in a grid of approximately 5.4 10^5 nodes. The size of typical cells in the forebay and intake channel were approximately (22 ft, 29 ft, 5 ft) and (2.5 ft, 19 ft, 3 ft), respectively.

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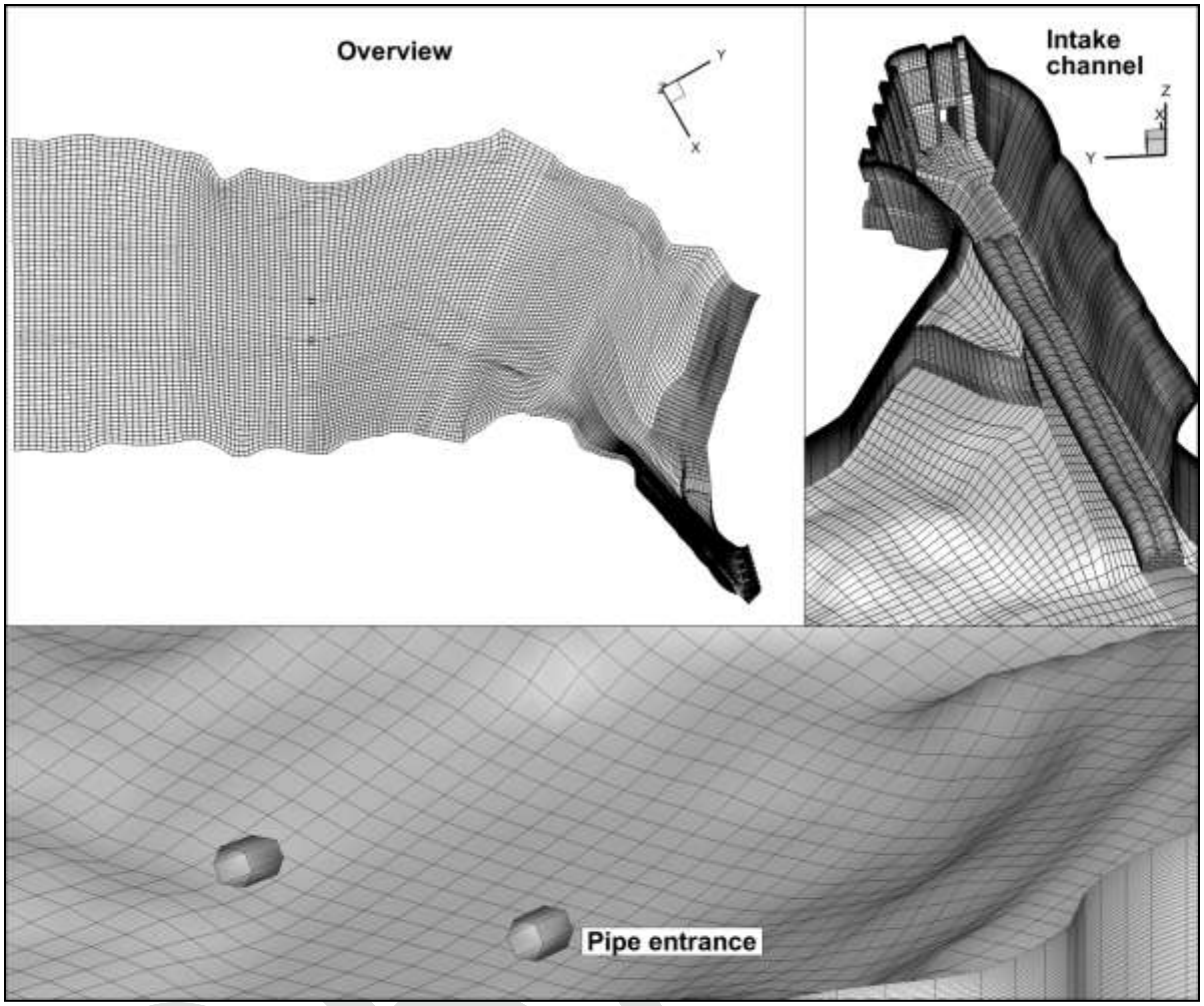

Figure 5-6. Views of the grid used in the simplified 3D model

Figures 5-7 to 5-9 show temperature contours obtained with the pump system on October 17, 21 and 27, 2002. An animation of this figure is found at Figure5-8.AVI in the attached DVD.

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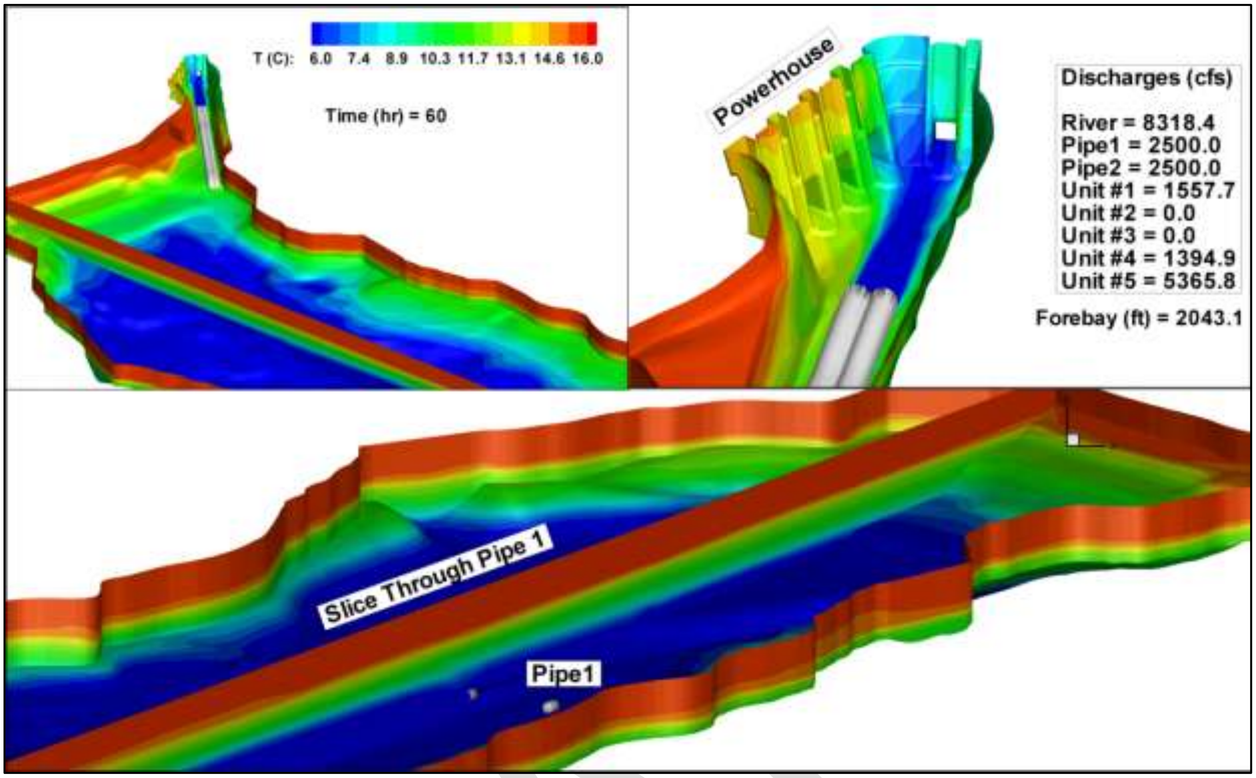

Figure 5-7. Temperature distribution with the HPS on October 17, 2002

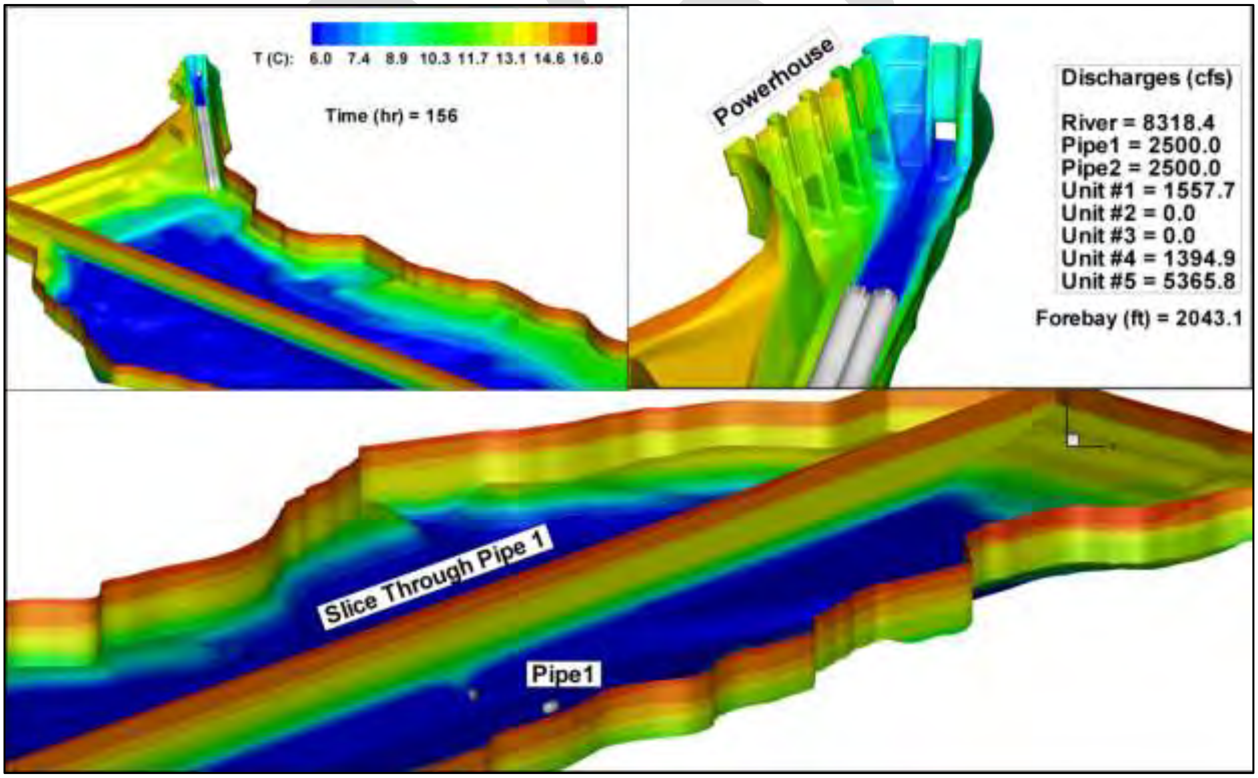

Figure 5-8. Temperature distribution with the HPS on October 21, 2002

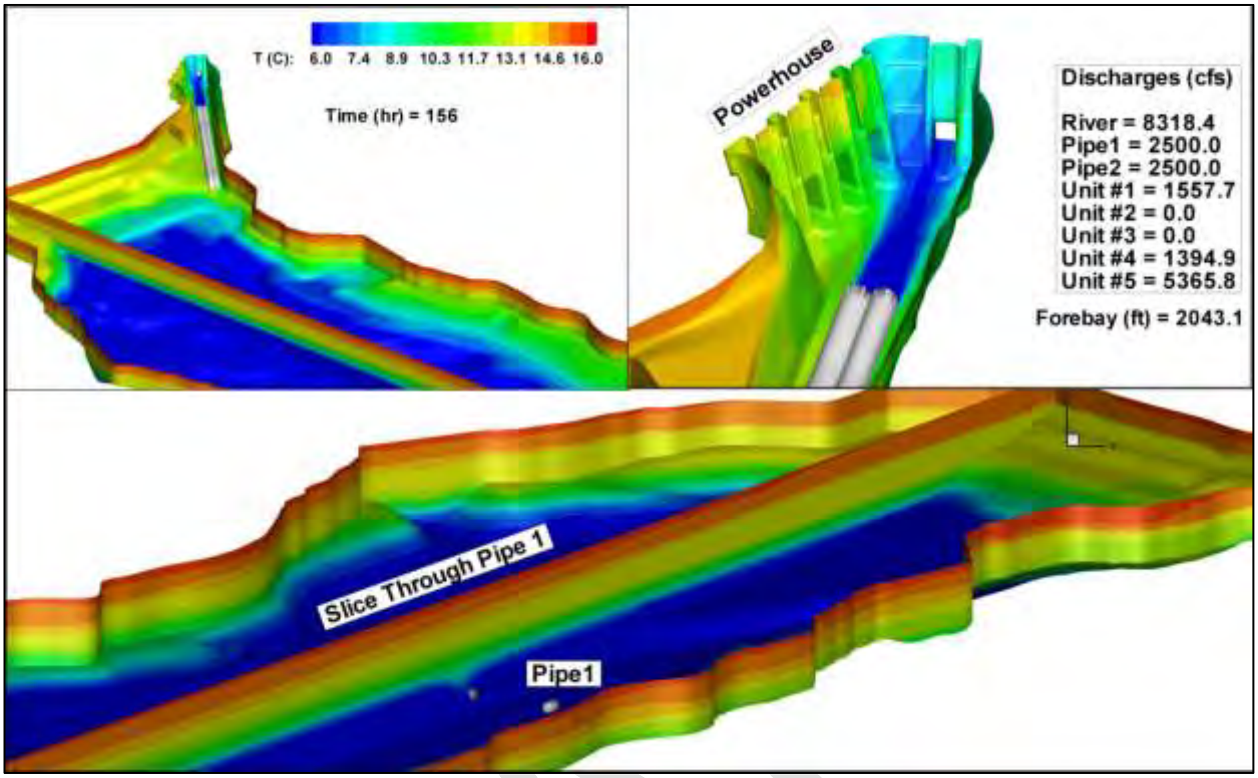

Figure 5-9. Temperature distribution with the HPS on October 27, 2002

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As obtained with the refined model, the HPS slightly affects the thermocline during the beginning of the simulation. However, as the elevation of the thermocline and availability of cold water is reduced with pumping, the pipes begin drawing slightly warmer water.

The temperature distribution predicted with the simplified model in the forebay is similar to that predicted with the refined model. However, the temperature in the intake channel is considerably different because of the difference in the geometry of the modeled pipes (Figure 5-10).

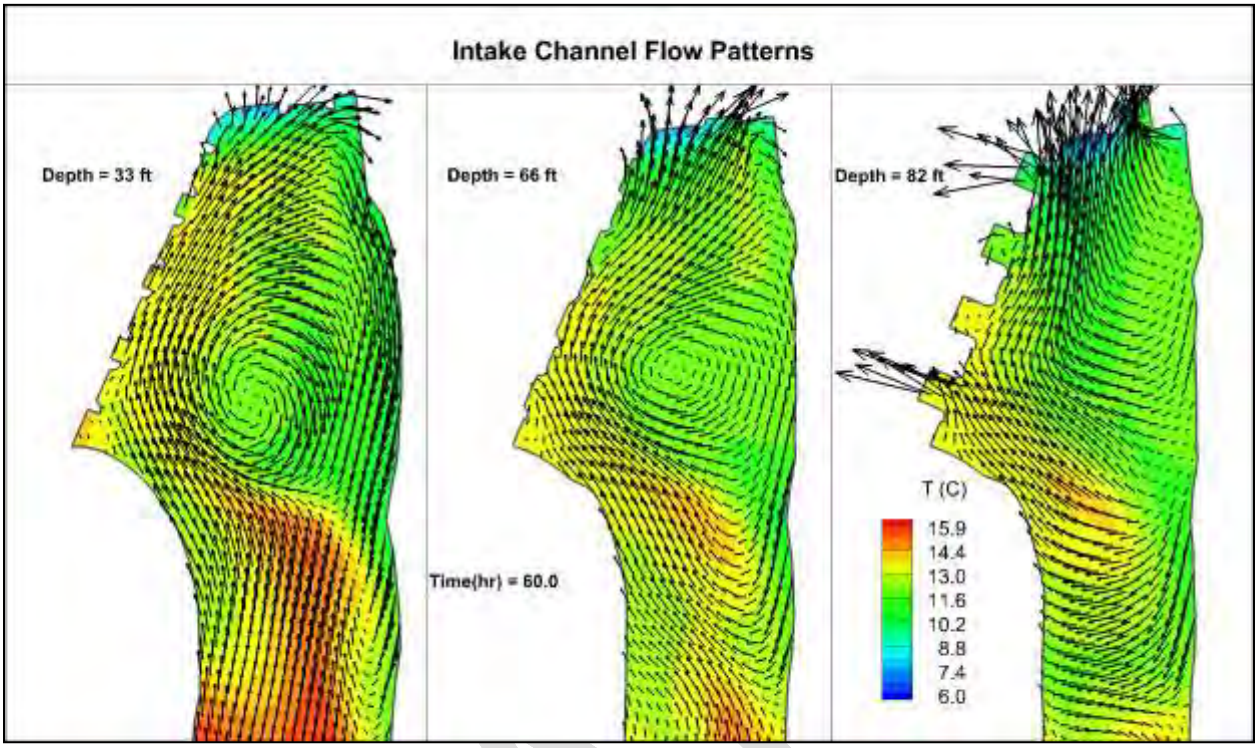

Figure 5-10. Temperature distribution with the HPS on October 27, 2002

Figure 5-11 shows streamlines colored by temperature on October 17, 2002. An animation of this figure is available in Figure5-12.AVI in the attached DVD. Water from the right pipe of the HPS is directed toward unit #5 while water in the left pipe impacts the wall separating intakes #4 and #5. When the jet impacts the wall, water is moved toward the free surface, creating a big recirculation. Note that the big eddy in the central area upstream of the intakes generated by the pipe causes significant thermal mixing. Warm water traveling near the free surface (red streamlines) decreases temperature as it moves into the eddy. On the other hand, cold water from the pipe (blue streamlines) increases temperature while traveling near the water surface. Water flowing to unit #1 is not affected as much by the HPS. Note that the flow pattern predicted with the simplified model is substantially different than that predicted with the comprehensive model (Figures 5-4). The pipe geometry in the intake channel in these models is different. In the comprehensive model, the pipes are separated and the western pipe is oriented toward units #2 and #3 while in the simplified model both pipes are together, directing most of the water toward the eastern region.

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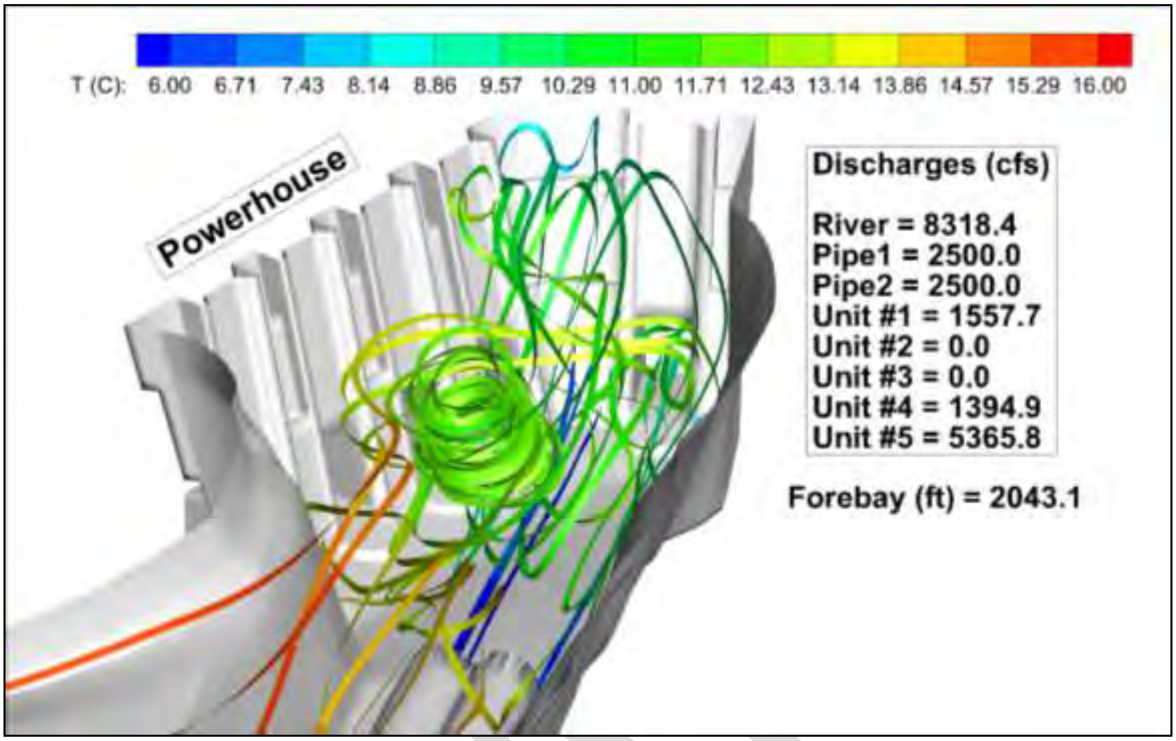

Figure 5-11. Streamlines colored by temperature at the intake channel on October 17, 2002 with the HPS

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Figure 5-12 shows the evolution of the flowrate averaged temperature of water drawn by the pipes and at the intake penstocks. During 14 days, the temperature of water at the pipe entrances changes from 5.3 to 9.3 °C. The temperature obtained with the simplified model the first 72 hours is comparable to that obtained with the comprehensive model. After 180 hr (7.5 days) the water temperature in the pipes increases considerably with time as a result of less cold water. The height of the hypolimnion is reduced and the pipes start drawing warm water from the metalimnion. During the simulated 14 days, the flowrate averaged temperature of all intakes ranges from approximately 9.3 to 10.8 °C. Turbine #5 carries out about 65% of total turbine flows. The pipes direct most of the cold water to unit #5 decreasing the temperature in this unit and the resulting flowrate averaged temperature. After 180 hr, pipes are drawing warmer water and therefore the temperature in the turbine intakes increases.

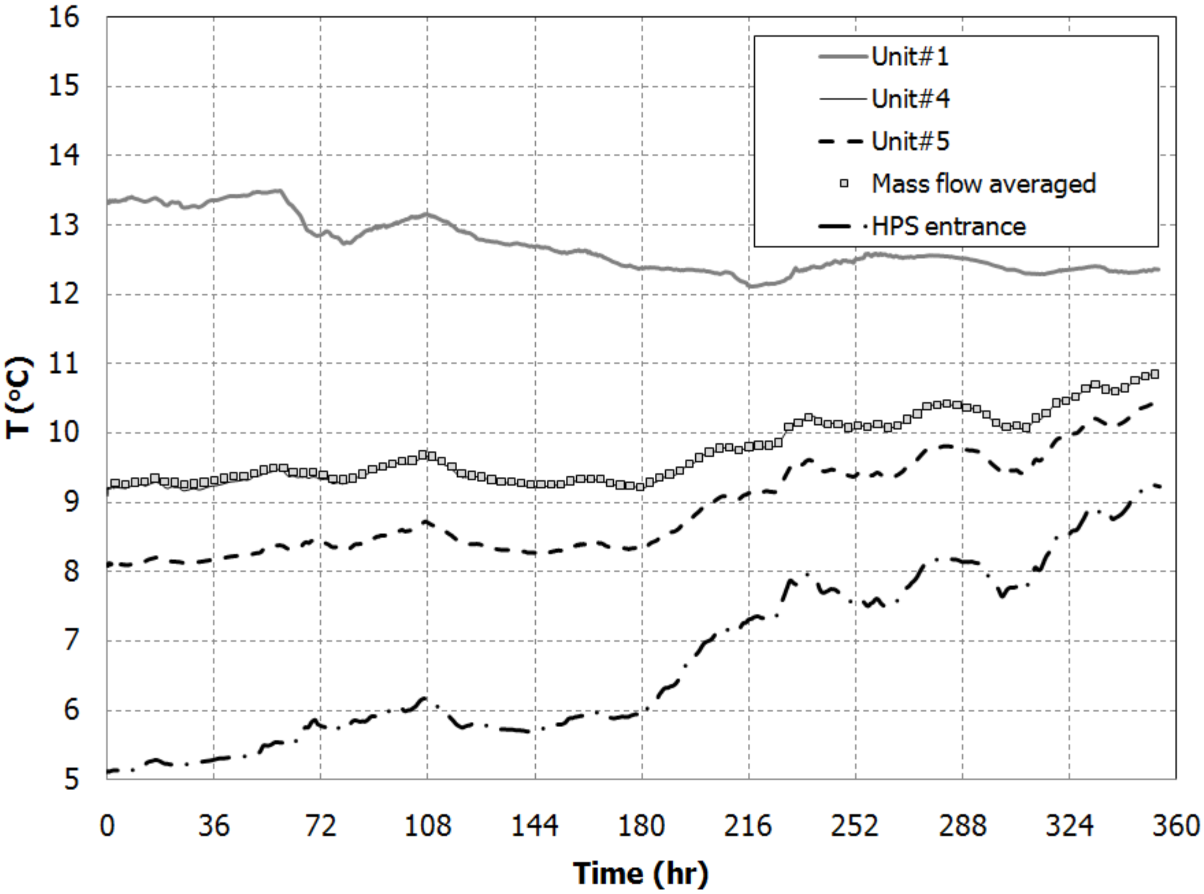

Figure 5-12. Evolution of the temperature at the intake penstocks on 2002 with the HPS

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5.2 Simulation 2002

The simplified model was used to simulate the Brownlee forebay without the water pump system. The purpose of this simulation was to validate the model using data measured in the right channel downstream of turbine T5 and also provide a baseline scenario to evaluate changes in the reservoir due to operation of the HPS.

Figures 5-13 to 5-15 show temperature contours on October 17, 21 and 27, 2002. An animation of this figure during fourteen days is found at Figure5-13.AVI in the attached DVD. The forebay and most of the intake channel are strongly stratified. However, without the HPS, warmer temperatures are predicted near the powerhouse. Temperatures are colder and the stratification is weaker as time advances due to lower air temperature and smaller solar radiation.

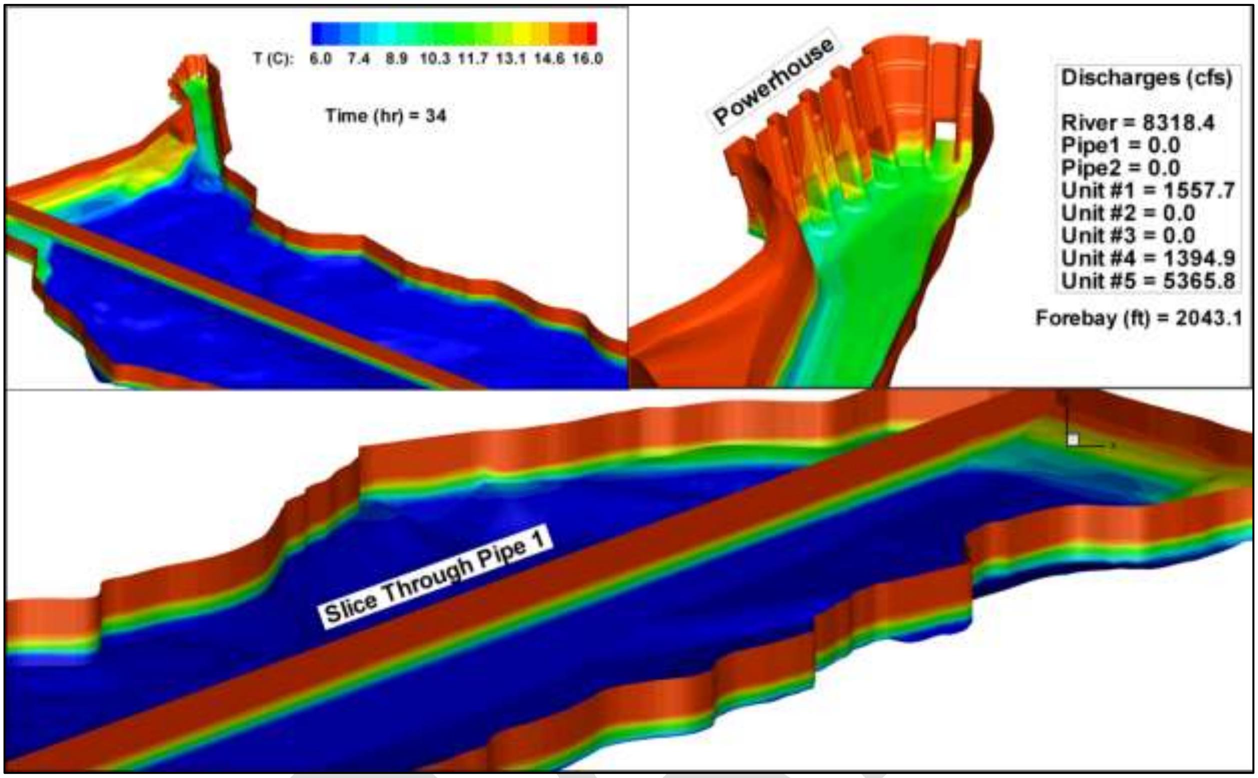

Figure 5-13. Temperature distribution on October 17, 2002

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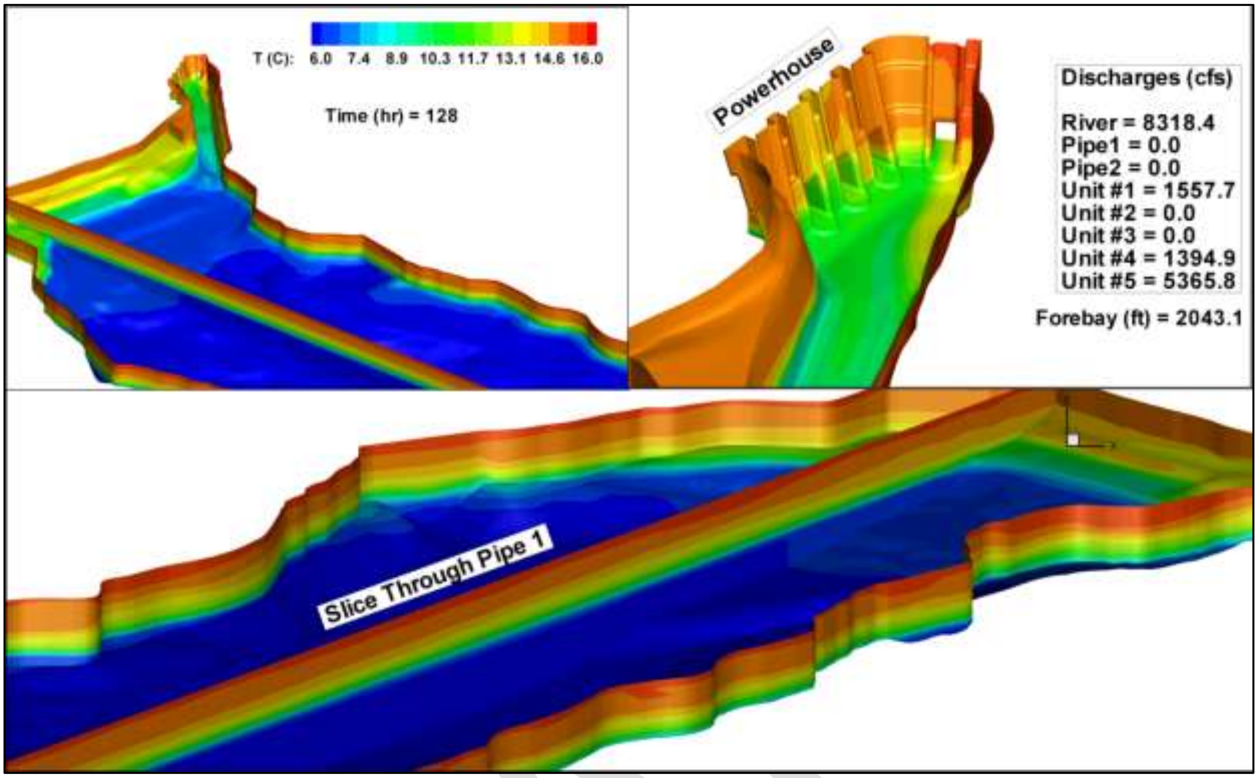

Figure 5-14. Temperature distribution on October 21, 2002

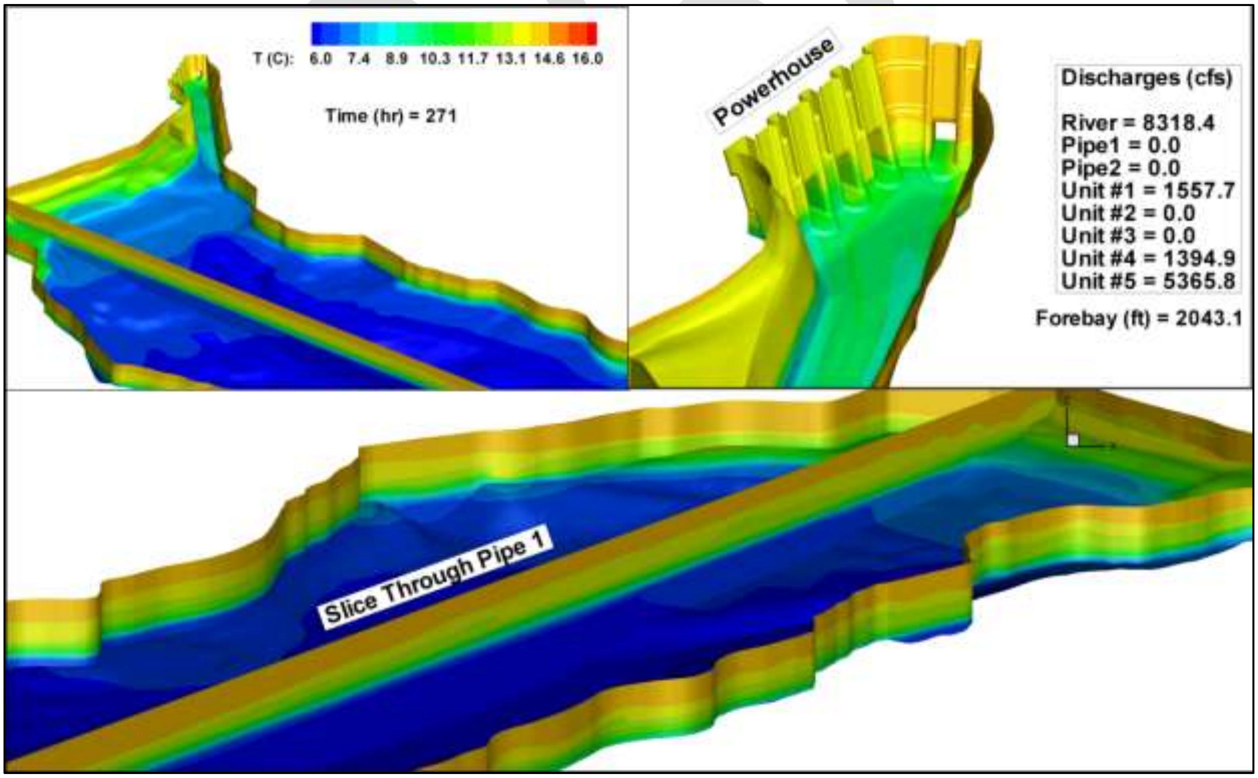

Figure 5-15. Temperature distribution on October 27, 2002

Figure 5-16 shows streamlines colored by temperature in the intake channel on October 17, 2002. An animation of the streamlines is shown in Figure5-16.AVI. Temperature mixing near the powerhouse is insignificant compared to that predicted with the HPS. Some warm water from the surface layers in attracted by unit #5, which has the highest flowrate.

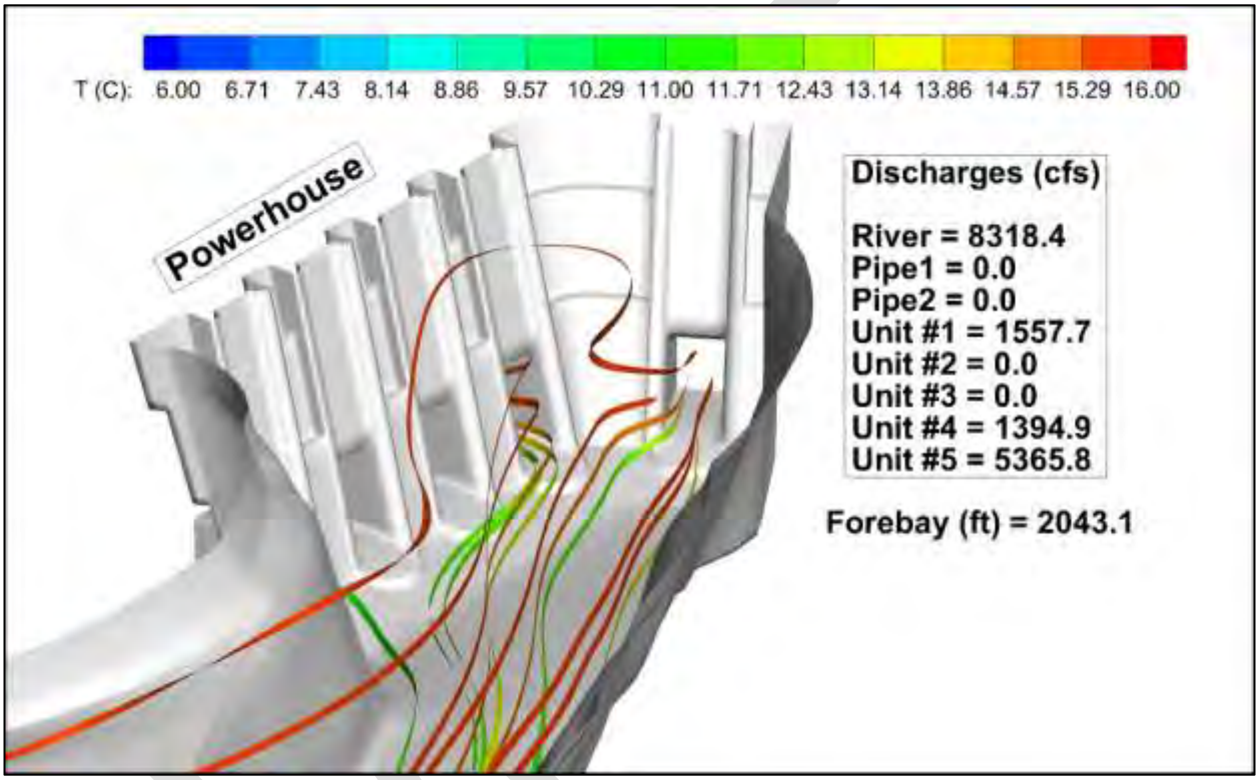

Figure 5-16. Streamlines colored by temperature at the intake channel on October 17, 2002

The evolution of the temperature at the intake penstocks is shown in Figure 5-17. The temperature decreases with time as a result of lower forebay temperatures. The lowest temperature is observed in the closed turbines (units #2 and #3). Temperatures in closed turbines or near the channel bed are between 11 ^{o}C to 14.5 ^{o}C, which are consistent with temperatures observed in the metalimnion. The highest temperature is observed in unit #5. In this year, this unit carries approximately 65% of the total turbine flow. Higher flow rate is able to disrupt the thermocline and draw some water from the surface layers. The flowrate average temperature ranges from approximately 15 °C in October 15, 2002 to about 13 °C at the end of October, 2002.

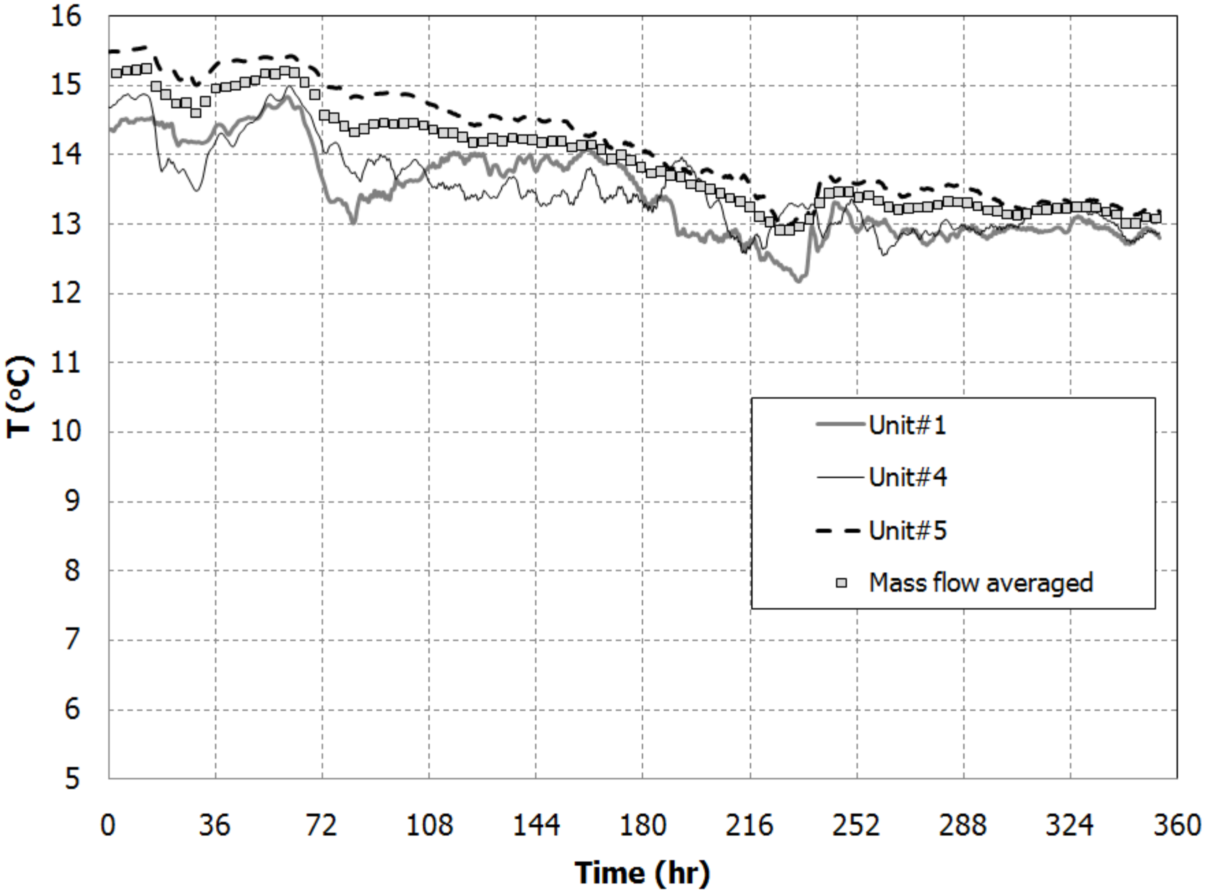

Figure 5-17. Evolution of the temperature at the turbine penstocks on 2002

Predicted temperature for unit #5 was compared to measurements at the right channel location on the bridge downstream of Brownlee in Figure 5-18. This temperature is representative of turbine #5. The model agrees reasonably well with field data. Measured data have more variability than the predicted values because the model assumes steady flow conditions, but the turbine flowrate actually changed considerably during the day.

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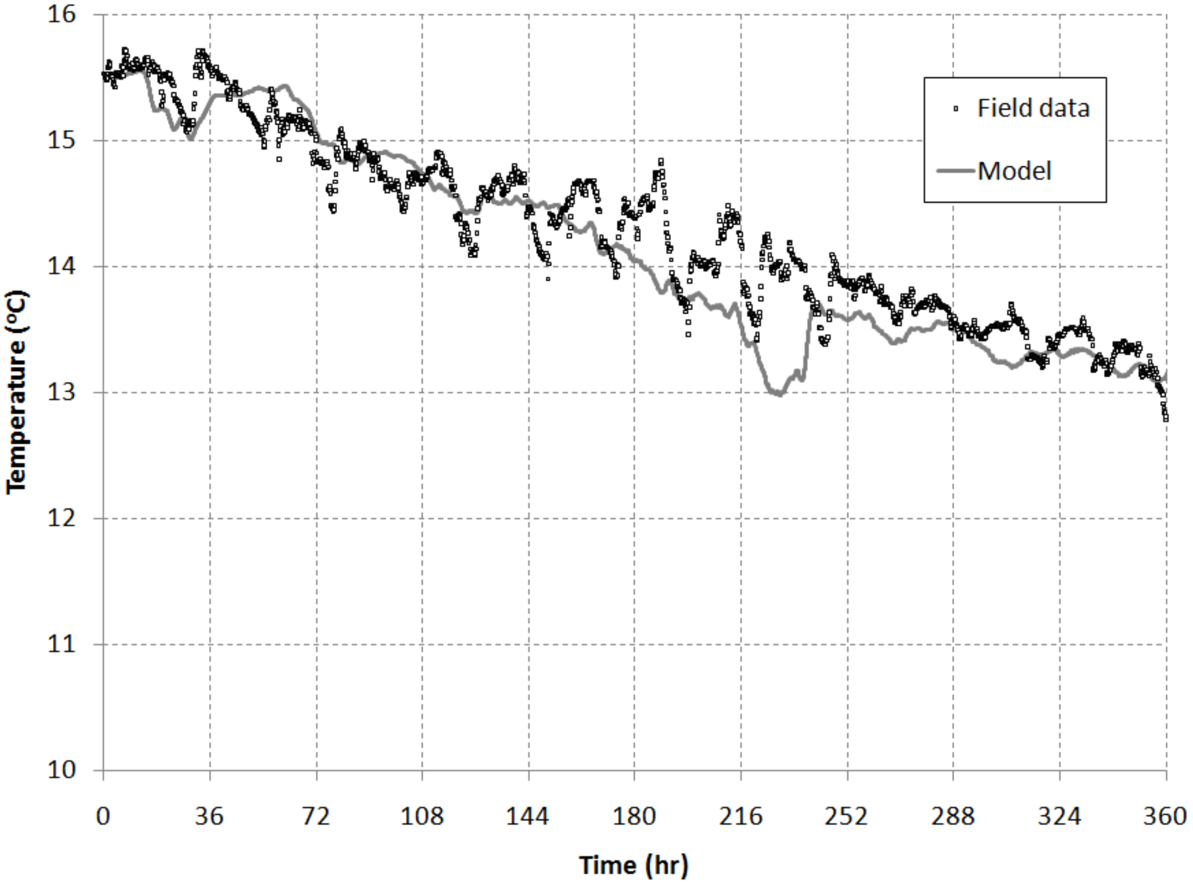

Figure 5-18. Model predictions in turbine #5 and temperature measured at the downstream right channel on 2002

Figure 5-19 shows temperature profile measurements and model predictions at the location where the pipe entrances are planned to be installed. The model is able to reproduce the distinct thermal layers and the general profile shape of the measured thermocline.

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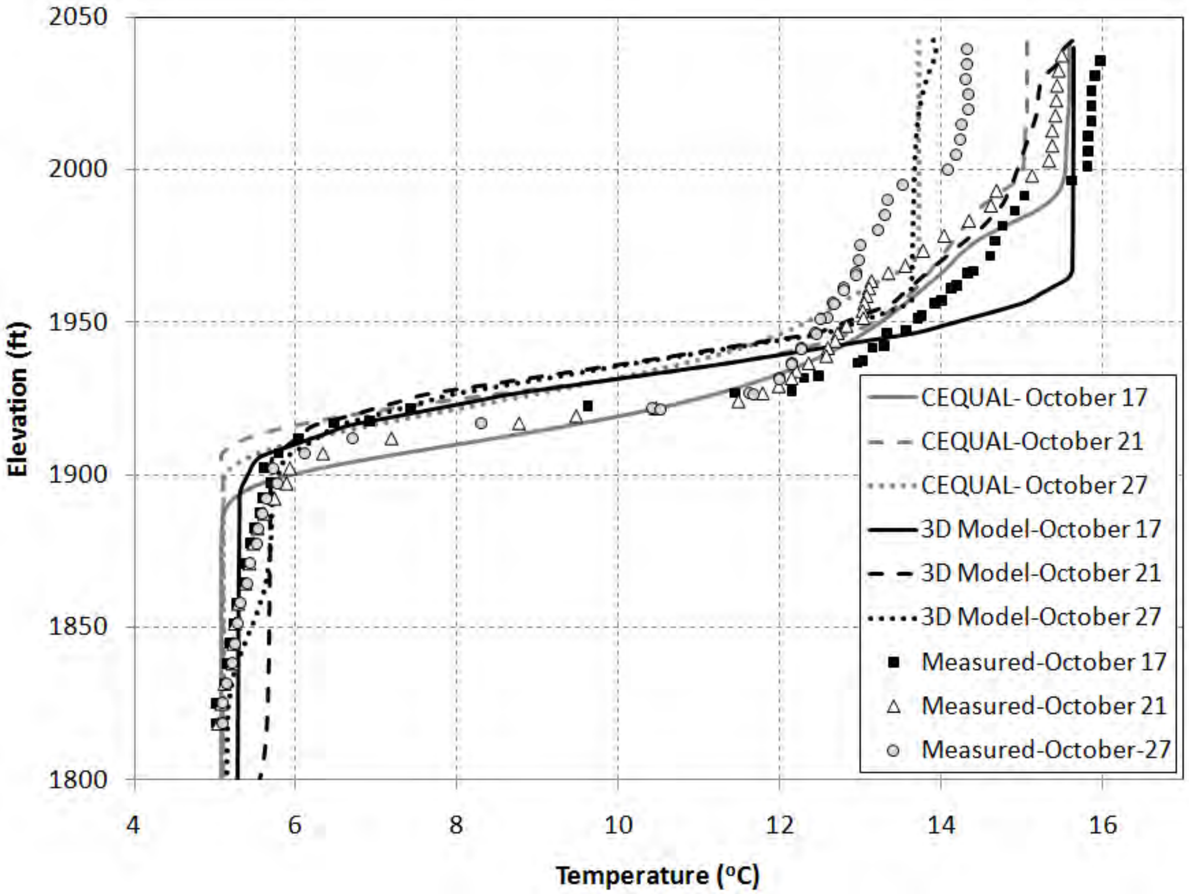

Figure 5-27. Measured, CE-QUAL modeled and 3D modeled temperature profiles on 2002

5.3 Effect of the HPS

In 2002, the thermocline remained stable throughout the HPS operation, however, as the thermocline was lowered closer to the intakes the temperature of the pumped water did increase from 5.3 to 9.3 ^{o}C. The daily flowrate weighted averaged temperatures in the turbine penstock is found in Table 5-1. According to the model, in 2002 operating the HPS at capacity reduced the downstream temperature by about 5.8 ^{o}C at the beginning of the simulation to 2.3 ^{o}C at the end of October. The daily flowrate weighted maximum temperatures in the turbine penstock is found in Tables 5-2. No significant differences were found between average and maximum daily values.

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Table 5-1. Average temperature at the turbine penstocks, with and without the HPS, on 2002

		Daily Average Temperatures (°C) - 2002					
		Unit#1	Unit#2	Unit#3	Unit#4	Unit#5	Flowrate Weighted Average
WPS	15-Oct	13.35	13.07	11.61	9.24	8.13	9.29
	16-Oct	13.34	13.03	11.59	9.25	8.17	9.32
	17-Oct	13.26	12.99	11.63	9.40	8.35	9.44
	18-Oct	12.87	12.64	11.41	9.38	8.41	9.41
	19-Oct	13.06	12.81	11.59	9.56	8.59	9.59
	20-Oct	12.76	12.56	11.33	9.31	8.33	9.32
	21-Oct	12.62	12.42	11.23	9.28	8.34	9.30
	22-Oct	12.40	12.20	11.11	9.28	8.40	9.30
	23-Oct	12.30	12.12	11.23	9.68	8.94	9.69
	24-Oct	12.24	12.07	11.32	10.00	9.35	10.00
	25-Oct	12.50	12.33	11.52	10.11	9.40	10.10
	26-Oct	12.54	12.41	11.65	10.31	9.66	10.31
	27-Oct	12.40	12.25	11.50	10.19	9.55	10.19
	28-Oct	12.35	12.20	11.59	10.49	9.94	10.49
	29-Oct	12.33	12.22	11.68	10.73	10.26	10.72
NO WPS	15-Oct	14.44	12.81	14.01	14.47	15.41	15.07
	16-Oct	14.32	13.33	14.33	14.02	15.25	14.87
	17-Oct	14.52	14.43	14.79	14.68	15.35	15.08
	18-Oct	13.34	12.31	13.04	13.91	14.89	14.44
	19-Oct	13.78	12.32	12.98	13.66	14.73	14.38
	20-Oct	13.87	11.81	12.68	13.46	14.50	14.21
	21-Oct	13.93	11.87	13.58	13.45	14.39	14.14
	22-Oct	13.50	11.30	13.25	13.45	14.02	13.83
	23-Oct	12.81	11.21	12.41	13.27	13.71	13.47
	24-Oct	12.48	11.48	12.58	13.06	13.20	13.04
	25-Oct	13.03	12.31	13.01	12.96	13.60	13.39
	26-Oct	12.83	11.93	12.90	12.89	13.48	13.26
	27-Oct	12.91	11.32	12.75	12.98	13.33	13.19
	28-Oct	12.96	11.57	12.72	13.19	13.31	13.23
	29-Oct	12.82	11.81	12.81	12.87	13.18	13.06
ΔT = NO WPS - WPS	15-Oct	1.09	-0.26	2.40	5.23	7.28	5.78
	16-Oct	0.98	0.30	2.74	4.77	7.08	5.55
	17-Oct	1.26	1.43	3.16	5.28	7.00	5.64
	18-Oct	0.47	-0.33	1.62	4.53	6.48	5.03
	19-Oct	0.73	-0.48	1.39	4.10	6.15	4.79
	20-Oct	1.11	-0.76	1.35	4.16	6.17	4.89
	21-Oct	1.31	-0.54	2.35	4.16	6.05	4.85
	22-Oct	1.10	-0.90	2.14	4.17	5.62	4.53
	23-Oct	0.51	-0.91	1.19	3.59	4.77	3.77
	24-Oct	0.24	-0.59	1.27	3.07	3.85	3.04
	25-Oct	0.53	-0.02	1.49	2.86	4.20	3.29
	26-Oct	0.29	-0.48	1.26	2.58	3.83	2.96
	27-Oct	0.51	-0.93	1.25	2.79	3.78	3.00
	28-Oct	0.61	-0.63	1.14	2.70	3.37	2.74
	29-Oct	0.49	-0.42	1.13	2.14	2.92	2.33

Table 5-2. Maximum temperature at the turbine penstocks, with and without the HPS, on 2002

		Daily Average Temperatures (^{o}C) - 2002					
		Unit#1	Unit#2	Unit#3	Unit#4	Unit#5	Flowrate Weighted Average
WPS	15-Oct	13.40	13.15	11.67	9.30	8.20	9.35
	16-Oct	13.43	13.13	11.68	9.34	8.23	9.39
	17-Oct	13.49	13.22	11.81	9.49	8.46	9.52
	18-Oct	13.00	12.77	11.56	9.55	8.56	9.56
	19-Oct	13.15	12.89	11.69	9.68	8.71	9.71
	20-Oct	12.91	12.68	11.43	9.37	8.40	9.41
	21-Oct	12.69	12.48	11.27	9.34	8.41	9.35
	22-Oct	12.51	12.33	11.18	9.42	8.60	9.44
	23-Oct	12.36	12.17	11.29	9.79	9.12	9.80
	24-Oct	12.40	12.26	11.53	10.25	9.60	10.23
	25-Oct	12.59	12.43	11.60	10.16	9.48	10.14
	26-Oct	12.56	12.44	11.69	10.42	9.80	10.42
	27-Oct	12.52	12.36	11.64	10.37	9.76	10.38
	28-Oct	12.40	12.29	11.72	10.71	10.20	10.70
	29-Oct	12.37	12.27	11.76	10.86	10.41	10.85
NO WPS	15-Oct	14.54	13.55	14.36	14.87	15.55	15.24
	16-Oct	14.54	14.66	14.95	14.46	15.37	15.06
	17-Oct	14.84	14.80	15.10	14.99	15.43	15.24
	18-Oct	13.62	13.25	14.15	14.17	15.06	14.63
	19-Oct	14.03	12.57	13.35	13.93	14.90	14.47
	20-Oct	14.02	12.47	13.12	13.68	14.57	14.24
	21-Oct	14.09	12.85	14.24	13.81	14.52	14.20
	22-Oct	13.93	11.92	13.92	13.91	14.18	13.99
	23-Oct	12.93	11.86	13.24	13.96	13.87	13.69
	24-Oct	12.96	12.00	13.14	13.30	13.64	13.33
	25-Oct	13.31	13.01	13.45	13.36	13.71	13.47
	26-Oct	12.97	12.84	13.26	13.07	13.57	13.33
	27-Oct	12.98	12.25	13.15	13.21	13.51	13.31
	28-Oct	13.11	12.05	13.12	13.28	13.35	13.27
	29-Oct	12.94	12.24	12.93	13.06	13.28	13.18
ΔT = NO WPS - WPS	15-Oct	1.14	0.40	2.69	5.57	7.36	5.89
	16-Oct	1.11	1.53	3.27	5.12	7.15	5.67
	17-Oct	1.35	1.58	3.29	5.50	6.97	5.72
	18-Oct	0.62	0.47	2.59	4.63	6.50	5.07
	19-Oct	0.88	-0.32	1.66	4.25	6.18	4.76
	20-Oct	1.11	-0.21	1.69	4.31	6.17	4.84
	21-Oct	1.40	0.37	2.97	4.47	6.11	4.85
	22-Oct	1.42	-0.41	2.74	4.49	5.58	4.56
	23-Oct	0.57	-0.31	1.95	4.17	4.75	3.89
	24-Oct	0.56	-0.27	1.61	3.05	4.04	3.10
	25-Oct	0.72	0.59	1.84	3.20	4.23	3.33
	26-Oct	0.42	0.39	1.57	2.65	3.77	2.91
	27-Oct	0.46	-0.11	1.51	2.84	3.75	2.93
	28-Oct	0.71	-0.24	1.39	2.58	3.15	2.57
	29-Oct	0.58	-0.02	1.17	2.20	2.87	2.33

The HPS flow rate was based on the maximum conceptual capacity of the system (i.e. 5000 cfs) in order to evaluate in-reservoir effects. This flow rate was likely greater than what would necessary to cool the outflow to meet the temperature criteria. The eastern turbines are the most affected by the HPS due to the orientation of the pipes. The temperature reduction in Unit #2 is minimal because this turbine is closed and it is also located in a region where the influence of the HPS appeared insignificant in this model. This model is not optimized for pipe inlet or outlet location, orientation or configuration.

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6. 1999 SIMULATIONS

6.1 Simulation 1999-HPS

3D Simplified Model

The water surface elevation in the simplified model used for the 2002 simulation was reduced to 2029.9 ft to represent the conditions observed in 1999.

Figures 6-1 to 6-3 show temperature distribution obtained with the pump system on October 17, 21 and 29, 1999. An animated version of this figure is found in Figure6-5.AVI. The temperature of the hypolimnion is warmer and stratification weaker, than that in 2002.

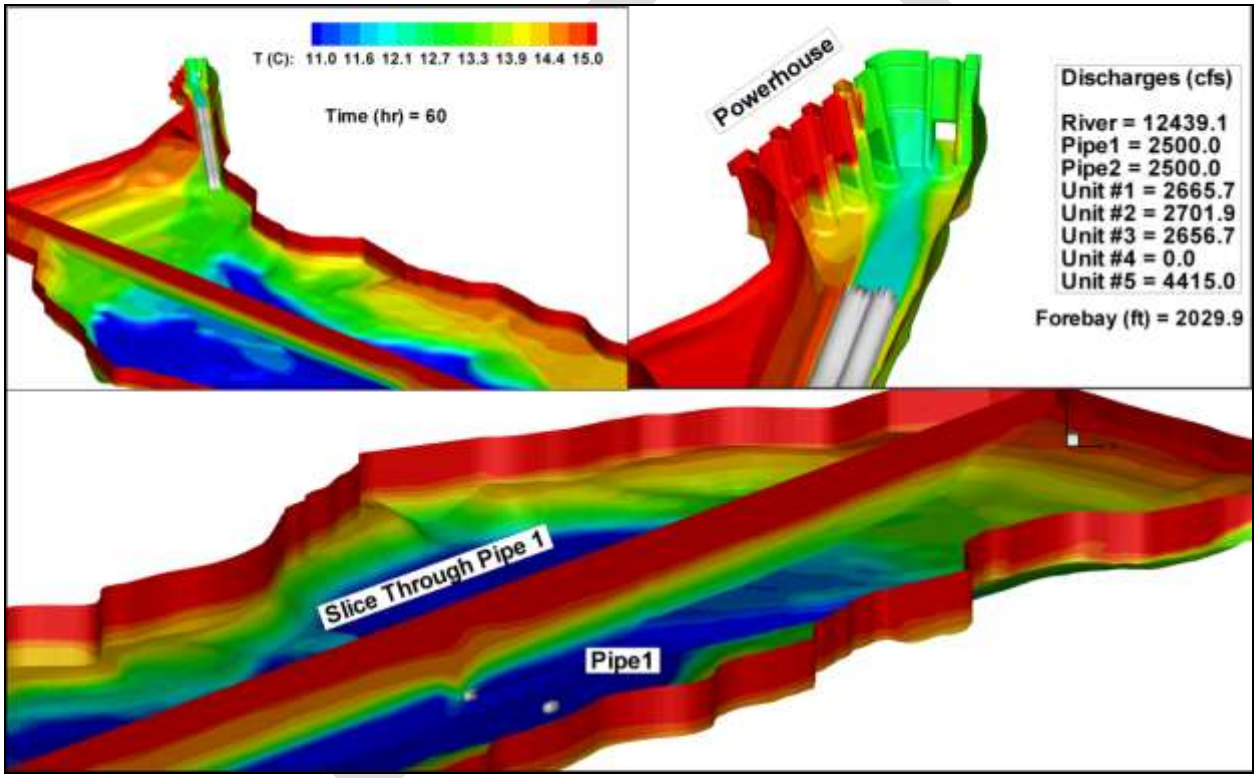

Figure 6-1. Temperature distribution obtained on October 17, 1999 with the HPS

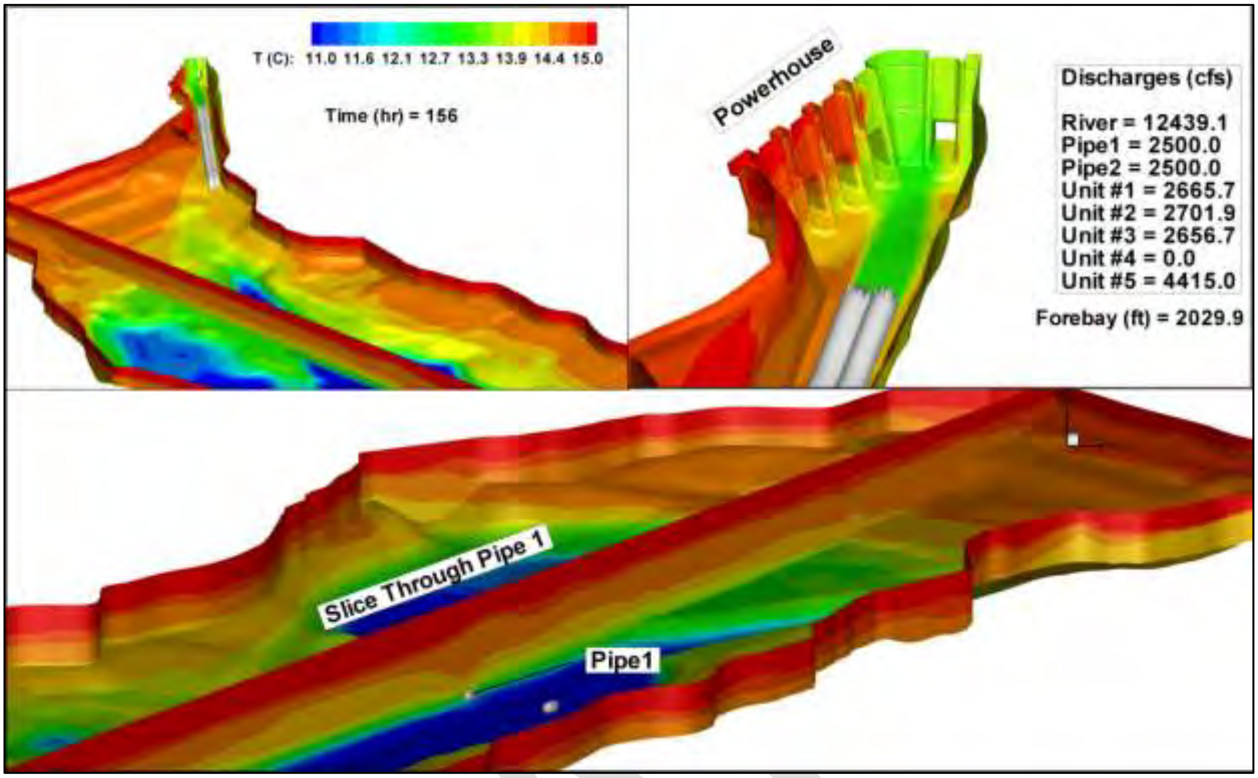

Figure 6-2. Temperature distribution obtained with on October 21, 1999 with the HPS

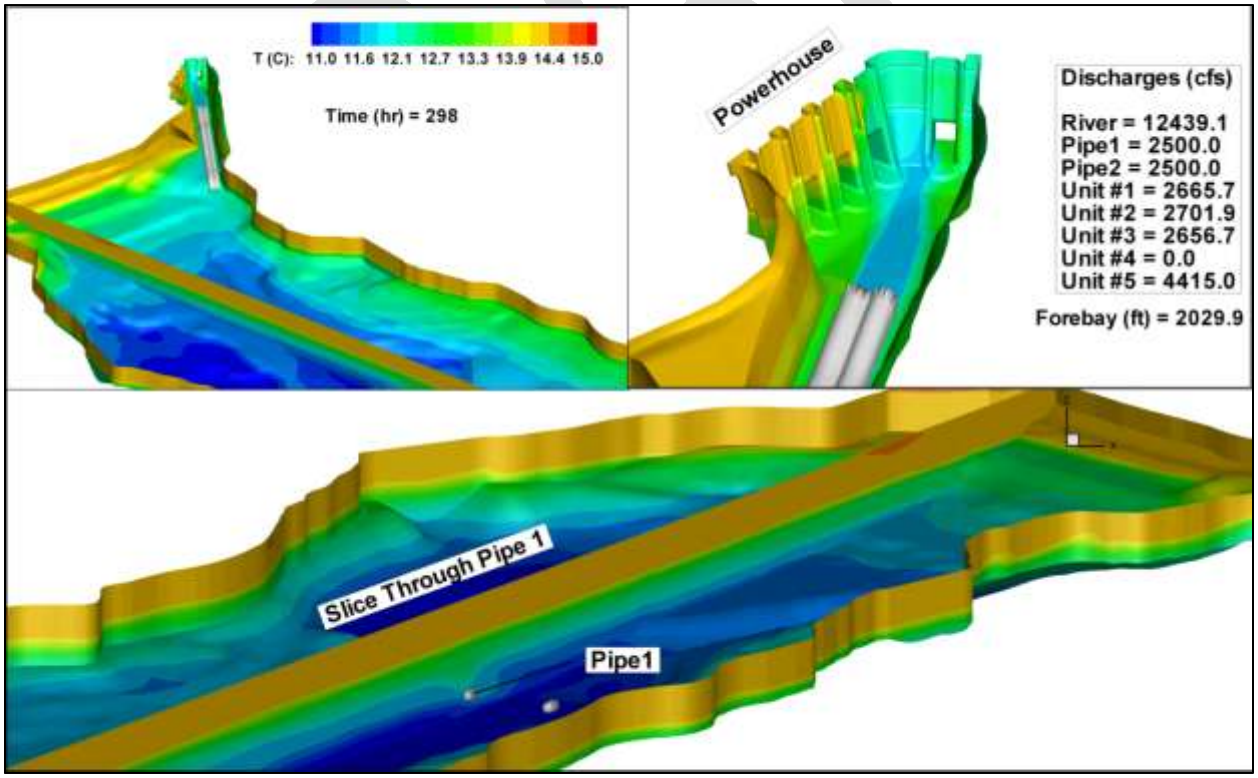

Figure 6-3. Temperature distribution obtained with on October 27, 1999 with the HPS

Figure 6-4 shows velocity vectors and temperature contours in horizontal slices at different elevations from the free surface. The highest temperature is predicted on the western region of the intake channel. At that region, the influence of the water pump system is minimal. A recirculation is observed at the center of the intake channel near the free surface. Note the elevated water velocity on the pipes in the center of the intake channel at 82 ft beneath the water surface. The top and bottom of the turbine inlets are at about 48 and 98 ft from the free surface.

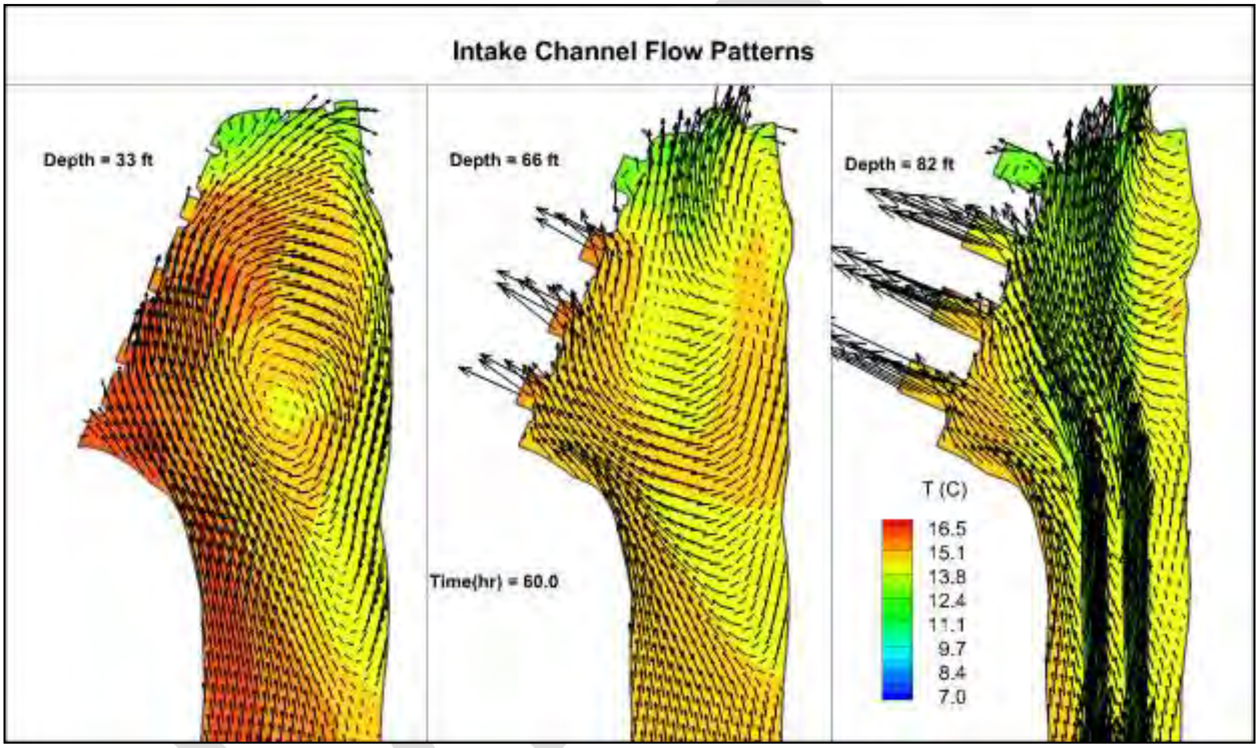

Figure 6-4. Velocity vectors and temperature contours at the intake channel on October 17, 2002

Streamlines colored by temperature in Figure 6-5 illustrate the flow pattern and temperature distribution in the intake channel. An animated version of this figure is found in Figure6-5.AVI in the attached DVD. The HPS causes several recirculations and increases the velocity in the intake channel, which result in important thermal mixing.

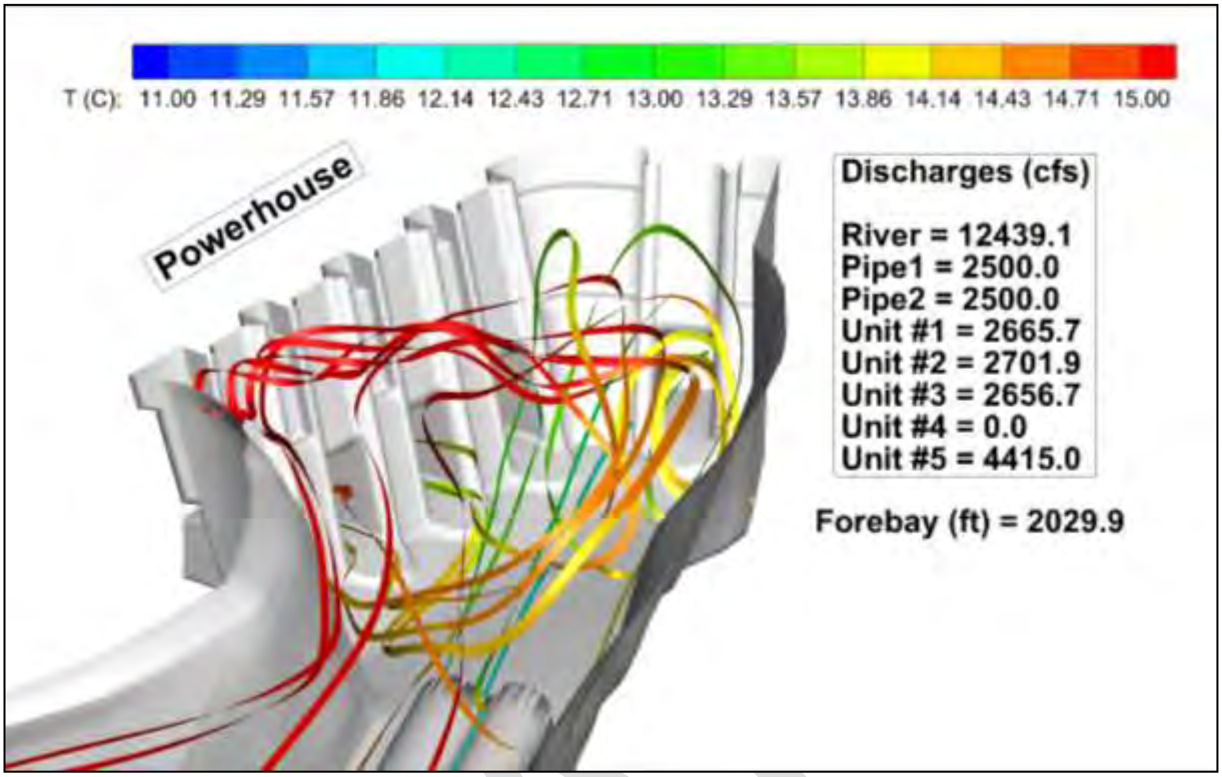

Figure 6-5. Streamlines colored by temperature at the intake channel on October 17, 1999 with the HPS

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Figure 6-6 shows the evolution of the flowrate average temperature of water drawn by the pipes and at the turbine penstocks. During 14 days, the temperature in the pipes ranges from approximately 11.5 °C to 13.5 °C. The initial temperature of the pumped water (i.e. approximately 12 °C) indicates that the pump accessed water both from the hypolimnion (i.e. 10.5 °C, Figure 4-8) and warmer layers of the metalimnion. This is due to the weak stratification condition and relatively small hypolimnion volume in 1999, combined with the elevation of the intakes. The first week the temperature of the pumped water increases as the HPS is taking hypolimnion water from the reservoir. However, on October 22, more cold water is available upstream (i.e. plunging Snake River inflow) and the temperature of the hypolimnion and metalimnion starts to decrease (Figure 4-7). The temperature drawn by the HPS on 1999 is approximately 4.5-6.5 °C higher than that in 2002. This is the result of a warmer hypolimnion, with about 5 °C higher temperature on 1999, and a weaker stratification that causes some of the water from the metalimnion to be drawn by the pipes. During the 14 simulated days, the flowrate averaged temperature ranges from approximately 14.0 °C to 12.8 °C. Temperature in turbine #5 is the lowest of all operating turbines.

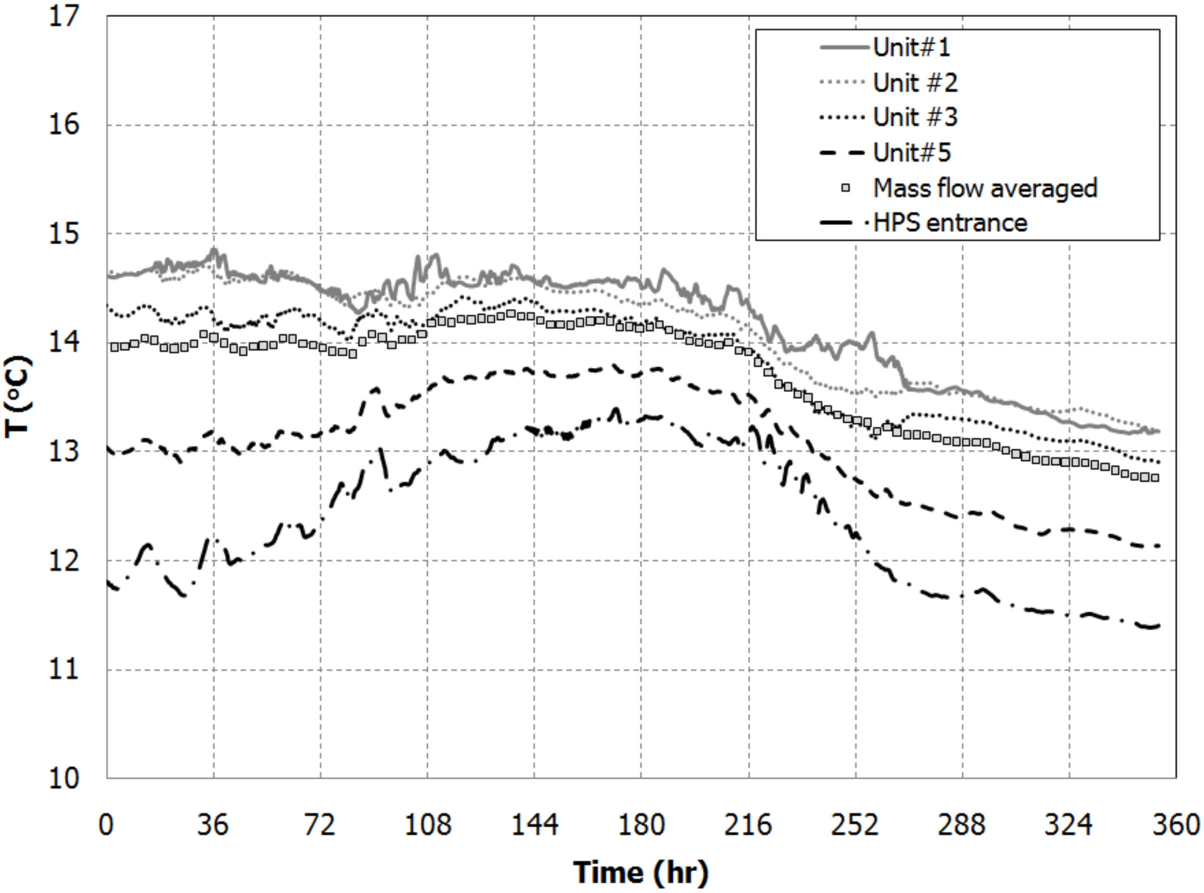

Figure 6-6. Evolution of the temperature at the pipe inlet and intake penstock on 1999 with the HPS

6.2 Simulation 1999

Figures 6-7 to 6-10 shows temperature contours obtained on October 17, 21 and 27, 2002. An animation of this plot is found in Figure6-7.AVI in the attached DVD. The forebay cooling is noticeable at the end of October in 1999. In the first days, temperatures predicted near the powerhouse are approximately 1 °C warmer than those obtained with the HPS. However, after the October 23 the effect of the HPS is negligible and, in the last days, the temperature in the turbines with the HPS operating is higher.

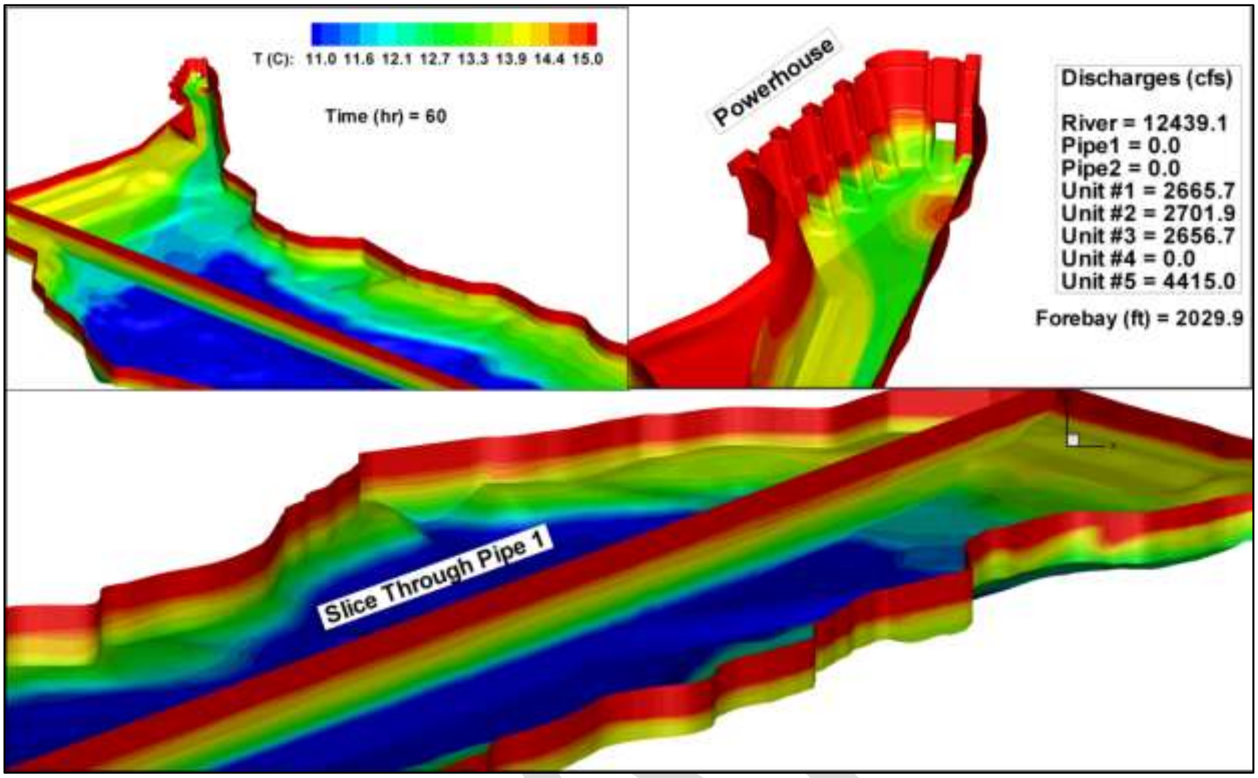

Figure 6-7. Temperature distribution on October 17, 1999

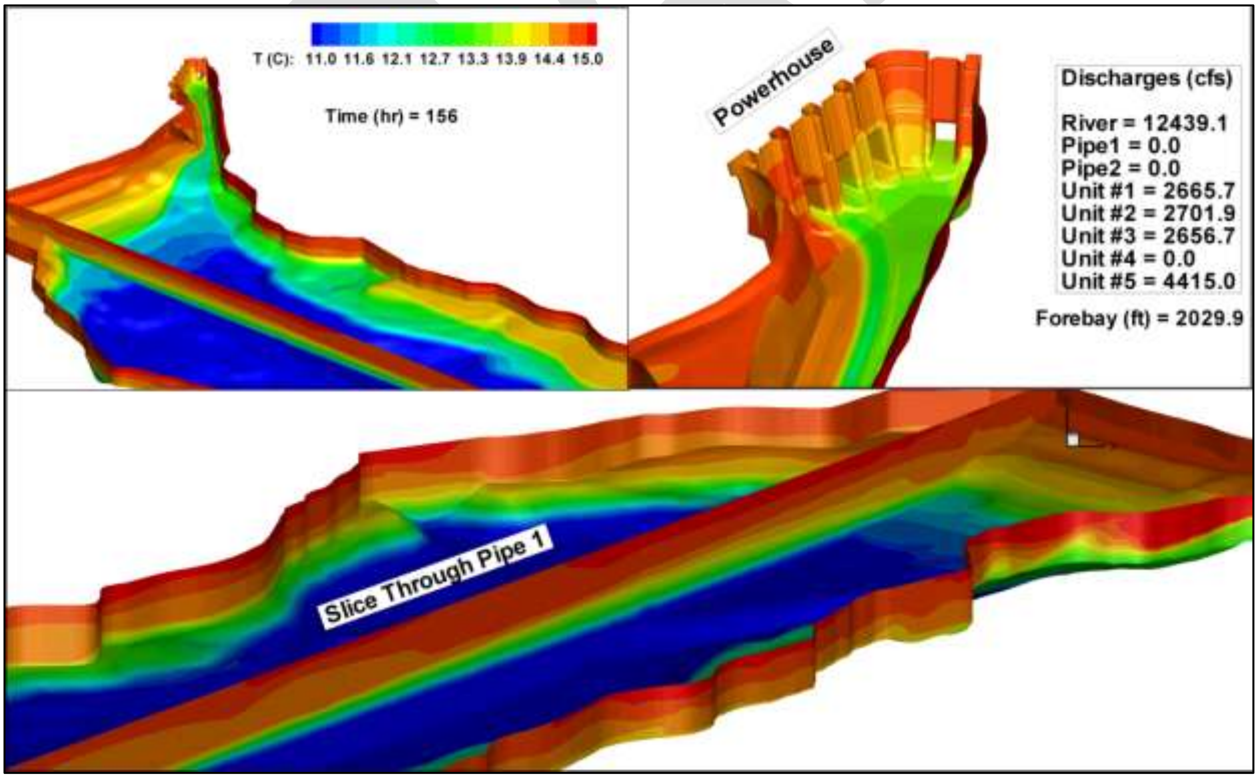

Figure 6-8. Temperature distribution obtained on October 21, 1999

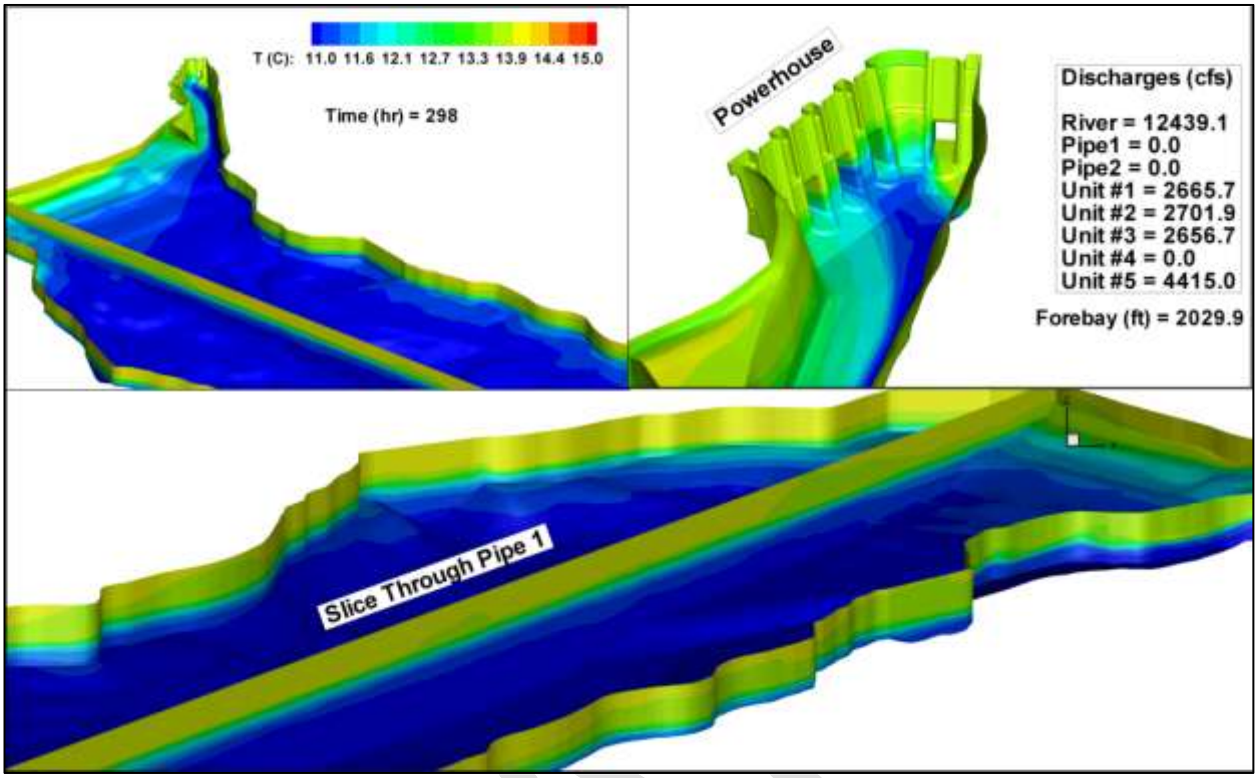

Figure 6-9. Temperature distribution on October 27, 1999

Figure 6-10 shows streamlines colored by temperature. An animation of this figure is in Figure6-10.AVI in the attached DVD. Similar to predicted on 2002, the temperature mixing near the powerhouse is insignificant compared to that with the HPS. However, a big eddy causing thermal mixing is predicted in front of turbine #5. Warm water from the western region near the free surface is attracted by turbines #1 and #2.

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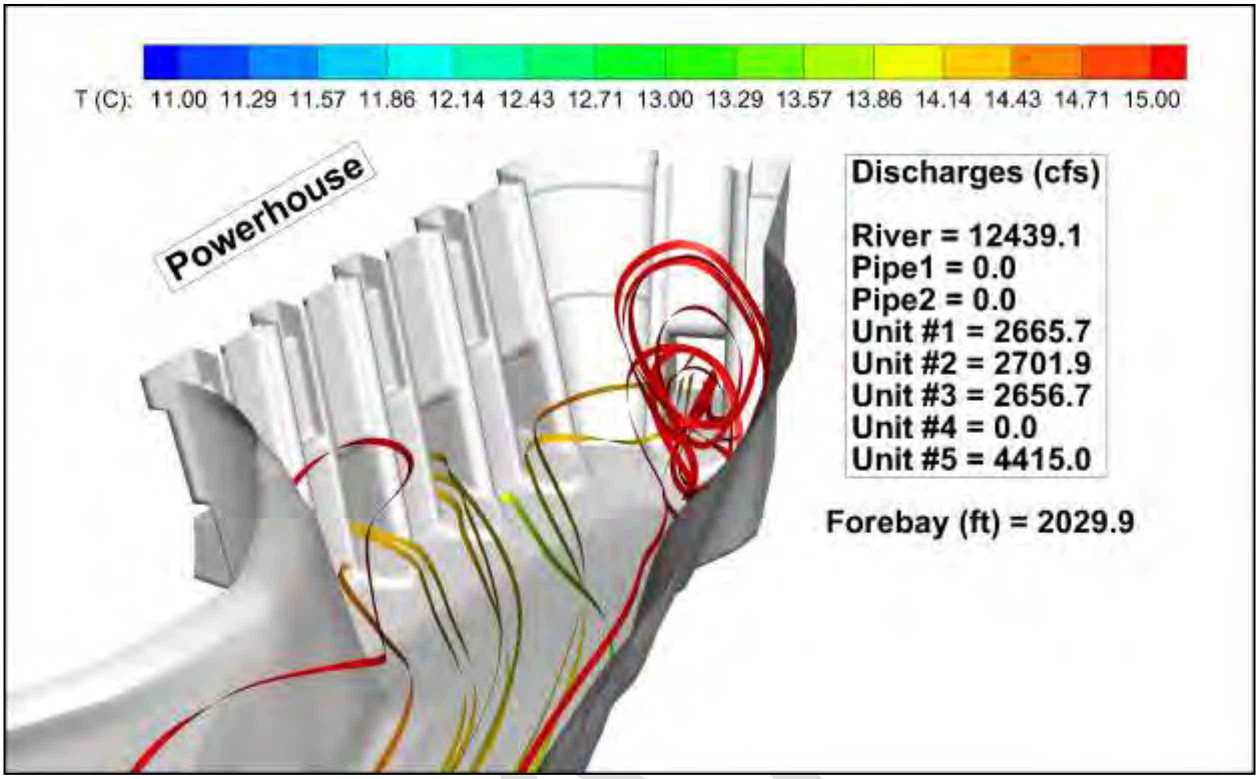

Figure 6-10. Streamlines colored by temperature on October 17, 1999

The evolution of the temperature at the turbine penstocks is shown in Figure 6-11. The highest temperature is observed in unit #1. The temperature in turbine #5 is lower than predicted for 2002 without the HWS. Note that on 2002, turbine #5 comprises 64% of the total flow and some water is drawn from surface warmer layers. On the other hand, on 1999, turbine #5 carries 35% of turbine flows, decreasing the possibility of drawing surface water. In addition, the big predicted eddy in front of turbine #5 contributes to temperature mixing before entering to the turbine. The flowrate average temperature ranges from approximately 15 °C in October 15, 1999 to 12.7 °C at the end of October, 1999.

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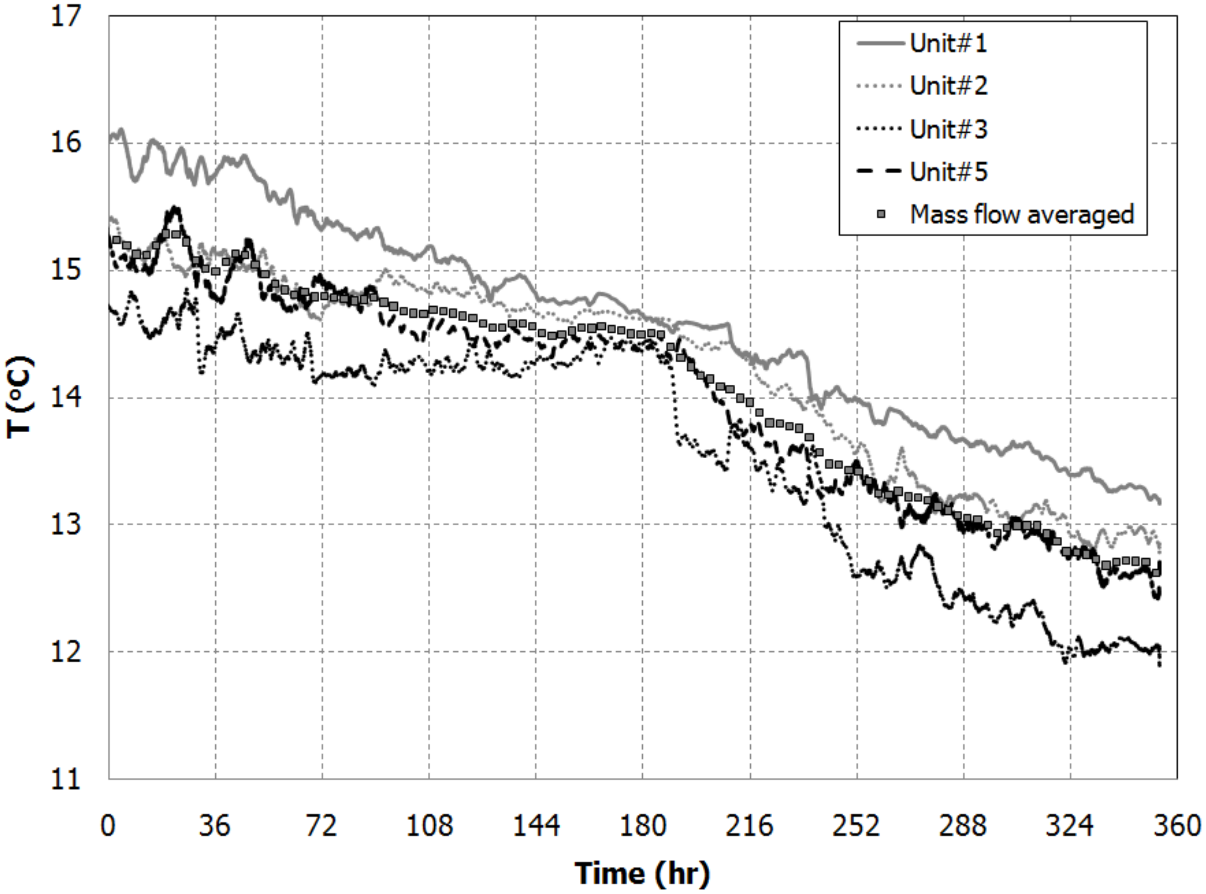

Figure 6-11. Evolution of the temperature at the temperature penstocks in 1999

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Figure 6-12 shows model prediction at unit #5 against measurements at the right channel near the bridge downstream of Brownlee. Good agreement is found between numerical predictions and field data.

Figure 6-13 shows predicted temperature profiles at the pipe entrance location against temperature profiles simulated with CEQUAL at 0.5 miles upstream of Brownlee Dam. Both models predict similar profiles.

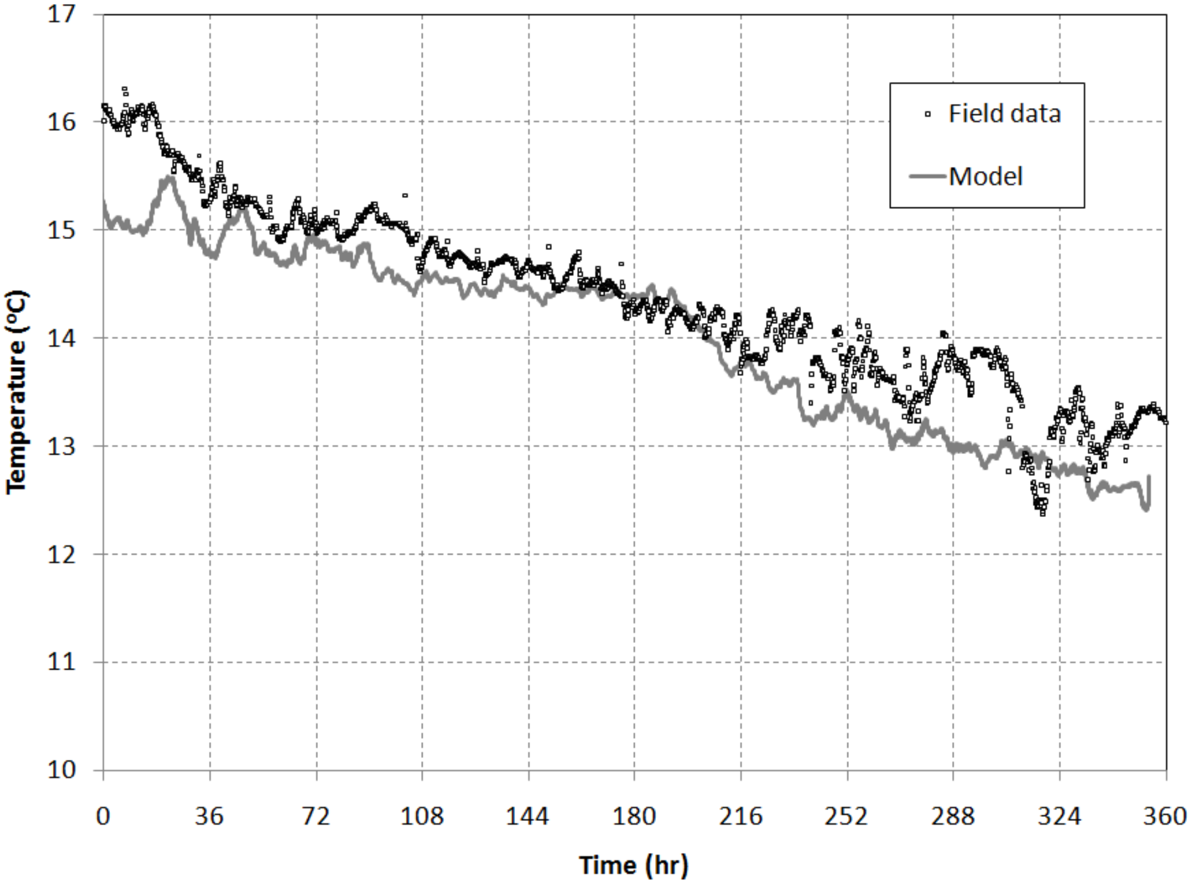

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Figure 6-12. Model predictions in turbine #5 and temperature measured at the downstream right channel on 1999

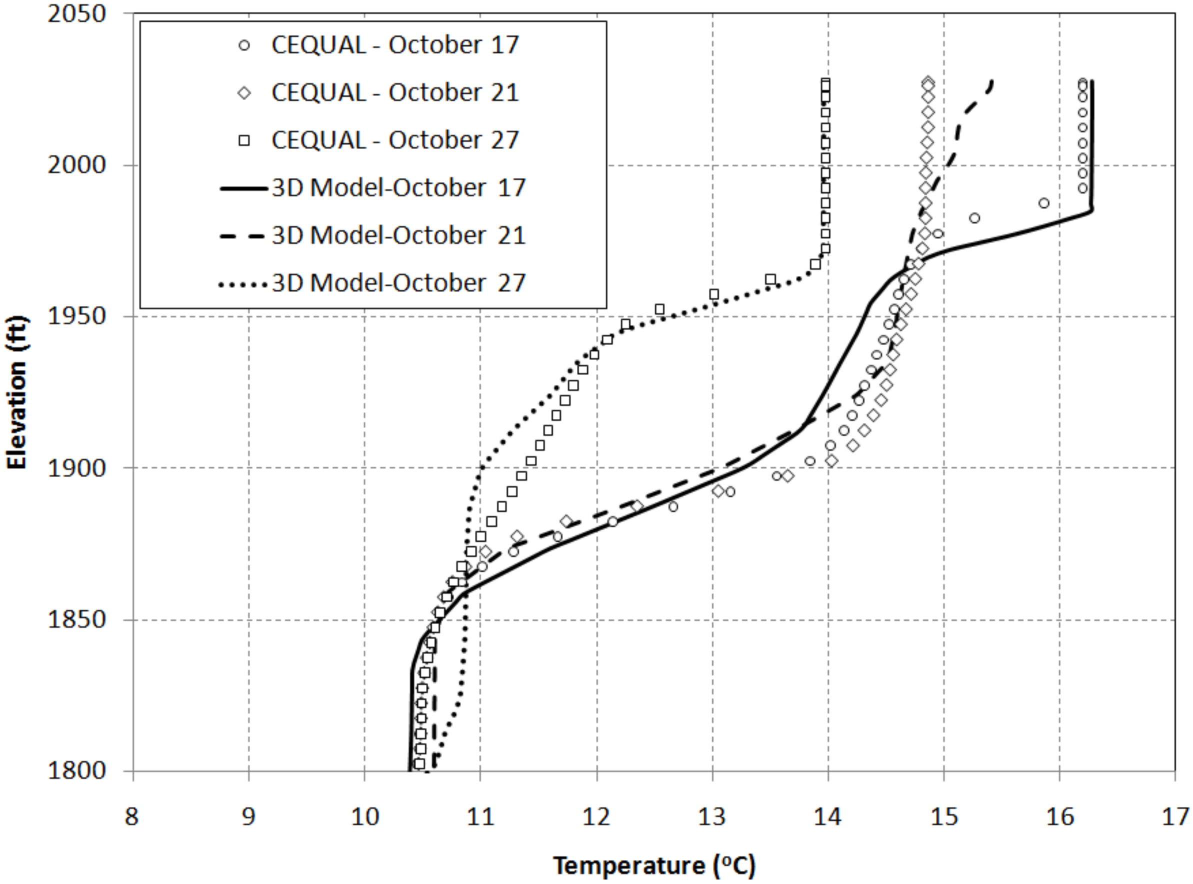

Figure 6-17. CE-QUAL modeled and 3D modeled temperature profiles on 1999

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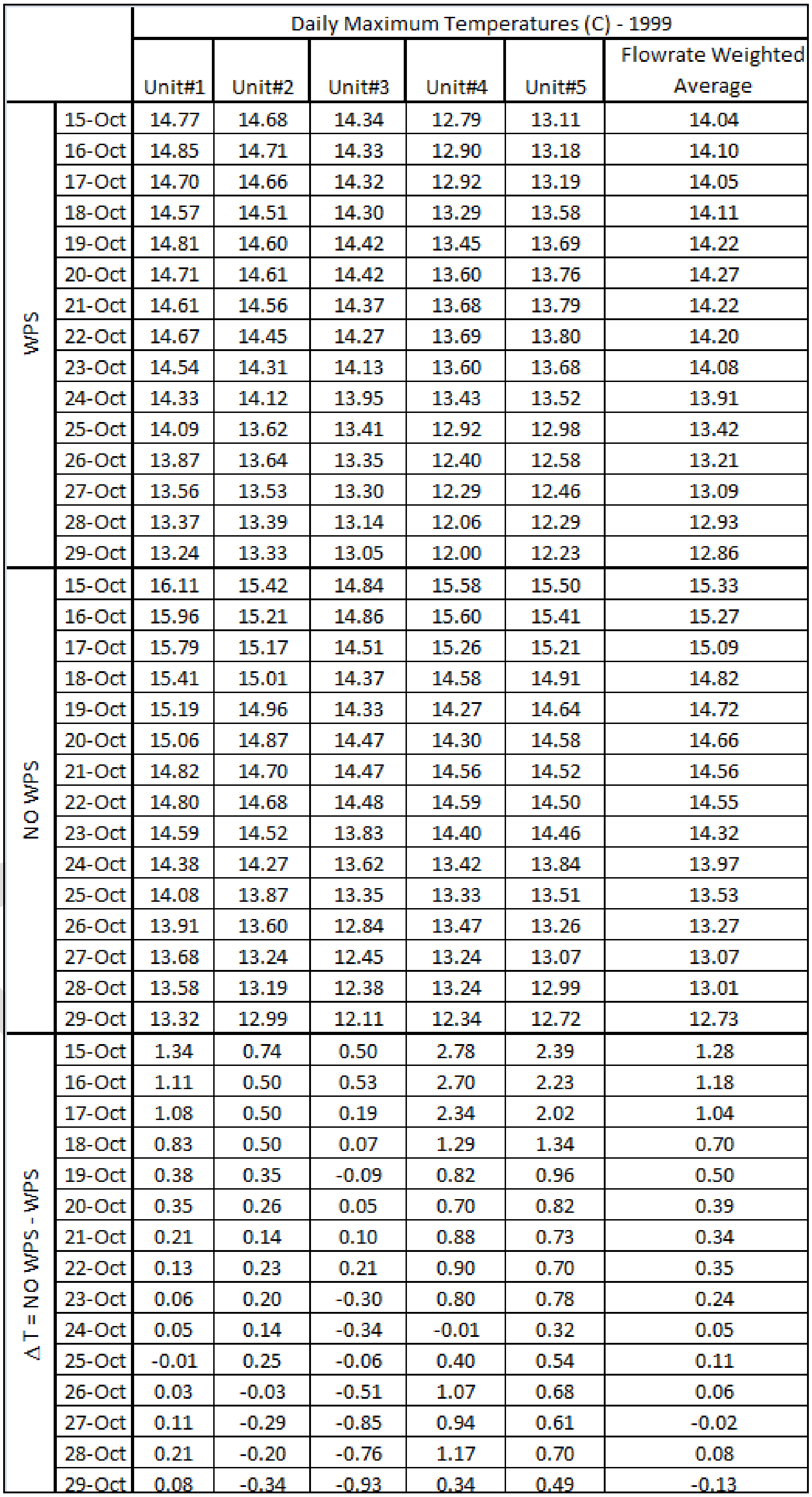
6.3 Effect of the HPS

In 1999 it appears that a warmer, smaller hypolimnion and weak stratification conditions combined with elevation of the intakes caused the pump to draw water that was slightly warmer than the coolest water available. This means that the thermocline was disturbed and both hypolimnetic and metalimnetic water was mixed into the intakes. However, the HPS was still able to provide cooler water than the baseline outflow for the majority of the time period. Tables 6-1 and 6-2 show average and maximum daily temperature in the turbine penstocks, with and without the HPS. Unit 4 (closed unit) is, at the beginning of the simulation, about 2 °C warmer than the closed units in 2002. This is in part explained by the higher temperature observed in the metalimnion in 1999, which greatly contributes to turbine flows. In 1999, the HPS reduced the downstream temperature from October 15 to October 26 by about 1.2 °C to 0.04 °C.

Table 6-1. Average temperature at the turbine penstocks, with and without the HPS, on 1999

		Daily Average Temperatures (C) - 1999					
		Unit#1	Unit#2	Unit#3	Unit#4	Unit#5	Flowrate Weighted Average
WPS	15-Oct	14.66	14.63	14.27	12.69	13.02	13.99
	16-Oct	14.70	14.62	14.21	12.78	13.05	13.99
	17-Oct	14.59	14.59	14.24	12.85	13.12	13.99
	18-Oct	14.42	14.43	14.17	13.07	13.33	13.98
	19-Oct	14.60	14.46	14.24	13.33	13.55	14.12
	20-Oct	14.60	14.57	14.37	13.52	13.71	14.23
	21-Oct	14.54	14.48	14.30	13.61	13.72	14.19
	22-Oct	14.56	14.38	14.19	13.66	13.73	14.15
	23-Oct	14.42	14.24	14.06	13.50	13.56	14.00
	24-Oct	14.06	13.85	13.65	13.14	13.22	13.63
	25-Oct	13.95	13.56	13.28	12.64	12.75	13.29
	26-Oct	13.61	13.58	13.31	12.31	12.48	13.14
	27-Oct	13.47	13.46	13.23	12.20	12.38	13.03
	28-Oct	13.29	13.37	13.10	12.04	12.27	12.90
	29-Oct	13.18	13.23	12.95	11.92	12.15	12.78
NO WPS	15-Oct	15.91	15.18	14.62	15.15	15.16	15.21
	16-Oct	15.82	15.07	14.51	14.99	15.02	15.09
	17-Oct	15.54	14.86	14.32	14.76	14.82	14.88
	18-Oct	15.29	14.82	14.20	14.33	14.76	14.77
	19-Oct	15.11	14.86	14.25	14.12	14.54	14.67
	20-Oct	14.91	14.74	14.26	14.18	14.47	14.58
	21-Oct	14.77	14.65	14.32	14.33	14.43	14.52
	22-Oct	14.65	14.62	14.34	13.99	14.39	14.49
	23-Oct	14.51	14.41	13.62	13.79	14.03	14.13
	24-Oct	14.26	14.04	13.38	13.11	13.57	13.78
	25-Oct	13.95	13.56	12.74	12.80	13.31	13.38
	26-Oct	13.76	13.30	12.59	13.15	13.10	13.18
	27-Oct	13.62	13.12	12.33	12.72	12.95	13.00
	28-Oct	13.44	12.99	12.07	12.55	12.80	12.82
	29-Oct	13.27	12.92	12.05	12.25	12.60	12.69
Δ T = NO WPS - WPS	15-Oct	1.25	0.56	0.35	2.46	2.14	1.22
	16-Oct	1.11	0.45	0.29	2.21	1.97	1.10
	17-Oct	0.95	0.26	0.08	1.92	1.70	0.88
	18-Oct	0.87	0.39	0.03	1.26	1.44	0.79
	19-Oct	0.52	0.40	0.01	0.78	0.99	0.55
	20-Oct	0.31	0.17	-0.10	0.66	0.75	0.35
	21-Oct	0.22	0.17	0.02	0.72	0.70	0.34
	22-Oct	0.09	0.24	0.16	0.33	0.66	0.34
	23-Oct	0.10	0.16	-0.44	0.29	0.47	0.13
	24-Oct	0.20	0.19	-0.27	-0.04	0.35	0.15
	25-Oct	0.00	0.00	-0.53	0.16	0.57	0.09
	26-Oct	0.15	-0.28	-0.72	0.85	0.63	0.04
	27-Oct	0.14	-0.34	-0.90	0.52	0.58	-0.03
	28-Oct	0.15	-0.38	-1.03	0.51	0.53	-0.08
	29-Oct	0.09	-0.32	-0.90	0.33	0.45	-0.08

Table 6-2. Maximum temperature at the turbine penstocks, with and without the HPS, on 1999



		Daily Maximum Temperatures (C) - 1999					
		Unit#1	Unit#2	Unit#3	Unit#4	Unit#5	Flowrate Weighted Average
WPS	15-Oct	14.77	14.68	14.34	12.79	13.11	14.04
	16-Oct	14.85	14.71	14.33	12.90	13.18	14.10
	17-Oct	14.70	14.66	14.32	12.92	13.19	14.05
	18-Oct	14.57	14.51	14.30	13.29	13.58	14.11
	19-Oct	14.81	14.60	14.42	13.45	13.69	14.22
	20-Oct	14.71	14.61	14.42	13.60	13.76	14.27
	21-Oct	14.61	14.56	14.37	13.68	13.79	14.22
	22-Oct	14.67	14.45	14.27	13.69	13.80	14.20
	23-Oct	14.54	14.31	14.13	13.60	13.68	14.08
	24-Oct	14.33	14.12	13.95	13.43	13.52	13.91
	25-Oct	14.09	13.62	13.41	12.92	12.98	13.42
	26-Oct	13.87	13.64	13.35	12.40	12.58	13.21
	27-Oct	13.56	13.53	13.30	12.29	12.46	13.09
	28-Oct	13.37	13.39	13.14	12.06	12.29	12.93
	29-Oct	13.24	13.33	13.05	12.00	12.23	12.86
NO WPS	15-Oct	16.11	15.42	14.84	15.58	15.50	15.33
	16-Oct	15.96	15.21	14.86	15.60	15.41	15.27
	17-Oct	15.79	15.17	14.51	15.26	15.21	15.09
	18-Oct	15.41	15.01	14.37	14.58	14.91	14.82
	19-Oct	15.19	14.96	14.33	14.27	14.64	14.72
	20-Oct	15.06	14.87	14.47	14.30	14.58	14.66
	21-Oct	14.82	14.70	14.47	14.56	14.52	14.56
	22-Oct	14.80	14.68	14.48	14.59	14.50	14.55
	23-Oct	14.59	14.52	13.83	14.40	14.46	14.32
	24-Oct	14.38	14.27	13.62	13.42	13.84	13.97
	25-Oct	14.08	13.87	13.35	13.33	13.51	13.53
	26-Oct	13.91	13.60	12.84	13.47	13.26	13.27
	27-Oct	13.68	13.24	12.45	13.24	13.07	13.07
	28-Oct	13.58	13.19	12.38	13.24	12.99	13.01
	29-Oct	13.32	12.99	12.11	12.34	12.72	12.73
Δ T = NO WPS - WPS	15-Oct	1.34	0.74	0.50	2.78	2.39	1.28
	16-Oct	1.11	0.50	0.53	2.70	2.23	1.18
	17-Oct	1.08	0.50	0.19	2.34	2.02	1.04
	18-Oct	0.83	0.50	0.07	1.29	1.34	0.70
	19-Oct	0.38	0.35	-0.09	0.82	0.96	0.50
	20-Oct	0.35	0.26	0.05	0.70	0.82	0.39
	21-Oct	0.21	0.14	0.10	0.88	0.73	0.34
	22-Oct	0.13	0.23	0.21	0.90	0.70	0.35
	23-Oct	0.06	0.20	-0.30	0.80	0.78	0.24
	24-Oct	0.05	0.14	-0.34	-0.01	0.32	0.05
	25-Oct	-0.01	0.25	-0.06	0.40	0.54	0.11
	26-Oct	0.03	-0.03	-0.51	1.07	0.68	0.06
	27-Oct	0.11	-0.29	-0.85	0.94	0.61	-0.02
	28-Oct	0.21	-0.20	-0.76	1.17	0.70	0.08
	29-Oct	0.08	-0.34	-0.93	0.34	0.49	-0.13

7. SUMMARY AND CONCLUSIONS

An unsteady 3D thermal model considering the effect of the solar radiation, air temperature, and wind was implemented into the commercial code Fluent to model the temperature dynamics in Brownlee Reservoir. The effect of buoyancy, which is a dominant process in the forebay, was taken into account into the model.

A comprehensive model, which includes the pipes in the forebay and intake channel, and forebay details near the river bank and spillway, was constructed. The model extends about 0.7 miles upstream of the dam. The model was run 3.5 days on October 2002 and numerical results indicate that the pump system is capable of drawing cold water to the intake channel, decreasing water temperature in the turbine inlets.

Running the 3D comprehensive model was slow. Therefore, some simplifications were used to allow the model to run in real time with current computer capabilities. A simplified model using a coarser and better quality grid was constructed. The pump system was modeled considering only a small portion of the pipes in the forebay to take into account the effect of the pump system on the forebay. The pipes were included in the intake channel. The availability of cold water and inlet boundary condition was obtained with a 2D model that includes 1.4 miles of the forebay. Similar temperature profiles and average temperature at the pipe entrances were predicted with the refined and simplified models.

Two river flow conditions, with and without the HPS, were simulated with the simplified model to evaluate the pump system performance during fourteen days at the end of October. Operational and atmospheric conditions observed on 1999 and 2002 were used.

Model results were compared against temperature measured at the right channel downstream of intake #5. Good agreement between model and field data was found.

According to the model, during the low flow condition observed in October 2002, the pipe entrances draws water from the hypolimnion at approximately 5.2 ^{o}C at the beginning of the simulation to 9.2 ^{o}C at the end of October. In average, the flowrate average temperature in the turbine penstocks was reduced due to the incorporation of the water pump system, from 13.9 ^{o}C

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to 9.8 °C. The HPS flow rate was based on the maximum conceptual capacity of the system (i.e. 5,000 cfs) in order to evaluate in-reservoir effects.

During the high flow condition observed in 1999, the stratification was weaker and temperature in the hypolimnion was about 5 °C higher than in 2002. The HPS was still able to provide cooler water than the baseline outflow for the majority of the time period. However, it appears that the thermocline was disturbed and both hypolimnetic and metalimnetic water was mixed into the intakes.

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8. REFERENCES

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Exhibit 7.1-12

May 4, 2004, Federal Energy Regulatory Commission (FERC) request for additional information

FEDERAL ENERGY REGULATORY COMMISSION
WASHINGTON, D.C. 20426

May 4, 2004

OFFICE OF ENERGY PROJECTS

Project No. 1971-079 B Idaho/Oregon
Hells Canyon Project
Idaho Power Company

Mr. Robert W. Stahman
Vice President, Secretary, and General Counsel
Idaho Power Company
P.O. Box 70
Boise, ID 83707

Reference: Request for Additional Information

Dear Mr. Stahman:

We need additional information before we can complete our evaluation of your license application for this project. Under section 4.32(g) of the Commission's regulations, you have from 3 months to 9 months from the date of this letter to provide the information we request in the enclosed Schedule A. If the requested information causes any other part of the application to be inaccurate, that part must also be revised and refiled by the due date.

In some items, we ask you to provide both agency comments and your response to those comments. Within five days of receipt, you should provide a copy of this letter and the enclosed schedule to all agencies that we ask you to consult. Then, when you complete your response, make a written request to the agencies for comment. Allow the agencies at least 30 days to respond before filing and include in your filing copies of all agency comments and recommendations, as well as how you addressed them. If the agencies do not reply, you should provide us dated copies of your request for comments.

Please file your responses to this request (an original and eight copies) with Magalie Salas, Secretary, Federal Energy Regulatory Commission, 888 First Street, N.E., Washington, D.C. 20426. Please put FERC Docket Number P-1971-079 on the first page of your responses.

When you file the requested information with us, you must at the same time serve copies of the filing on each agency consulted under section 16.8 of the regulations.

For your information, the current schedule for processing your license application is as follows:

Major Milestone	Target Date
Request for Additional Information	April 2004
Scoping Document 2	June 2004
Receipt of Additional Information	February 2005
Ready for Environmental Analysis Notice, requesting final terms and conditions, recommendations, comments, and reply comments	February 2005
Draft EIS Issued	September 2005
Draft EIS Meeting	September/October 2005
Final EIS Issued	March 2006

We believe that a meeting would be beneficial to clarify our requests and answer any questions you might have. We will be contacting you shortly to discuss arranging such a meeting.

If you have any questions regarding the information requested in this letter, please contact Alan Mitchnick at 202-502-6074, alan.mitchnick@ferc.gov; or Emily Carter at 202-502-6512, emily.carter@ferc.gov.

Sincerely,

Timothy J. Welch
Chief
Hydro West Branch 2

Enclosure: Schedule A
cc: Public Files
Service List

SCHEDULE A
ADDITIONAL INFORMATION REQUEST (AIR)
HELLS CANYON PROJECT (FERC NO. 1971-079)

The requests included in this Schedule A begin with two requests concerning general operations, and then appear in the same order in which resource issues were addressed in Scoping Document 1, Section 6.0. Each AIR indicates the number of months from the letter issuance date when the additional information is due to be filed with the Commission. The AIRs appear in the following order:

Resource/AIR Number	AIR Description	Filing Due
General Operations		
OP-1	Operational Scenarios	9 months
OP-2	Current Operations Scenario	3 months
Geology and Soils		
S-1	Sediment Transport	9 months
Water Quantity and Quality		
WQ-1	Dissolved Oxygen Augmentation	9 months
WQ-2	Temperature Control	9 months
Aquatic Resources		
AR-1	Hells Canyon Fish Trap Modifications	6 months
AR-2	Listed Molluscs	9 months
Terrestrial Resources		
TR-1	Habitat Resource Management	9 months
Land Use		
LU-1	Project Boundary Change	6 months
Developmental Resources		
DR-1	Thermal Alternative Cost of Capital	3 months
DR-2	Flood Control	6 months
DR-3	Power Economics	6 months
DR-4	Estimated Cost of PM&E Measures	9 months
Transmission Lines		
TL-1	Transmission Line Jurisdiction	3 months

GENERAL OPERATIONS

OP-1 Operational Scenarios
Time Required: 9 months

In our NEPA analysis, we will need to evaluate the environmental and developmental effects of a wider range of operational alternatives than was included in your final license application. Therefore, we need you to evaluate the environmental and developmental effects of operating restrictions that would fully or partially stabilize outflows from Hells Canyon dam while maintaining flexibility to use the project to meet peaks in electrical demand and to preserve your ability to respond to project emergencies and atypical power system conditions. We also need you to evaluate the operational and resource effects of: providing a 350,000 acre-feet draft of Brownlee reservoir; drawing down Brownlee reservoir year-round to minimum operating pool to reduce the effects of the project on downstream water temperatures and improve conditions for the downstream migration of smolts through the reservoir; and seasonal drawdown of Brownlee reservoir to reduce water temperatures during the fall and reduce gas supersaturation, as requested by NOAA Fisheries in its September 18, 2003, letter requesting additional studies. We also need you to evaluate the effects of target flows that could improve downstream navigation conditions as requested by the Corps in its letter dated December 22, 2003. We will use this information to identify a set of reasonable alternatives in the EIS, and to examine the costs and benefits of these potential operating restrictions on sediment transport, water quality, aquatic and terrestrial resources, recreation, navigation, power generation, and flood control.

These alternative scenarios should include the following:

1. Using Hells Canyon reservoir to re-regulate outflows, as follows:

    (a) the instantaneous outflow from Hells Canyon dam equals the average inflow to the Hells Canyon reservoir during the previous 24 hours;

    (b) maximum ramping rate of 2 inches per hour (year-round) as measured within 1.0 mile of Hells Canyon dam;

    (c) maximum ramping rate of 6 inches per hour (year-round) as measured within 1.0 mile of Hells Canyon dam;

    (d) maximum ramping rate of 2 inches per hour (March 1 through May 31) as measured within 1.0 mile of Hells Canyon dam

    (e) maximum ramping rate of 6 inches per hour (March 1 through May 31) as measured within 1.0 mile of Hells Canyon dam;

    (f) maximum ramping rate of 2 inches per hour March 1 through May 31 and 6 inches per hour for the rest of the year, plus a maximum total daily fluctuation of 2.0 feet year-round as measured within 1.0 mile of Hells Canyon dam;

2. Using Brownlee reservoir storage for flow augmentation and Hells Canyon reservoir to re-regulate outflows. Maximum ramping rate of 2 inches per hour (March 1 through May 31) as measured within 1.0 mile of Hells Canyon dam, plus a 350,000-acre-foot draft of Brownlee reservoir. Identical to Scenario 1(d) except that up to 350,000 acre-feet of water would be drafted between June 21 and July 31 each year. The reservoir target elevation would be 2,049 mean sea level (msl), and no additional water could be stored (increased water surface elevation) prior to August 31, but the reservoir could be drafted further as needed to meet power needs.
3. Operating to achieve navigation flow targets consisting of (a) an instantaneous, year-round minimum flow of 8,500 cfs above the mouth of the Salmon River as Measured at the Snake River at Hells Canyon Dam gage (no. 13290450), River Mile (RM) 247.0; and (b) an instantaneous minimum flow of 11,500 cfs below the mouth of the Salmon River as Measured at the Snake River below China Gardens Rapids gage (no. 13317660), RM 175.5. When daily flows into Brownlee reservoir drop below 8,500 cfs, the instantaneous minimum release required from Hells Canyon dam for the current day would be equal to the previous 3-day moving average for Brownlee reservoir inflow. At all times, the maximum variation in river stage would not exceed 1 foot per hour as measured at the Snake River at Johnson Bar gage (no. 13290460), RM 230.
4. Scenario 3 in combination with Scenario 1(f), wherein the Scenario 1(f) ramping rate and daily fluctuation limits would be overlain on the Scenario 3 navigation targets.
5. Operating Brownlee reservoir at minimum operating pool year-round, with Oxbow and Hells Canyon reservoirs held at full pool (inflow equals outflow).
6. Increasing drawdown of Brownlee reservoir during the fall and winter months to speed the cooling of outflows from the project and to reduce the incidence and severity of gas supersaturation associated with flood events. The timing and extent of reservoir drawdown to be evaluated in this scenario should be developed in consultation with the agencies and Tribes that are identified at the end of this AIR.

Your analysis of each scenario should assume that all of the proposed operating constraints identified in tables B-1, B-2 and B-3 of Scoping Document 1 (or tables B-1, B-3, and B-4 of your application) would be included, with the exception that the Hells Canyon reservoir drawdown limit would be relaxed as needed to implement each alternative scenario. This exception should enable you to follow load at the upper two developments despite the more restrictive constraints on outflows from Hells Canyon dam. In all cases, compliance with current and proposed Corps flood control requirements and provisions related to the “fall chinook program” would be maintained, as would all of your other proposed operating constraints except as specifically required to be modified by the requirements of the operational scenario being evaluated.

You do not need to re-run all of your resource-specific models for each of these scenarios, only those indicated in sections (a) through (h) below. In addition, it is not necessary to update the Technical Appendices that you provided with your final License Application. The requested analyses are described below for resource areas that we believe could be affected by increasing flows downstream of Hells Canyon dam, by reducing flow or water-level fluctuations downstream of Hells Canyon dam, by increasing daily fluctuation of the Hells Canyon reservoir, or by drafting Brownlee reservoir to meet flow augmentation, temperature, or gas supersaturation objectives.

(a) Power economics

Since the foregoing operational scenarios may affect the power production attributes of the project, please use the method you develop in your response to AIR DR-3, *Power Economics*, to provide the following information for each scenario:

(i) The estimated on-peak energy, off-peak energy, dependable capacity, and any other power supply attributes identified in your response to AIR DR-3;

(ii) The net change in the foregoing power supply attributes in relationship to current conditions and your proposed operation; and

(iii) The economic value, or cost, of these changes.

(b) Flood control storage

For each operational scenario, please confirm, that there is no effect on flood control storage, or describe any effects that you identify.

(c) Navigation

Since reduced flow fluctuations or higher flows may affect navigation conditions, please use your operational models to simulate river flows and stage changes for each of the 5 representative years (1992, 1994, 1995, 1999, and 1997). For each year and for each scenario, provide the following data plots:

(i) River flows as predicted for the Hells Canyon Dam gage (no. 13290450) (1-hour intervals, year-round);

(ii) River flows as predicted for the China Gardens Rapids gage (no. 13317660) (1-hour intervals, year-round); and

(iii) Hourly change in river stage (feet per hour) as predicted for the Johnson Bar gage (no. 13290460) (year-round).

Each of the foregoing graphs should be provided in a full-page, black-and-white format to ensure that all data series are visible in both hard copy and electronic formats. To facilitate side-by-side comparison, please provide the same information for your current and proposed operations[1] in the same scale and format as for the other scenarios.

(d) Sediment transport

In order to assist us with evaluating the effects of your proposed and alternative operations on erosion and sediment transport, please provide the following information:

(i) Develop flow duration curves at Pine Bar (RM 227.5), Salt Creek Bar (RM 222.4), Fish Trap Bar (RM 216.4), and the China Bar (RM 192.3) for the extreme low (1992), low (1994), medium (1995), high (1999), and extreme high (1997) flow years for proposed operations and for each of the operational scenarios and sub-scenarios identified above. Plot horizontal lines for $Q_{1.0}$, $Q_{1.5}$ (the peak flows that have a 1.0 and 1.5 year average recurrence interval) and flows at which incipient motion of medium sand (1 mm) occurs at each site as determined in Part 3 of AIR S-1, *Sediment Transport*. (Please indicate the period of record that was used to determine the $Q_{1.0}$ and $Q_{1.5}$ flows, and indicate whether these represent peak instantaneous or peak daily average flows.) If the duration or extent of sand mobilization under proposed operations varies significantly from any of the operational scenarios or sub-scenarios, please evaluate the potential impacts of these changes, such as accelerated sandbar erosion.

(e) Water quality

Because drawdown of Brownlee reservoir may affect downstream water quality, please provide the following information for Scenarios 2, 5 and 6. In your model runs of this scenario, please assume implementation of aeration of Brownlee reservoir as you have proposed and venting of Brownlee units 1 through 5.

(i) A plot of simulated hourly water temperatures below Hells Canyon dam from January 1 through December 31 for each of the 5 representative years (1992, 1994, 1995, 1999, and 1997).

(ii) A plot of simulated hourly dissolved oxygen (DO) levels below Hells Canyon dam from January 1 through December 31 for each of the 5 representative years (1992, 1994, 1995, 1999, and 1997).

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[1] In AIR OP-2, *Current Operations Scenarios*, we ask you to determine whether your proposed operations are the same as your current operations.

(iii) Semi-monthly plots (February, April, June, August, October, and December) of simulated temperature and DO isopleths in Brownlee reservoir for each of the 5 representative years (1992, 1994, 1995, 1999, and 1997). These plots should be similar in format to the plots that you provided in figures 13 and 26 of Technical Appendix E.2.2-2, except that each plot should be provided in a full-page, black-and-white format.

(iv) A qualitative evaluation of the potential effects on ammonia levels, pH levels, and concentrations of mercury and organo-chlorine compounds in waters discharged from Hells Canyon dam for each of the 5 representative years (1992, 1994, 1995, 1999, and 1997).

(f) Aquatic resources

(i) For us to evaluate the effects of project operations on aquatic habitats, including invertebrate habitat, we need additional information on river flows and the amount of wetted stream area that would be available under the alternative operations described above. For each scenario (Scenarios 1 through 6), please use your operational models to simulate river flows and water levels for each of the 5 representative years (1992, 1994, 1995, 1999, and 1997). For each year and scenario, provide the following graphs:

(1) River flows as predicted for the Hells Canyon dam gage (no. 13290450) (15-minute intervals, January 1 through December 31).

(2) River flows as predicted for the Snake River near Anatone, Washington, gage (no. 13334300) below the confluence with the Salmon River (15-minute intervals, January 1 through December 31).

(3) Total wetted stream area upstream of the confluence with the Salmon River (15-minute intervals, January 1 through December 31).

(4) Total wetted stream area downstream of the confluence with the Salmon River (15-minute intervals, January 1 through December 31).

(5) Water levels in the Brownlee, Oxbow, and Hells Canyon reservoirs (1-hour intervals in graphic format and end-of-day values in tabular format, January 1 through December 31).

To help us understand how modeled proposed operations compare to recent historical operations, please also provide a set of the foregoing graphs based on actual measured flow and water levels that occurred in the 5 representative years. (If there are periods of missing data due to gage outages or other causes, provide your best estimate for the missing data and clearly identify those periods and locations where estimated data are used.)

(ii) Fish Habitat: For each of the scenarios identified above, provide hourly time series plots of weighted usable area (WUA) (January 1 through December 31) for each of the 5 representative years and each of the species and lifestages that were modeled in your instream flow assessment. On each plot, show total WUA in the upper Hells Canyon reach (Hells Canyon dam to the Salmon River) and lower Hells Canyon reach (Salmon River to Asotin). For fall chinook rearing, include separate plots showing predicted WUA-based on both the 1D and the 2D habitat models. For redband and bull trout, please ensure that your plots show WUA values for the full calendar year, and provide plots of WUA determined with your existing suitability criteria and with the depth limitation removed (see comments on page 12 of ODFW's September 16, 2003, additional study request [ASR] letter).

(iii) Brownlee passage: In your analysis of reintroduction alternatives, you review data that indicate that the outmigration survival of spring and fall chinook smolts showed a four-fold increase between 1963 and 1964 after the drawdown of Brownlee reservoir was increased from 21 to 89 feet below full pool (E.3.1-2, chapter 11, page 5). In order for us to evaluate the potential for restoring anadromous fish to areas upstream of the project, we need to have sufficient information to evaluate the effects of reservoir drawdown on the survival rates of smolts migrating through Brownlee reservoir. Accordingly, please evaluate the effect of year-round operation of Brownlee reservoir at minimum operating pool (Scenario 5) on the potential rate of outmigration survival for fall chinook, spring chinook, and steelhead smolts.

(iv) Fish stranding: In your responses to agency comments on the draft license application, you indicate that the potential for fish stranding downstream of the project is limited by the scarcity of areas with shallow bank slopes, but you also acknowledge that the effects of stranding on fish populations in the Hells Canyon reach is largely unknown and that localized stranding may occur. Because this reach is used for rearing by juvenile Snake River fall chinook, we need to ensure that we have sufficient information to evaluate operational effects on this ESA-listed species. Accordingly, in consultation with NOAA Fisheries, IDFG and ODFW, evaluate the effects of each operational scenario on fish stranding, and provide the results of your analysis with your filing.

(g) Terrestrial resources

(i) Technical Report E.3.3-3 discusses the effects of two operational scenarios on riparian vegetation within the Hells Canyon corridor, based on extensive data collection, correlations with environmental variables (e.g., hydrology, slope, substrate) and HC_REM analysis. We need the same types of information to evaluate the effects of the 6 operational scenarios and sub-scenarios listed in at the beginning of this AIR.

Please include the predicted increases or decreases in acreage of vegetation that would occur as a result of these scenarios for each of the six plant groups described in your original modeling efforts (FRA, FRP, HYD, ORA, ORP, and RA). Also, please describe predicted effects on the abundance and distribution of noxious weeds, non-native plants, and special status plant species.

Please evaluate the potential effects of more restrictive ramping rates on riparian vegetation along the Hells Canyon reach of the Snake River, relating predicted changes in vegetation to existing substrate type or to changes in erosion, deposition, or sediment transport that may also result from implementation of these scenarios.

(ii) Technical Report E.3.2-45 includes a summary table (table 2) showing the estimated acres affected by your current and proposed operations[2] of the Hells Canyon Project. To ensure we have comparable information for all scenarios, please provide a similar table presenting estimates of acreage at Brownlee, Oxbow, and Hells Canyon reservoirs and the Hells Canyon reach of the Snake River that would be affected by implementation of each of the scenarios listed above.

(h) CHEOPS model input files

Please provide your operations model data input files for each of the 6 operational scenarios and sub-scenarios. We will use the files to confirm that the scenarios were modeled as we intended.

Please prepare your responses to parts (d), (e), (f) and (g) of this AIR after consultation with NOAA Fisheries, U.S. Fish and Wildlife Service (FWS), U.S. Forest

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[2] In AIR OP-2, *Current Operations Scenarios,* we ask you to determine whether your proposed operations are the same as your current operations.

Service (FS), U.S. Bureau of Land Management (BLM), Idaho Department of Fish and Game (IDFG), Idaho Department of Environmental Quality (IDEQ), Oregon Department of Fish and Wildlife (ODFW), Oregon Department of Environmental Quality (ODEQ) Columbia River Inter-Tribal Fish Commission (CRITFC), Nez Perce Tribe (NPT), Shoshone-Bannock Tribes (SBT), Shoshone-Paiute Tribes of the Duck Valley Indian Reservation (SPT), Burns Paiute Tribe (BPT), the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), and the Confederated Tribes of Warm Springs (CTWS). Include comments from the consulted entities on your response to items (d), (e), (f) and (g) and your response to their comments with your filing.

In all parts of your response where graphics are requested, full page black-and-white graphics should be provided to ensure readability in both hard copy and electronic formats. In order to facilitate side-by-side comparisons, please provide the graphs that we ask for in subparts (e)(i) through (e)(iii) and subparts (f)(i) and (f)(ii) of this AIR for both current and your proposed operations.[3]

OP-2 Current Operations Scenario
Time Required: 3 months

In your application, you state that your proposed project operation is representative of your current operation. Specifically, you state that modeled proposed operations represent the typical operating guidelines and constraints that Idaho Power currently follows (New License Application, Second Stage Consultation CD, page 172). In ODFW's comments on Scoping Document 1 (SD1) (dated September 22, 2003), ODFW suggests that current and proposed operations are not the same. ODFW states that in medium- and high-flow years, your proposed operation would result in releases below Hells Canyon being decreased by over 10,000 cfs during May because your proposed reservoir refill date is earlier than occurs under your current operation. ODFW further argues that current operations involve a more aggressive July/August drawdown of Brownlee reservoir than would occur in your proposed operation.

Your license application did not provide supporting evidence that your proposed operation is the same as your current operations. Therefore, please clarify your proposed May through August Brownlee reservoir operation in light of ODFW's comments, and compare and contrast this operation with recent typical operations.[4] We need this clarification to ensure that our NEPA analysis is properly structured with respect to baseline operations.

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[3] In AIR OP-2, *Current Operations Scenarios*, we ask you to determine whether your proposed operations are the same as your current operations.

[4] We consider "recent typical operations" to be those operational guidelines and constraints that characterized your Hells Canyon Project operations from mid-2001 to mid-2003 (subsequent to the termination of the flow augmentation program).

If you conclude that your proposed operations are not representative of the typical operating guidelines and constraints that you have followed since mid-2001, provide a new current operations scenario for comparison with your proposed operation. The new current operations scenario should be characterized using the information requested in AIRs OP-1, *Operational Scenarios;* WQ-1, *Dissolved Oxygen Augmentation;* and WQ-2, *Temperature Control,* such that the new current operations scenario can be readily compared with your proposed operations and with alternative operational scenarios.[5] Additionally, if you conclude that your proposed operations are not representative of current operations, you should revise your exhibit B tables B-1, B-3, and B-4 by adding a new column showing operational guidelines and constraints under the current operations scenario.

GEOLOGY AND SOILS

S-1 Sediment Transport
Time Required: 9 months

In section E.3 of your license application and in Technical Appendices E.1-1 and E.1-2, you provide information on the effects of the project on sediment transport and erosional processes in the Hells Canyon reach of the Snake River. However, several aspects of your analysis have not been verified based on field-conducted measurements, including the volumes of sediment that have been retained in the lower two reservoirs and your estimates of flows that mobilize sand and gravels. Furthermore, your studies do not evaluate the effects of sandbar toe erosion, and your sandbar slope stability analysis did not consider a range of flows that is representative of proposed operations. Therefore, please provide the following information, which we will use to evaluate the effects of the Project on sediment transport and to evaluate what types of measures might be implemented to protect and enhance sensitive beach and terrace areas.

(a) Using existing data, perform an analysis to confirm the volume of sediments trapped behind Oxbow and Hells Canyon. Use available pre-impoundment and post-impoundment bathymetric data to determine the volume of sediment trapped behind each dam. Compute the ratio of sediment volumes calculated based on this volumetric approach to the volumes previously calculated using tributary transport equations. Determine the average of this ratio for all three dams, including Brownlee, Oxbow, and Hells Canyon dams. This average ratio should then be used to validate and/or adjust the sediment transport calculation results for the Snake River below Hells Canyon dam. If sediment grain size data are available, please report the distribution of sand, gravel, and larger particles for the sediments trapped behind Oxbow and Hells Canyon dams.

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[5] In AIR OP-1, *Operational Scenarios*, we asked for data in specific formats related to power economics, flood control, navigation, sediment, aquatic resources, and terrestrial resources.

(b) Your sandbar stability analyses have not taken into account toe erosion as a possible mechanism for sandbar deformation. Please perform an area inundation analysis for Pine Bar (RM 227.5), Salt Creek Bar (RM 222.4), Fish Trap Bar (RM 216.4), and China Bar (RM 192.3) for flows between 5,000 cfs and 30,000 cfs in increments of 5,000 cfs (e.g., 5,000 cfs, 10,000 cfs, 15,000 cfs … 30,000 cfs). Provide maps of each site showing the areas that would be inundated at each of the flow increments modeled. These plots will illustrate the minimum flows at which inundation and possible toe erosion may occur for each of these heavily used recreational sites.

(c) The minimum flows capable of mobilizing sand (1mm) downstream from Hells Canyon dam have not been clearly established from previous modeling studies and analyses. Using the existing MIKE 11 and MIKE 21 models, perform additional modeling for each site identified in Part 2, above, using a range of flows between 5,000 cfs and 30,000 cfs in increments of 5,000 cfs. Determine the minimum flow (in increments of 5,000 cfs) at which sand is mobilized at each of the sites. For flows equal to or exceeding the identified threshold for mobilization, provide plots delineating the areas in which sand is mobilized.

(d) Where sand is determined to be mobile in Part 3 above, determine whether an armor layer lies beneath the finer sediments and whether these sites are aggrading or incising. If an armor layer exists and these mobile sites represent locations where active bedload was deposited on top of the armor layer, calculate the volume of these active bedload deposits. These calculations will provide critical information for refining the sediment budget and understanding the relative importance of tributary sediment inputs and active bedload transport on spawning gravels and sandbars.

(e) Modeling estimates of sand and gravel mobilization have not been verified. Additionally, it has not been clearly established whether or not an active bedload component is present above the channel armor layer. In order to provide validation for modeling and transport calculations and to address the possibility of an active bedload component, please conduct field measurements of sand and gravel mobilization in representative regions where mobility was indicated in Part 3 above. Use Helly-Smith bedload sampling or other techniques to monitor sand and gravel bedload at the flow thresholds for sand and gravel mobility as predicted in Part 3 above.

(f) The sandbar slope stability analysis performed for the final license application did not consider a range of flows representative of proposed operations. Please repeat the sandbar slope stability analysis using a reduction in flow from 20,000 cfs to 10,000 cfs over a 2-hour period. This additional analysis will help to resolve concerns about sandbar stability.

(g) Supporting materials for the spatial and temporal analysis of sandbar distribution have not been included in the license application. Please provide the aerial photographs and sandbar mapping utilized for the sandbar analyses. This information will allow for a more complete review of the analysis and interpretations regarding geomorphic alteration within the river downstream of Hells Canyon dam.

WATER QUANTITY AND QUALITY

WQ-1 Dissolved Oxygen Augmentation
Time Required: 9 months

In exhibit E of your license application, you propose to implement the following DO measures:

1. Inject oxygen into the transition zone or upper end of the lacustrine zone of Brownlee reservoir to supplement DO by 1,450 tons annually;
2. Install and operate turbine-venting systems in units 1 through 4 at the Brownlee development; and
3. Investigate, and install and operate, if practical, a system to inject oxygen or atmospheric air into water passing through unit 5 at the Brownlee development.

However, you do not provide enough specific information on the design and operation of the system that would be used to inject oxygen into Brownlee reservoir or detailed results on the effects of your turbine aeration testing. We need additional information about these proposed measures in order to evaluate the economic costs, resource benefits, and potential secondary effects (e.g., elevated total dissolved gas levels) of your proposal. Accordingly, please provide the following information after consultation with the ODEQ, IDEQ, and NOAA Fisheries.

(a) A report that presents the methods and results of hub-baffle aeration testing that you performed on Brownlee unit 4 in 2001 as referenced on page 47 of your *Application for Certification Pursuant to Section 401 of the Clean Water Act for the Relicensing of the Hells Canyon Hydroelectric Project*. These results should include an assessment of the effects of the baffles on both DO and total dissolved gas levels, if they were both monitored.

(b) A conceptual design and operational plan for the proposed reservoir aeration system. The plan should include consideration and evaluation of alternative locations, system designs, and augmentation schedules that are designed to maximize system efficiency and water quality benefits to important aquatic resources, including fall chinook spawning.

(c) A detailed estimate of design, construction, and operating costs, and any future capital costs for major overhaul or equipment replacement, as well as any anticipated effects on project generation and power benefits. Please provide your estimate of capital and operating costs and any effects on project generation or dependable capacity by year over the term of the next license, assuming a 30-year license.

(d) An assessment of the effects of reservoir aeration and turbine venting on levels of DO, total dissolved gas, ammonia, pH, and mercury and organo-chlorine compounds. Since there is uncertainty regarding how long it will take to fully implement the Total Maximum Daily Loads (TMDLs) that will affect the amount of nutrients that are delivered from upstream sources, please conduct your analysis for two scenarios: 1) with full attainment of nutrient load allocations from upstream TMDLs; and 2) with no improvement from upstream TMDLs.

This assessment should include the following:

(i) A plot of simulated hourly DO levels below Hells Canyon dam from January 1 through December 31 for each of the 5 representative years (1992, 1994, 1995, 1999, and 1997).

(ii) Semi-monthly plots (February, April, June, August, October, and December) of simulated DO isopleths in Brownlee reservoir for each of the 5 representative years (1992, 1994, 1995, 1999, and 1997). These plots should be similar in format to the plots that you provided in figures 13 and 26 of Technical Appendix E.2.2-2, except that each plot should be provided in a full-page, black-and-white format.

(iii) A qualitative evaluation of the potential effects on water temperatures, total dissolved gas levels, ammonia levels, pH levels, and concentrations of mercury and organo-chlorine compounds in the waters discharged from Hells Canyon dam for each of the 5 representative years (1992, 1994, 1995, 1999, and 1997).

Each of these graphs should be provided in a full-page, black-and-white format to ensure that all data series are visible in both hard copy and in electronic formats. To facilitate side-by-side comparisons, please provide the same graphs for your current and proposed operations[6] without implementation of reservoir aeration or turbine venting and without improvements from meeting other TMDL loading allocations. Please use the same scale and format that you use in the graphs that you provide in your response to parts (e)(ii) through (e)(iv) of AIR OP-1.

Include comments from the consulted entities and your response to their comments with your filing.

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[6] In AIR OP-2, *Current Operations Scenarios,* we ask you to determine whether your proposed operations are the same as your current operations.

WQ-2 Temperature Control
Time Required: 9 months

Nearly all of the agencies, Tribes, and NGOs involved in this proceeding have requested that you evaluate the potential benefits of modifying the Brownlee intake to allow the depth of withdrawal to be adjusted to provide some control over the temperature of water that is discharged from the project. Your application, however, provides little information about this potential enhancement measure. In our EIS on this licensing action, we will need to consider the costs and benefits of this and other measures that could protect and enhance aquatic resources. Therefore, you should evaluate this measure and provide the information that is listed below. We will use this information to examine the effects of variable level releases in terms of improving the reproductive success and growth of fall chinook and effects on other aquatic resources downstream of the project.

Since low oxygen levels frequently occur in the deeper parts of the water column at Brownlee reservoir, your evaluation will need to consider the effects of installing and operating a temperature control structure on downstream DO levels and, if it is needed to avoid adverse effects, the oxygenation of water that is withdrawn at depth from the reservoir. Your evaluation should also consider improvements expected from implementation of the reservoir aeration and turbine venting measures that you proposed in your license application.

To allow us to evaluate this measure, please provide the following information with your evaluation:

(a) Conceptual design report.

Within 3 months of the date of this AIR, please prepare and file with the Commission a conceptual design report on alternative designs for temperature control structures that could be installed at the Brownlee intake. The first part of this report should identify seasonal temperature and DO objectives designed to enhance conditions for fall chinook spawning, incubation, rearing, and migration in the Hells Canyon reach. These objectives should encompass: (1) providing cooler water during the early part of the fall chinook spawning season; (2) accelerating the warming of water temperatures in the spring to promote growth and early emigration; and (3) providing adequate DO levels. The second part of the report should provide conceptual designs and costs of alternative temperature control structures, including any oxygenation measures that may be needed to meet DO objectives.

Your report should include conceptual designs and costs (capital and operation and maintenance [O&M] separately) for at least the following alternatives:

(i) Full depth control (to a depth of approximately 250 feet below full pool) for at least 10,000 cfs of intake capacity. This would entail construction of a full height, gated intake tower and a conduit leading to the intake for unit 5 (11,800-cfs capacity) or to multiple units (units 1 through 4 have a 5,675-cfs capacity for each unit).

(ii) Depth control for all units within the range that is possible using the existing intake channel (up to approximately 150 feet below full pool). This could entail a gated structure across the entrance of the intake channel.

(iii) A combination of Subparts (i) and (ii).

(iv) Full depth control (to a depth of approximately 250 feet below full pool) for all units. This could be accomplished using a control structure constructed across the entrance of the intake channel with a large conduit leading to a gated intake tower.

(b) Preliminary screening of alternative designs to meet temperature objectives.

Within 6 months of the date of this AIR, prepare and file a report that lists each alternative design and evaluates the potential effectiveness of each alternative design for meeting the temperature objectives identified in part (a). Your assessment should include modeling of conditions in each of the 5 representative years (1992, 1994, 1995, 1999, and 1997) under proposed operations and for the flow augmentation scenario described in Scenario 2 of AIR OP-1, *Operational Scenarios*. This report should identify a preferred design that is considered to be the best suited for meeting the temperature objectives that were defined in Part 1 of AIR WQ-2.

(c) Detailed evaluation of the preferred design.

Within 9 months of the date of this AIR, prepare and file a report that provides a detailed evaluation of the potential effectiveness of the preferred design that was identified in part (b) of AIR WQ-2. This report should include modeling of the temperature and DO levels of waters discharged from Hells Canyon dam for each of the 5 representative years (1992, 1994, 1995, 1999, and 1997) under proposed operations and for the flow augmentation scenario described in Scenario 2 of AIR OP-1, *Operational Scenarios*. Your evaluation should include multiple model runs as needed to develop and refine a seasonal strategy for withdrawing water from selected depth(s), including blends of water drawn from more than one depth, to meet the seasonal temperature objectives identified in part (a) of AIR WQ-2. Your report should identify a preferred seasonal withdrawal strategy and determine the timing and amount of oxygen that would need to be added to outflows from the Brownlee development to meet the DO objectives identified in part (a) of AIR WQ-2. In addition, please provide a qualitative evaluation of the potential effects of that strategy on ammonia levels, pH levels, and concentrations of mercury and organo-chlorine compounds in the waters discharged from Hells Canyon dam. In your simulations, please assume implementation of aeration of Brownlee reservoir as you have proposed, as well as venting of Brownlee units 1 through 5. Also provide a proposed implementation schedule and a detailed estimate of design, construction, and operation costs (including any oxygen augmentation measures that are needed to meet DO objectives that are not explicitly addressed in AIR WQ-1, *Dissolved Oxygen Augmentation*) and any effects on project generation or dependable capacity from implementing the preferred alternative. Please provide your estimate of capital and operating costs and any effects on project generation or dependable capacity by year over the term of the next license, assuming a 30-year license.

For your proposed withdrawal strategy, please provide plots of the following information for both proposed operations and for the flow augmentation scenario:

(i) A plot of simulated hourly water temperatures below Hells Canyon dam from January 1 through December 31 for each of the 5 representative years (1992, 1994, 1995, 1999, and 1997).

(ii) A plot of simulated hourly DO levels below Hells Canyon dam from January 1 through December 31 for each of the 5 representative years (1992, 1994, 1995, 1999, and 1997).

(iii) Semi-monthly plots (February, April, June, August, October and December) of simulated temperature and DO isopleths in Brownlee reservoir for each of the 5 representative years (1992, 1994, 1995, 1999, and 1997). These plots should be similar in format to the plots that you provided in figures 13 and 26 of Technical Appendix E.2.2-2, except that each plot should be provided in a full-page, black-and-white format.

(iv) A qualitative evaluation of the potential effects on ammonia levels, pH levels, and concentrations of mercury and organo-chlorine compounds in the waters discharged from Hells Canyon dam for each of the 5 representative years (1992, 1994, 1995, 1999, and 1997).

Each of these graphs should be provided in a full-page, black-and-white format to ensure that all data series are visible both in hard copy and electronic formats. To facilitate side-by-side comparisons, please provide the same graphs for your current and proposed operations[7] using the existing intake configuration and the current depth of withdrawal.[8]

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[7] In AIR OP-2, *Current Operations Scenarios,* we ask you to determine whether your proposed operations are the same as your current operations.

[8] If agreement can be achieved with the consulted agencies, the number of alternatives, scenarios, and time-steps (days and months) that are modeled in parts (a) and (b) of this request can be reduced.

Please use the same scale and format that you use in the graphs that you provide in your response to parts (e)(i) through (e)(iv) of AIR OP-1.

Include comments from NOAA Fisheries, FWS, IDFG, IDEQ, ODFW, ODEQ, CRITFC, NPT, SBT, SPT, BPT, CTUIR, and CTWS on the information identified in parts (a), (b), and (c) of this AIR and your response to their comments with your filing.

AQUATIC RESOURCES

AR-1 Hells Canyon Fish Trap Modifications
Time Required: 6 months

You propose to develop detailed engineering plans for modifications to the existing Hells Canyon trap within 1 year after license issuance. You have not, however, provided functional design drawings of these proposed modifications as required by the Commission's regulations.[9] We need these drawings to understand the scope of the proposed modifications and their relationship to project structures and operations and to assess their potential effects on ESA-listed species. Therefore, after consultation with NOAA Fisheries, FWS, IDFG, and ODFW, design trap modifications that would allow onsite sorting and holding of adult resident salmonids and anadromous fish, a safe and efficient means of returning wild fish to the river after sorting, scanning of fish for PIT-tags and coded-wire tags, and collection of native resident salmonids. In your response, please provide functional design drawings, an operating plan, and a cost estimate for construction and operation of these facilities. Please provide your estimate of capital and operating costs and any impacts to project generation or dependable capacity by year over the term of the next license, assuming a 30-year license.

Include comments from NOAA Fisheries, FWS, IDFG, and ODFW on your response to this item and your response to their comments with your filing.

AR-2 Listed Molluscs
Time Required: 9 months

FWS has indicated that it believes that your invertebrate surveys were not adequately designed to detect rare species, and we concur with their assessment. FWS notes that certain rare, listed, and sensitive species are frequently restricted to specialized microhabitats and that such habitats should be more thoroughly surveyed to determine presence or absence. FWS has also recommended that additional surveys be conducted to verify the taxonomic identity of snails collected near the Pine Bar site in the Hells Canyon reach that were initially identified as Bliss Rapids, but whose taxonomic identity could not be verified. We recognize that seasonal flow conditions could affect sampling efficiency, and that sampling could be conducted most efficiently during the fall when river flows are low.

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[9] See 18 CFR Section 4.51(f)(3)(v).

Accordingly, after consultation with FWS, develop a plan to conduct targeted surveys to provide additional information on the presence or absence of listed, rare, or sensitive molluscs in project-affected areas. If any Bliss Rapids snails are identified during these surveys, you should submit these specimens to a qualified molluscan taxonomist for identification. Within 2 months of the date of this AIR, please provide a draft of the plan to the FWS, with a request for its comments. Your draft study plan should include a description of your proposed study methods, a schedule for conducting the surveys, a description of how the results will be reported, and a schedule for consulting with FWS. Within 4 months of the date of this AIR, please file the plan with the Commission, including any comments that you received from FWS on the draft plan and indicating how those comments were addressed in the final plan.

You should provide a draft report of your findings to the FWS within 7 months of the date of this AIR. The draft report should include a description of your study methods, results, assessment of the results, and any recommendations stemming from the study results. Within 9 months of the date of this AIR, you should file the final report of your findings with the Commission, including any comments that you received from FWS on the draft report and a discussion of how those comments were addressed in the final report.

TERRESTRIAL RESOURCES

TR-1 Habitat Resource Management

Time Required: 9 months

The license application provides a detailed assessment of ongoing project effects on upland and riparian habitat and on mule deer winter range, in particular. It provides a general description of your proposals for mitigation of these effects, but does not identify (1) parcels that would be targeted for acquisition; (2) parcels already in Idaho Power's ownership that would be managed for wildlife; (3) methods of habitat protection or enhancement; (4) methods of monitoring; or (5) mechanisms of plan implementation, including consultation, reporting, or adaptive management over the long term. We understand that Idaho Power and members of the Terrestrial Resources Working Group (TRWG) have continued to discuss these issues since the license application was filed.

We understand that acquisition of particular parcels of land would ultimately depend on whether owners of suitable habitat are willing to sell titles or easements at a reasonable price. However, without more specific information about the program and each of its elements, Commission staff is unable to assess the value of the program in improving terrestrial resources. After consultation with FS, BLM, FWS, IDFG, ODFW, NPT, SPT, SBT, BPT, CTUIR and CTWS, provide the following:

(a) Acquisition of upland and riparian habitat

  (i) Develop a set of options for meeting the acreage targets you identified in the license application (22,761 upland acres; 821 riparian/wetland acres), using information you have already compiled (or similar information) about ownership, acreage, vegetation cover types and elevations for the following:

(1) Land in private and public ownership in the Brownlee-Oxbow reach;

(2) Land along tributaries to all three reservoirs; and

(3) Land along the Snake River from Hells Canyon dam to the confluence of the Salmon River.

(ii) Discuss how each option would meet the needs identified by the TRWG in terms of size, contiguity with large blocks of habitat, proximity to the project, geographic distribution, and/or benefits to high priority habitats or species.

(iii) Provide an analysis of alternative or additional wildlife protection, mitigation, and enhancement (PM&E) lands that may be recommended by the consulted entities, the basis for not adopting any of the recommendations, and a discussion of how each option would meet the needs identified by the TRWG.

(b) Management of wildlife resources on Idaho Power-owned lands

(i) Regarding the integrated wildlife habitat program, you state "[t]he Applicant would potentially include some of its currently owned lands that have high wildlife value." Please explain how land referenced in this measure relates to the "special management areas" or other resource designations described in the Hells Canyon Resource Management Plan.

(ii) Please provide the following information about each parcel of Idaho Power-owned land you would include in the integrated wildlife habitat program:

(1) A site map, showing adjacent land ownership and features such as roads, trails, recreational facilities, or other development;

(2) The acreage of each vegetation cover type within the parcel; and

(3) Descriptions of habitat conditions and value to wildlife; presence of any special status plants or wildlife or potential habitat for such species; current management practices; site constraints that could reduce habitat suitability or the potential for enhancements; and specific PM&E measures (e.g., planting, fencing) you would consider implementing within the parcel.

(iii) Discuss how each option contributes to your wildlife habitat mitigation program in terms of its size, contiguity with large blocks of habitat, proximity to the project, geographic distribution, and/or benefits to high priority habitats or species.

(c) Integrated wildlife habitat program

  (i) In the license application, you mention that you have already identified several projects that are needed for wildlife, including protection of bald eagle winter roosts, bald eagle nests, big game concentration areas, colonial waterbird rookeries, and bat hibernacula. Please explain how these projects fit into your proposal for an integrated wildlife habitat program. For each project, please provide specific information about the location where the project is to be implemented, methods to be used to protect or enhance habitat, and methods of monitoring the effectiveness of treatments.

Please update your cost estimates to reflect any changes made in your proposal. Please provide your estimate of capital and operating costs over the term of the next license, assuming a 30-year license.

Include comments from consulted entities on your response to items (a) – (c) and your response to their comments with your filing.

LAND USE

LU-1 Project Boundary Change
Time Required: 6 months

In your license application, you propose to reduce the area within the project boundary by 3,800 acres. In exhibit A.6, you state that the 3,800 acres of land within the current project boundary but outside the proposed project boundary are not necessary for project purposes, such as public recreation, shoreline control, or protection of environmental resources. You further indicate that the proposed project boundary change would have no effect on mitigation of project effects on any lands near the project. However, you provide no support for these statements in your application.

More information on the basis for your decision to propose removal of the lands from the project boundary is needed. Therefore, after consultation with FS, BLM, IDFG, and ODFW, provide the following information for each parcel proposed for exclusion from the project boundary:

(a) Acreage of the parcel.

(b) Description of existing improvements on the land.

(c) Description of existing land use.

(d) Substantial evidence that the land is not needed for project purposes, such as operation and maintenance, flowage, recreation, public access, endangered species protection, cultural resource protection, and other natural resource protection, or shoreline control, including shoreline aesthetic values.

> Parcels with similar characteristics may be grouped in the narrative, as long as all parcels within the group are clearly identified in Subpart (a) and cross-referenced to the map(s). The narrative may be submitted in a standard template or table format to facilitate compilation and review of the information.
>
> The information should include a map (or maps) and supporting text. The map(s) (7.5-min. U.S. Geological Survey [USGS] quads.) should show the 3,800 acres proposed for exclusion, identifying the current boundary, proposed boundary, contour elevations, and land ownership.

Include comments from consulted entities on your response to items (a) through (d) and your response to their comments with your filing.

DEVELOPMENTAL RESOURCES

DR-1 Thermal Alternative Cost of Capital
Time Required: 3 months

In your license application (section H.3.3.2), you provide information supporting your estimate for the alternative cost of power based on gas-fired generating resources. This information is largely based on your 2002 Integrated Resource Plan. However, with the information provided we are unable to replicate the annual estimated cost of the capital component of your alternative cost. We need to be able to replicate this cost so that we can fully understand your calculations and support our analysis in the developmental resources section of the EIS.

Please provide the calculation sequence on pages H-23 through H-25 of your application in Microsoft Excel, including the supporting formulas. If your 2004 Integrated Resource Plan updates and modifies any of the economic parameters or thermal resource planning criteria (such as reserves, fuel costs, heat rates, and O&M costs), please provide the updated values in your submittal. We note that your discount rate of 7.13% is less than your weighted average cost of capital of 8.48%. Please provide an explanation of this 1.35 percentage point discrepancy.

Also, please file a copy of the 2004 Integrated Resource Plan with the Commission within 60 days of publication.

DR-2 Flood Control
Time Required: 6 months

In your license application (exhibits B and E) you describe the operations of Brownlee reservoir for the purpose of flood control.

The Corps, in its December 22, 2003, letter responding to the Commission’s request for comments on SD1, indicates that “[i]t is crucial that the current flood control requirements be maintained as part of any new license [but additionally] the Corps is requesting a requirement to provide winter flood control space of between 50,000 and 100,000 acre-feet at Brownlee upon demand to control winter flood events."

Your application provides no details on criteria for determining the winter flood control storage amount or the period of the year over which the requirement would apply. In your Response to Comment ACOE 1-2 (New License Application, Volume 11, Second Stage Consultation), you state that, based on recent discussions with the Corps, winter flood control storage (50,000 to 100,000 acre-feet) would be needed infrequently, if ever; would be best handled on a case-by-case basis; and would not necessarily need to be part of a license article. Please provide additional information supporting your position that this additional flood control storage request from the Corps does not need to be addressed in this relicensing, and provide confirmation from the Corps that the Corps agrees with your position.

DR-3 Power Economics

Time Required: 6 months

In your license application (exhibits D and H) you provide the estimated average annual cost of the project and you estimate the value of the project based on replacement costs, but there is no information regarding the cost of implementing potential operational changes that we may need to assess in our NEPA analysis.[10]

Accordingly, please provide the following information:

(a) A power generation and economic baseline consistent with your simulation of current and proposed operations[11] that details the project's power generation attributes and their economic value within Idaho Power's overall power supply system. This baseline, at a minimum, should include the following:

  (i) Monthly on-peak generation for each of your 5 representative years (1992, 1994, 1995, 1999, and 1997);

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[10] In your Response to Comment FERC 1-141 (New License Application, Volume 11, Second Stage Consultation), you state that you performed an analysis to estimate the economic cost to implement the fall chinook plan, one aspect of the current and proposed operation. You state that the costs of the fall chinook plan are attributable to "…differences in heavy-load/light-load energy production, reserves, and spring flow requirement…." You estimate the costs of the fall chinook plan at $75 million over 30 years ($2.5 million annually), but you provide insufficient detail on methods, assumptions and calculations to allow us to independently confirm your estimate or to apply your method to other potential operational scenarios that may require evaluation in our environmental analysis for this relicensing.

[11] In making this request, we assume that your proposed operations are the same as current operations. In the event that you determine in your response to AIR OP-2 that there is a difference between your proposed operations and current operations, please provide the requested information separately for current operations and for proposed operations.

(ii) Monthly off-peak generation for each of your 5 representative years;

(iii) Dependable capacity reflecting the seasonal effects of low inflow and your seasonal load requirements; and

(iv) The economic value of the foregoing attributes.

(b) A fully detailed method for estimating the power system and economic impacts (in relation to the baseline) associated with potential operational changes, such as alternative minimum flow levels and ramp rate restrictions downstream of Hells Canyon dam, alternative daily reservoir-level fluctuation limits at Hells Canyon reservoir, and potential late summer drawdowns of Brownlee reservoir (reference AIR OP-1, *Operational Scenarios*). Your method should be designed to capture as much of the economic impact of the Hells Canyon Project operational changes on your overall power supply system as feasible. If you use a project-based analysis, the analysis should specify the effect of the operational changes on all of the project's significant power supply attributes (e.g., dependable capacity, on-peak energy, off-peak energy, system reserve) and provide estimates of the value of these attributes within your integrated power supply system. If you use a system-wide cost of power analysis, the analysis should show the effect of any operational changes at the Hells Canyon Project on overall system power production costs, assuming no change in overall system reliability.

Your method should be transparent and your assumptions explicit. All power system-related project attributes that you believe could be affected by potential operational changes, including ancillary services, should be addressed, at least qualitatively. The method should be based on current power values and should exclude the effects of inflation, but should otherwise be consistent with your integrated resource planning process that you describe in your Integrated Resource Plan (Technical Report H.2-1.)[12] Provide any data and supporting calculations, including formulas, in Microsoft Excel.

Within 60 days of the date of this additional information request, provide a description of your proposed method for Commission staff review. Any comments received from the Commission staff should be addressed in your filing with an explanation of how these comments were addressed.

DR-4 Estimated Cost of PM&E Measures
Time Required: 9 months

In the Executive Summary of your license application, you provide the estimated total cost of each of your proposed PM&E measures, and in exhibit E you provide

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[12] If you update this information in your response to AIR DR-1, *Thermal Alternative Cost of Capital,* please use the more current Integrated Resource Plan information.

information as to the nature and timing of the costs for each measure. Also, you indicate which measures are a continuation of existing operations and which measures would be new. However, the information provided lacks the specific cash-flow information that would enable us to replicate your annual cost calculations and to independently evaluate your assumptions. Further, tables D-1 and D-2 in exhibit D of your application fail to differentiate between existing PM&E measures and new PM&E measures. The economic baseline for our developmental analysis is current project cost, inclusive of existing PM&E measures. It is unclear in which column of tables D-1 and D-2 existing PM&E measures are included.

Subsequent to the Commission's Notice of Ready for Environmental Analysis, interested parties will submit recommendations, terms and conditions, and prescriptions. To ensure a consistent approach to estimating the cost of proposed and alternative PM&E measures, we require that you provide cost estimates for the alternative measures in a format consistent with the cost estimates for your proposed measures.

Accordingly, please provide the following:

(a) A 30-year cash-flow table showing, for each existing measure you propose for continuation: (a) the capital costs of the measure in the year(s) incurred; (b) the O&M costs of the measure over the 30-year period of analysis; (c) the levelized annual capital cost; (d) the levelized annual O&M cost; and (e) the total levelized annual cost of the measure. Within the table, the measures should be grouped by resource, and the table should include summations of the total levelized annual cost by resource. The cash-flow table should be in Microsoft Excel and include the supporting formulas.

(b) A 30-year cash-flow table showing, for each proposed new measure: (a) the capital costs of the measure in the year(s) incurred; (b) the O&M costs of the measure over the 30-year period of analysis; (c) the levelized annual capital cost; (d) the levelized annual O&M cost; and (e) the total levelized annual cost of the measure. Within the table, the measures should be grouped by resource, and the table should include summations of the total levelized annual cost by resource. The cash-flow table should be in Microsoft Excel and include the supporting formulas.

(c) Revised tables D-1 and D-2 that are consistent with the above cash-flow tables, and which provide data for (i) conditions with no PM&E measures; (ii) conditions with proposed continuation of existing PM&E measures; and (iii) conditions with both (1) proposed continuation of existing PM&E measures and (2) proposed new PM&E measures. In Table D-1 of your license application, you estimate the cost of your relicensing process at $208.5 million, without escalation. Please provide documentation supporting this figure.

TRANSMISSION LINES

TL-1 Transmission Line Jurisdiction
Time required: 3 months

You only include the Pine Creek--Hells Canyon transmission line in your license application. We assume that you are proposing to remove from any new license the other 11 lines that are currently included in the existing license for the project because they no longer meet the Commission's definition of being primary lines. Subsequently, you filed an amendment of license application on February 23, 2004, to remove the Boise Bench-Midpoint and Boise-Brady No. 2 transmission lines from the project.

We need more information to make a preliminary determination regarding the Commission's jurisdiction over these lines (other than those covered in your February 23, 2004, amendment of license application) in the draft environmental impact statement. Therefore, please provide a one line diagram of your transmission system and explain why each line no longer meets the Commission's definition of being a primary line. For each transmission line, please (a) identify the point at which the line begins and terminates and the type of termination, such as, breaker stations, substation, and other appurtenant facilities; (b) the length, voltage, and type (overhead, underground, wood-pole, number of circuit, etc.) of the line; and (c) transformer-type (bank of three single-phased or three-phased), rating in kilovolt-ampere (kVA), and primary and secondary voltages.

Exhibit 7.1-13

January 2005 Hells Canyon Complex (HCC) settlement process—interim agreement

IDAHO POWER
An IDACORP Company

IDAHO POWER COMPANY
P.O. BOX 70
BOISE, IDAHO 83707

JAMES C. TUCKER
Senior Attorney

January 7, 2005

Honorable Magalie R. Salas
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington DC 20426

Reference: Idaho Power Company -- Project No. 1971 (Idaho/Oregon)
Hells Canyon Hydroelectric Project Settlement Process – Interim Agreement

Dear Secretary:

In accordance with my letter to J. Mark Robinson of December 30, 2004, I have enclosed for filing an original and eight copies of the *Hells Canyon Hydroelectric Project Settlement Process – Interim Agreement* ("*Interim Agreement*"). The *Interim Agreement* has been agreed to, by the execution of separate signature pages, by the following parties to the Hells Canyon Complex (HCC) settlement process:

Party	Date
Idaho Power Company	December 20, 2004
NOAA Fisheries	December 20, 2004
USDA – Forest Service	December 20, 2004
U. S. Fish & Wildlife Service	December 21, 2004
U. S. Bureau of Land Management	December 21, 2004
Idaho Rivers United	December 22, 2004
American Rivers	December 22, 2004
Oregon Department of Environmental Quality	December 22, 2004
Oregon Department of Fish and Wildlife	December 22, 2004
Shoshone Paiute Tribes	December 27, 2004
Nez Perce Tribe	December 29, 2004
Shoshone-Bannock Tribes	December 30, 2004

Telephone: (208) 388-2112; Facsimile: (208) 388-6935
E-mail: jamestucker@idahopower.com

The HCC settlement process has been established consistent with the discussions between the parties and Commission Staff on September 9, 2004. As indicated in the correspondence between the Commission Staff and NOAA Fisheries dated October 28 and November 12, 2004, the initial objective of the HCC settlement process was to address interim operations at the HCC project in an effort to provide agreed upon measures to the Commission by April 2005. Under this approach formal consultation under the Endangered Species Act (ESA) would be initiated after the comprehensive settlement agreement is completed and the draft EIS is issued.

The *Interim Agreement* is therefore intended to address issues relating to operations of the HCC and ESA-listed species in advance of the issuance of a new license while the parties develop a comprehensive settlement agreement. In accordance with the provisions of the Interim Agreement, IPC has agreed to implement certain measures until a new license is issued for the HCC. IPC has also agreed to implement certain additional measures on an annual basis, provided that the parties remain engaged in settlement discussions intended to resolve long-term relicensing issues. The signatories agree that the measures in the *Interim Agreement* are intended to provide reasonable protection for ESA-listed species during the term of the *Interim Agreement* and also establish a basis for comprehensive settlement discussions to continue.[1]

Some parties involved in the HCC settlement process chose not to sign the *Interim Agreement*. Their reasons for doing so are their own. In this regard, enclosed is a copy of a letter received (electronically) from Ms. Harriet Hensley, Deputy Attorney General for the State of Idaho, indicating the basis for the State of Idaho's decision to not sign the *Interim Agreement*. As Ms. Hensley's letter indicates, Idaho's decision is based on the relationship between some of the flow related measures contained in the *Interim Agreement* and other pending settlement processes that resulted from the Snake River Basin Adjudication (SRBA) mediation, a multi-year settlement process involving the State of Idaho, the United States, including the U.S. Department of Interior and NOAA Fisheries, the Nez Perce Tribe, and various private water user interests in Idaho. Through personal communications, I understand that some of the Idaho water user interests did not sign the *Interim Agreement* for similar reasons. Nonetheless, as Ms. Hensley's letter indicates, the State of Idaho supports the settlement process and intends to be a full participant in the settlement discussions. I have been advised as well that the water user interests intend to continue to participate in the settlement discussions relating to a comprehensive settlement agreement.

Finally, consistent with ¶ 5 (pg. 10) of the *Interim Agreement*, IPC is filing the *Interim Agreement* with the Commission for informational purposes only. IPC is authorized to proceed with implementation of the measures set forth in the Interim Agreement under the existing license for the HCC.

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[1] Contrary to Mr. Campbell's letter of January 5, 2005, we did not intend to imply that all of the parties to the settlement process agreed to the *Interim Agreement*, only that a proposed interim agreement was taken from the settlement working group to the respective parties for review and consideration.

If you have any questions with regard to the enclosures, please feel free to contact me. The next meetings for the HCC settlement process are scheduled for January 11 & 12, 2005. Consistent with my December 30th letter, we will report to Mr. Robinson on the progress of the settlement process by the end of January 2005.

Very truly yours,

James C. Tucker

cc: Service List

J. Mark Robinson/FERC-OEP
Alan Mitchnick/FERC-OEP
M. Hathaway – J. Hastreiter/FERC non-decisional staff
NOAA Fisheries
USFWS
American Rivers
Idaho Rivers United
USDA – Forest Service
U. S. Bureau of Land Management
Oregon Department of Environmental Quality
Oregon Department of Fish and Wildlife
Shoshone Paiute Tribes
Nez Perce Tribe
Shoshone-Bannock Tribes
Parties to HCC Settlement Process

December 28, 2004

Mr. Jim Tucker
Idaho Power Company
P.O. Box 70
Boise, ID 83707

RE: Hells Canyon Complex Relicensing

Dear Jim:

As you are aware, the State of Idaho has been involved in the Hells Canyon Complex relicensing process since its inception and has been an active participant in the settlement process on interim operations. Settlement of the controversial issues that pertain to the project's relicensing continues to be in the public interest and Idaho intends to be a full participant in the negotiations commencing in January 2005 on the components of a new license for the projects.

Although the settlement process has been productive in many important ways, Idaho will not be a signatory to the settlement agreement on interim operations. IPC's role in passing and shaping water from the Bureau of Reclamation's projects in the Upper Snake River basin for the benefit of species listed under the Endangered Species Act is a fundamental component of the interim operations agreement. Likewise, the operation of the Bureau of Reclamation's projects in the Upper Snake River basin for that same purpose is a fundamental component of the proposed settlement of the Nez Perce tribal water right claims in the Snake River Basin Adjudication (SRBA).

The proposed SRBA settlement of the Nez Perce tribal water right claims is the result of many years of difficult negotiations and provides for protection of fish habitat, including both flow and non-flow related issues, while preserving existing water uses. Accordingly, we asked that members of the Settlement Working Group (SWG) refrain from initiating new litigation related to the flow augmentation component of the proposed SRBA settlement while engaged in negotiations on IPC's future role in that same program. American Rivers and Idaho Rivers United advised that they would not agree to this term, and, consequently, Idaho will not be a signatory to the interim operations agreement.

Nonetheless, Idaho fully supports the settlement process and intends to move forward collectively with the SWG in exploring the possibility for settlement. State of Idaho resource agencies will continue to play a critical role in technical discussions and in the development of any negotiated agreement and will, of course, work with IPC in carrying out the agencies' statutory responsibilities where those authorities intersect with implementation of the interim agreement.

I look forward to working with you and the SWG in the next stage of negotiations.

Sincerely,

HARRIET A. HENSLEY
Deputy Attorney General

HAH/jh

c: Mike Hughes (via electronic delivery)
Jody Erickson (via electronic delivery)
Settlement Working Group (via electronic delivery)
Frank Wilson (via facsimile)
Phil Rassier
Doug Conde
Scott Grunder
Mary Lucachick
Jim Yost

UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Idaho Power Company	)	**Project No. 1971-079**
(Hells Canyon Hydroelectric Project)	)	

Hells Canyon Hydroelectric Project Settlement Process

Interim Agreement

The Idaho Power Company (IPC), the National Marine Fisheries Service (NOAA Fisheries), the U.S. Fish and Wildlife Service (USFWS), the U.S. Bureau of Land Management (BLM), the U.S. Bureau of Reclamation (BoR), the USDA Forest Service, the Oregon Department of Environmental Quality, the Oregon Department of Fish and Wildlife, the Oregon Water Resources Department, the Oregon Parks and Recreation Department, the Oregon Marine Board, the State of Idaho (ID), the Nez Perce Tribe (NPT), Shoshone-Paiute Tribe, Shoshone Bannock Tribes, American Rivers (AR), Idaho Rivers United (IRU), the Idaho Water Users Association (IWUA), Payette River Water Users Association, Pioneer, Settlers and Nampa Meridian irrigation districts, the Committee of Nine, the Idaho Farm Bureau, the Columbia River Inter-Tribal Fish Commission, the Idaho Council on Industry and the Environment (ICIE) and the J. R. Simplot Company (hereinafter at times collectively referred to as the Settlement Working Group (SWG)), consistent with the discussions before Federal Energy Regulatory Commission (Commission) staff on September 9, 2004 and the correspondence to the Commission from USFWS and NOAA Fisheries, dated September 24 and November 12, 2004, respectively, are in the process of establishing a Hells Canyon Complex (HCC) settlement process ("settlement process"). The intent of the settlement process is to identify, consider, and resolve issues associated with the issuance of a new license for the

HCC and develop a comprehensive licensing settlement agreement for submission to the Commission for approval.

This Interim Agreement is intended to address issues relating to operations of the HCC and ESA-listed species related to the project in advance of the issuance of a new license and while the SWG attempts to develop a comprehensive licensing settlement agreement. Should the assumptions that underlie this Interim Agreement change (including the assumptions about the BoR's flow augmentation program) the signatory parties (the parties) will reconvene to consider the implications of the change. The parties may amend or modify this Interim Agreement by mutual agreement or withdraw with notification to the other parties. Neither the execution of this Interim Agreement nor agreement to the matters or measures set forth herein shall constitute an admission against the interests of any of the parties and shall not be used in any pending or subsequent litigation. This Interim Agreement is intended to resolve contested issues on an interim basis while the SWG explores long-term settlement alternatives. Should any of the SWG members withdraw from or terminate long-term settlement discussions or otherwise fail to agree to a final settlement agreement, under all circumstances, all claims, defenses and legal and equitable remedies shall remain available to them and are not waived, relinquished nor abandoned by reason of the execution of this Interim Agreement or participation in the settlement process. Other than binding the parties to the specific interim measures contained in this Interim Agreement during its effective period, nothing herein shall set precedent or prejudice future arrangements, or affect any party's right to pursue alternative measures in connection with the development of a long-term agreement. The parties retain the option to make responsive filings with FERC pursuant to the relicensing process. Nothing in this agreement affects any party's rights or remedies in proceedings associated with relicensing of the project, including but not limited to proceedings under the Federal Power Act, the Clean Water Act or other federal or state laws; at the same time, the signatory parties will not take actions that undermine this agreement.

The signatory parties have determined that several issues relating to operations and ESA-listed species related to the project must be addressed in the near-term. The measures in this Interim Agreement are intended to provide reasonable protection for ESA-listed species during this Interim Agreement and to establish the basis for comprehensive settlement discussions to continue. To this end, the undersigned parties agree to address several key issues associated with the operation or relicensing of the HCC in advance of the settlement agreement and/or issuance of a new license, as follows:

1. Until a new license is issued for the HCC, IPC will:
    a. Monitor water flows in the Snake River above the HCC and take such action, as may be necessary, to protect and maintain the state water rights held by IPC.
    b. Provided that the federal flow augmentation program implemented by the BoR is consistent with state law, the SRBA Mediator's Term Sheet and the BoR's 2004 biological assessment, IPC will cooperate with the BoR in leasing water rights under I.C. § 42-108A for flow augmentation purposes and will pass all BoR flow augmentation water through its projects. (Parties to this settlement who are not parties to the SRBA Mediator's Term Sheet are not, by the language above, endorsing the Term Sheet.)
    c. Continue to implement the Fall Chinook Interim Recovery Plan and Study (IPC 1991) to protect spawning, incubating, and emerging fall chinook salmon below the HCC.
    d. From March 1 through May 31st of each year, monitor and identify

potential stranding sites in the Snake River below the HCC to the confluence with the Salmon River and operate the HCC, and/or take such other measures as may be necessary, to minimize the potential for stranding of juvenile fall chinook. In conjunction with these efforts, IPC will provide reports and updates regarding the status and progress of the monitoring to the SWG (or subcommittee thereof) and will seek the concurrence of NOAA and USFWS, and update the SWG as soon as possible, of any operations or measures necessary to minimize stranding.

e. Continue to fund the IPC hatchery program consistent with the terms of the 1980 Settlement Agreement, and continue to coordinate with state, federal, and tribal fish managers with regard to the implementation of the hatchery management measures contemplated by that Agreement and IPC's Final License Application (FLA), which shall include:

    i. Evaluating the need for screening the water intakes to provide safe passage at the Rapid River and Pahsimeroi hatcheries;

    ii. Providing an alternate water source at the Pahsimeroi Hatchery in an effort to manage whirling disease;

    iii. Moving forward with refinement of existing hatchery plans to facilitate: 1) ESA permitting procedures for hatchery facilities and 2) development and implementation of future hatchery genetic management plans; and

    iv. Identifying studies and analysis that are needed to determine the extent and effects of hatchery steelhead released from IPC hatchery programs, on natural steelhead populations.

2. IPC will implement the following measures in 2005, and will continue such measures in 2006 provided that the SWG remains engaged through November of 2005 in settlement discussions intended to resolve issues associated with the long-term licensing of the HCC, or as provided in Section 3.a. Should settlement discussions continue beyond 2005-2006, IPC will continue such measures in each calendar year thereafter provided the SWG remains engaged in settlement discussions through November of the preceding year (e.g. – IPC will continue such measures in 2007 provided the SWG is engaged in settlement discussions through November 2006.)
    a. 2005 – Consistent with this agreement, IPC will use best efforts to hold Brownlee Reservoir at or near full elevation (approximately 2077 msl) through June 20th; and thereafter, subject to the conditions below, will draft Brownlee Reservoir to elevation 2059 (releasing up to 237 kaf) by August 7th (hereinafter referred to as the F/A (flow augmentation) draft). IPC will provide up to 237 kaf F/A draft in 2005. The date upon which the F/A draft begins, and the extent and volume of the releases, up to 237 kaf, may be modified after consideration of the variables listed below (items i. and ii.). As the 2005 water year progresses or upon becoming aware of any variables that may impact either the filling of Brownlee Reservoir or the ability to provide the F/A draft, IPC will, to the extent feasible, seek a mutually acceptable solution with NOAA Fisheries and USFWS, regarding its response to those variables and will advise the SWG. The variables are:

i. Any potential impact to anadromous and resident fish and wildlife species, water quality, navigation, and recreation, including recreational issues associated with access to, and the use of, Brownlee Reservoir over the three-day July 4th holiday period.[1] The parties recognize that consideration of these issues may result in the F/A draft from Brownlee stopping over the 4th of July holiday or beginning after the July 4th holiday.

ii. The availability of water to fulfill the F/A draft and IPC's commitment to the Fall Chinook Plan and customer energy requirements. The volume of water available for release under the F/A draft is dependent upon the elevation of Brownlee Reservoir on the date that the F/A draft begins and the projected availability of inflows to refill Brownlee Reservoir for the purposes of the Fall Chinook Plan and system energy needs the following winter. The parties to this Interim Agreement acknowledge that the reservoir elevation on any given day and the availability of water to refill Brownlee Reservoir in preparation for the Fall Chinook Plan and winter operations are dependent upon variables that may be beyond IPC's control. These variables include, but are not limited to:

    1. Climatic conditions, Snake River inflows to the reservoir, emergency situations, and flood control and navigation requirements;

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[1] IPC has provided the SWG with a copy of its settlement agreement with Baker County dated October 3, 2003.

2. The necessity to utilize Brownlee Reservoir and the HCC to protect the performance, integrity, reliability, and stability of IPC's electrical system or the electrical systems with which it is connected, including compensating for an unscheduled loss of generation, providing generation during severe weather, energy shortages or periods of market instability, and providing Western Electric Coordinating Council and North American Electric Reliability Council reserves;

b. 2006 (and subsequent years provided the SWG remains engaged in settlement discussions or as provided in Section 3.a.) – The parties intend that the F/A draft of Brownlee Reservoir in 2006 will proceed as in 2005 and will result in the release of approximately 237 kaf of storage water at a financial impact no greater than approximately $2 Million to IPC and the ratepayers ($2 Million is also considered an approximate value in 2005, which is the basis upon which IPC provides 237 kaf in 2005) and that it will be subject to the same conditions and variables as the 2005 F/A draft (See: Section 2.a.). IPC will seek the concurrence of NOAA and USFWS, and update the SWG in the fall and winter of 2005 in preparation for the F/A draft in 2006. The parties will review the 2005 F/A draft program, exchange information relative to the projected energy market and water year influences on the 2006 F/A draft program, and work together to ensure that the 2006 F/A program meets the expectations of the parties, the conditions and variables outlined in Section 2.a. above, and the resource needs of listed species.

c. Provided that the federal flow augmentation program implemented by the BoR is consistent with state law, the SRBA Mediator's Term Sheet and the BoR's 2004 biological assessment, and provided further that the annual financial impact to IPC and the ratepayers from cooperating with the flow augmentation program, in conjunction with any impact from the F/A draft under Sections 2.a. & b., is not greater than approximately $2 Million. IPC will cooperate with the BoR in shaping BoR storage water releases from above Milner Dam that cannot be delivered to Brownlee Reservoir by August 31st by releasing up to 100 kaf of storage water from Brownlee Reservoir from June 21st to August 7th and refilling Brownlee with an equivalent amount of BoR water released for flow augmentation when that water reaches Brownlee Reservoir. IPC will ensure that any BoR releases for flow augmentation used to refill space at Brownlee Reservoir will be limited to the amount shaped and will be last of the BoR water released from above Milner Dam delivered to Brownlee Reservoir.

d. IPC will work with the SWG early in the long-term negotiation to set data collection priorities and ensure that adequate information is available to develop a comprehensive agreement.

e. For the purpose of supporting settlement discussions and reaching a comprehensive settlement agreement, IPC will work with the SWG to identify, develop and review information relative to potential structural modifications (including preliminary designs and feasibility studies) and/or operations intended to address aquatic resources and water quality related issues associated with the comprehensive settlement regarding operation and licensing of the HCC (including dissolved oxygen, total dissolved gas, and seasonal water temperatures).

f. IPC will work with state and federal agencies to provide water quality information to inform and support future ESA consultations and CWA §401 certifications.

g. The members of the SWG recognize that issues surrounding native resident and anadromous fish passage are unresolved and of critical importance to some members of the SWG and will be addressed in long-term settlement negotiations. In the interim, IPC agrees to disclose and share information, analysis and conclusions regarding past, current and proposed future studies. Further, the parties to this agreement recognize that the SWG has agreed to form an interim subcommittee comprised of all interested SWG members, to evaluate existing information and develop recommendations for future studies necessary to evaluate the feasibility of and potential options for native resident and anadromous fish passage. The subcommittee's evaluation and recommendations will be considered in development of a comprehensive settlement agreement.

3. The signatory parties to this Interim Agreement agree, based upon information currently available, that the measures provided for herein are intended to provide reasonable protection during the term of this Interim Agreement for ESA-listed species within and below the HCC and that parties will not seek any additional measures at the HCC to protect ESA-listed species so long as settlement discussions continue, provided:

a. If the settlement process results in a settlement agreement that provides for continuation of interim measures as set forth in this agreement and/or other measures in advance of the licensing of the HCC, IPC will undertake such action as is required to comply with the terms of the settlement agreement;

b. If additional information is identified as the HCC settlement process proceeds (e.g., through responses to additional information requests, IPC's ongoing monitoring, study or analysis associated with operations, or studies or analysis of third parties) that indicate either that modifications to the above measures or that additional measures may be necessary to protect ESA-listed species, NOAA Fisheries and the USFWS, in cooperation with the SWG, will review and consider such information and make recommendations to IPC. Should IPC fail to implement the recommended measures within a reasonable time or otherwise reach agreement on an appropriate way to address the issues raised by the recommendation, the issue may be referred to FERC for resolution or any of the parties may elect to withdraw from the settlement process and this Interim Agreement and pursue available legal remedies;

4. Except as otherwise provided in this agreement, IPC will work with the SWG in the implementation of this agreement.

5. The parties agree that IPC shall file this Interim Agreement with the Commission for informational purposes and that IPC may proceed with implementation of the measures set forth herein without Commission approval.

6. The signatory parties have executed this Interim Agreement by separate signature pages, each page indicating the date of execution and the identity and address of the party entering into this Interim Agreement.

Hells Canyon Hydroelectric Project Settlement Process

Interim Agreement

Signature Page

The Undersigned agrees to the Hells Canyon Hydroelectric Project Settlement Process Interim Agreement;

Dated this 20th day of December, 2004

Name of Party: Idaho Power Company

By:

Address: 1221 W Idaho

Boise, ID 83702

Telephone: (208) 388-2865

Hells Canyon Hydroelectric Project Settlement Process

Interim Agreement

Signature Page

The Undersigned agrees to the Hells Canyon Hydroelectric Project Settlement Process Interim Agreement;

Dated this 20th day of December, 2004

Name of Party: NOAA Fisheries

D. Robert Lohn

By: D. Robert Lohn, Regional Administrator

Address: 7600 Sand Point Way NE Bldg. 1

Seattle, WA 98115

Telephone: 503.231.2319

Hells Canyon Hydroelectric Project Settlement Process

Interim Agreement

Signature Page

The Undersigned agrees to the Hells Canyon Hydroelectric Project Settlement Process Interim Agreement;

Dated this 20 day of December, 2004

Name of Party: USDA Forest Service

By: Deputy Regional Forester

Address: 333 SW First Avenue
Portland, OR 97204

Telephone: 503.808.2202

Hells Canyon Hydroelectric Project Settlement Process

Interim Agreement

Signature Page

The Undersigned agrees to the Hells Canyon Hydroelectric Project Settlement Process Interim Agreement;

Dated this 21st day of Dec, 2004

Name of Party: U.S. Fish and Wildlife Service

By: Melissa Beck Haas

Address: 1387 S. Vinnell Way
Boise Idaho 83709

Telephone: (208) 378-5384

Hells Canyon Hydroelectric Project Settlement Process

Interim Agreement

Signature Page

The Undersigned agrees to the Hells Canyon Hydroelectric Project Settlement Process Interim Agreement;

Dated this 21st day of December 2004

Name of Party: DAVID R. Henderson

By: David R. Henderson

Address: Bureau of Land Mgmt.
100 Oregon ST. Vale, OR 97918

Telephone: 541 473 6201

Hells Canyon Hydroelectric Project Settlement Process

Interim Agreement

Signature Page

The Undersigned agrees to the Hells Canyon Hydroelectric Project Settlement Process Interim Agreement;

Dated this 22 day of December, 2004

Name of Party: Idaho Rivers United

By:

Address: P.O. Box 633

Boise, ID 83701

Telephone: (208) 343-7481

Hells Canyon Hydroelectric Project Settlement Process

Interim Agreement

Signature Page

The Undersigned agrees to the Hells Canyon Hydroelectric Project Settlement Process Interim Agreement;

Dated this 22nd day of December, 2004

Name of Party: AMERICAN RIVERS

By:

Address: 1025 VERMONT AVE NW STE 720
WASHINGTON DC 20005

Telephone: (202) 347 7550 x 3013

Hells Canyon Hydroelectric Project Settlement Process

Interim Agreement

Signature Page

The Undersigned agrees to the Hells Canyon Hydroelectric Project Settlement Process Interim Agreement;

Dated this 22nd day of December, 2004

Name of Party: Department of Environmental Quality

By:

Address: 700 SE Emigrant, #330
Pendleton, OR 97801

Telephone: 541 278 4610

Hells Canyon Hydroelectric Project Settlement Process

Interim Agreement

Signature Page

The Undersigned agrees to the Hells Canyon Hydroelectric Project Settlement Process Interim Agreement;

Dated this 23 day of DEC, 2004

Name of Party: Oregon Department of Fish and Wildlife

By: Lindsay A Ball

Address: 3406 Cherry Ave NE
Salem, Oregon 97303

Telephone: 503-947-6044

Hells Canyon Hydroelectric Project Settlement Process

Interim Agreement

Signature Page

The Undersigned agrees to the Hells Canyon Hydroelectric Project Settlement Process Interim Agreement;

Dated this 27th day of Dec., 2004

Name of Party: Shoshone Paiute Tribes

By:

Address: P.O. Box 219
Owyhee, NV. 89832

Telephone: (208) 759-3100

Hells Canyon Hydroelectric Project Settlement Process

Interim Agreement

Signature Page

The Undersigned agrees to the Hells Canyon Hydroelectric Project Settlement Process Interim Agreement;

Dated this 29th day of December, 2004

Name of Party: Nez Perce Tribe

By: Allen P. Slickpoo Jr.
Chairman, Nez Perce Tribal Executive Committee

By: Larry C. Greene
Secretary, Nez Perce Tribal Executive Committee

Address: P.O. Box 305
Lapwai, Idaho 83540

Telephone: (208) 843-2253

Hells Canyon Hydroelectric Project Settlement Process

Interim Agreement

Signature Page

The Undersigned agrees to the Hells Canyon Hydroelectric Project Settlement Process Interim Agreement;

Dated this 30th day of December, 2004

Name of Party:

By:

Address: SHOSHONE-BANNOCK TRIBES

P.O. BOX 306

Telephone: FORT HALL, IDAHO 83203

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Exhibit 7.1-14

September 29, 2005, Idaho Power Company's (IPC) response to the Federal Energy Regulatory Commission's (FERC) additional information request (AIR) WQ-2(c)

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REGULATORY COMMISSION

Craig A. Jones
Hells Canyon Relicensing Project Manager
Hydro Relicensing Department

(208) 388-2934
fax (208) 388-6902
e-mail cjones@idahopower.com

September 29, 2005

Magalie R. Salas, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Room 1A East
Washington, D.C. 20426

Re: Hells Canyon Project No. 1971-079, Responses to Requests for Additional Information

Dear Secretary:

By letter dated June 7, 2005, the Federal Energy Regulatory Commission (FERC) granted an extension of time to September 30, 2005, for Idaho Power Company (IPC) to file its response to AIR WQ-2(c). Accordingly, enclosed for filing with the FERC are one (1) original hard copy and eight (8) CD copies of IPC's response to the aforementioned AIR.

Finally, by copy of this letter, the Service List is hereby notified that IPC's response to WQ-2(c) will be available for viewing at ipchydro.org. In addition, CD copies of this AIR may by requested by contacting Dee Aulbach by phone at (208) 388-6109 or e-mail at daulbach@idahopower.com.

Please contact me if there are any questions regarding this filing.

Sincerely,

Craig A. Jones

CAJ/cs
cc: Service List
Jim Tucker, IPC
Dave Meyers, IPC
Jim Vasile, Davis Wright Termaine
Alan Mitchnick, FERC (CD)

*
CD/eLibrary

Idaho Power Company
Hells Canyon Complex (FERC Project No. 1971)

Bureau of Reclamation	
Judy Ellis	Adams County Commissioner
Sara Eddie	Advocates for the West
Connie Kelleher	American Rivers
County Judge	Baker, County of
Chairman	Blaine, County of
Regional Hydro Policy Specialist	Bureau of Indian Affairs
Mel Berg	Bureau of Land Management
Jim Clark	Bureau of Land Management
Eric Hoffman	Bureau of Land Management
John Martin	Bureau of Land Management
Dorothy Mason	Bureau of Land Management
Dean Adams	Burns Paiute Tribe
Denise Turner-Walsh	Burns Paiute Tribe
Mayor	City of Boise
Jennifer Frozena	Columbia River Inter-Tribal Fish Commission
Robert Lothrop	Columbia River Inter-Tribal Fish Commission
Carl Merkle	Confederated Tribes of the Umatilla Indian Reservation
Todd True	Earthjustice Legal Defense Fund
Daniel Ousley	Hells Canyon Preservation Council
Harriet Hensley	Idaho Attorney General's Office
Barry Burnell	Idaho Department of Environmental Quality
Doug Conde	Idaho Department of Environmental Quality
Scott Grunder	Idaho Department of Fish and Game
Steven Schuster	Idaho Department of Lands
Mary Lucachick	Idaho Department of Parks and Recreation
Phillip Rassier	Idaho Department of Water Resources
Dan Tomich	Idaho Department of Water Resources
Donald Howell, II	Idaho Public Utilities Commission
Randy Lobb	Idaho Public Utilities Commission
Kevin Lewis	Idaho Rivers United
David Hawk	J.R. Simplot Company
Chairman	Jerome, County of
Lee Sherline	Leighton & Sherline
Chairman	Linclon County
Robert Ling	Ling, Nielson & Robinson
Russ Hursh	Malheur County Court Judge
Chairman	Minidoka, County of
Scott Campbell	Moffat, Thomas, Barrett, Rock & Fields
David Cummings	Nez Perce Tribe
Greg Haller	Nez Perce Tribe
Ritchie Graves	NOAA Fisheries
Jane Hannuksela	NOAA Fisheries
Keith Kirkendall	NOAA Fisheries

Idaho Power Company
Hells Canyon Complex (FERC Project No. 1971)

Ed Chaney	Northwest Resource Information Center
Arthur Seamans	NW Professional Power Vessel Association
Paul DeVito	Oregon Department of Environmental Quality
Colleen Fagan	Oregon Department of Fish and Wildlife
Ken Homolka	Oregon Department of Fish and Wildlife
Kurt Burkholder	Oregon Department of Justice
Phil Ward	Oregon Department of Water Resources
Jan Houck	Oregon Parks and Recreation Department
Bill McNamee	Oregon Public Utility Commission
Randy Henry	Oregon State Marine Board
Craig Kohanek	Oregon Water Resources Department
Daniel Rohlf	Pacific Environmental Advocacy Center
Forest Supervisor	Payette National Forest
Chairman	Power County Commissioners
Ron Bliessner	Shoshone Bannock Tribes
Tribal Attorneys	Shoshone Bannock Tribes
Dan Israel	Shoshone-Bannock Tribe
Keith Kutchins	Shoshone-Bannock Tribes
Jocelyn Somers	U.S. Department of Agriculture
Frank Wilson	U.S. Department of Interior
Field Supervisor	U.S. Fish and Wildlife Service
Kristen Bonanno	U.S. Forest Service
Walter Dortch	U.S. Forest Service
County Judge	Wallowa County Court
Forest Supervisor	Wallowa-Whitman National Forest
Diana Thomas	Washington County Commission

Responses to FERC Additional Information Request WQ-2(c)

Detailed Evaluation of Alternative Temperature Control Structures

Hells Canyon Project
FERC No. P-1971-079

September 2005

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SCHEDULE A: ADDITIONAL INFORMATION REQUEST DETAILED EVALUATION OF ALTERNATIVE STRUCTURES

Time Required: Submit by September 30th, 2005

Original Text of WQ-2(c)

(c) Prepare and file a report that provides a detailed evaluation of the potential effectiveness of the preferred design that was identified in part(b) of AIR WQ-2. This report should include modeling of the temperature and DO levels of waters discharged from Hells Canyon dam for each of the 5 representative years (1992, 1994, 1995, 1999, and 1997) under proposed operations and for the flow augmentation scenario described in Scenario 2 of AIR OP-1, Operational Scenarios. Your evaluation should include multiple model runs as needed to develop and refine a seasonal strategy for withdrawing water from selected depths(s), including blends of water drawn from more than one depth, to meet seasonal temperature objectives identified in part (a) of AIR WQ-2. Your report should identify a preferred seasonal withdrawal strategy and determine the timing and amount of oxygen that would need to be added to outflows from Brownlee development to meet the DO objectives identified in part (a) of AIR WQ-2. In addition, please provide a qualitative evaluation of the potential effects of the strategy on ammonia levels, pH levels, and concentrations of mercury and organo-chlorine compounds in the waters discharged from Hells Canyon dam. In your simulations, please assume implementation of aeration of Brownlee reservoir as you have proposed, as well as venting of Brownlee units 1 through 5. Also provide a proposed implementation schedule and a detailed estimate of design, construction, and operation costs including any oxygen augmentation measures that are needed to meet DO objectives that are not explicitly addressed in AIR WQ-1, Dissolved Oxygen Augmentation) and any effects on project generation or dependable capacity from implementing the preferred alternative. Please provide your estimate of capital and operation costs and any effects on project generations or dependable capacity by year over the term of the next license, assuming a 30-year license.

For your proposed withdrawal strategy, please provide plots of the following information for both proposed operations and for the flow augmentation scenario:

(i) A plot of simulated hourly water temperatures below Hells Canyon dam from January 1 through December 31 for each of the 5 representative years (1992, 1994, 1995 , 1999, and 1997).

(ii) A plot of simulated hourly DO levels below Hells Canyon dam from January 1 through December 31 for each of the 5 representative years (1992, 1994, 1995 , 1999, and 1997).

(iii) Semi-monthly plots (February, April, June August, October and December) of simulated temperature and DO isopleths in Brownlee reservoir for each of the 5 representative years (1992, 1994, 1995, 1999, and 1997). These plots should be similar in format to the plots that you provided in figures 13 and 26 of Technical Appendix E.2.2-2, except that each plot should be provided in a full-page, black-and-white format.

(iv) A qualitative evaluation of the potential effects on ammonia levels, pH levels, and concentrations of mercury and organo-chlorine compounds in the waters discharged from Hells Canyon dam for each of the 5 representative years (1992, 1994, 1995, 1999, and 1997).

Each of these graphs should be provided in a full-page, black and white format to ensure that all data series are visible both in hard copy and electronic formats. To facilitate side-by-side comparisons, please provide the same graphs for your current and proposed operations using the existing intake configuration and the current depth of withdrawal.

Text of FERC letter of June 7, 2005

“You and the settlement group have been unable to reach consensus on a preferred temperature control alternative. Regardless of the results of the settlement discussions, we need sufficient information to address the various alternatives in the draft environmental impact statement (DEIS). Therefore, provide, by September 30, 2005, the information required by WQ-2(c) for the following three alternatives: (1) stoplog weir (alternative no. 1); (2 gated weir with tunnel (alternative no. 2); and (3) 35-kcfs intake tower (alternative no. 12). This will allow us to capture a complete range of potential effects of installing a temperature control device.”

1. INTRODUCTION

On June 7th, 2005, FERC transmitted a letter to Idaho Power Company (IPC) recognizing that IPC was working with the Settlement Work Group (SWG) to evaluate the downstream benefits of alternative temperature control structures, and thus extended the time period for submitting AIR WQ-2 part (c) to September 30th, 2005. In the letter, FERC also recognized that a preferred alternative had not been identified, and instead requested that IPC complete AIR WQ-2(c) for three temperature control structures (TCS): the Stop-Log Weir (StopL), Gated Weir and Tunnel (Gattun), and 35 kcfs Tower (35T).

By letter dated June 29, 2005, IPC provided the results of the U.S. Army Corps of Engineers (Corps) modeling to determine the influence of two temperature control structures at Brownlee Dam (StopL and Gattun) on water temperatures in the lower Snake River between the Anatone gauge and the Lower Granite Reservoir tailwater. This modeling effort was initiated by IPC in connection with the Hells Canyon Complex (HCC) settlement process to assist in determining the effect of installing a TCS in Brownlee Reservoir on water temperatures in the Snake River below the HCC through Lower Granite Reservoir, and correspondingly, the potential benefit, if any, that such temperature changes may have on juvenile fall Chinook emerging and migrating from below Hells Canyon Dam through Lower Granite Reservoir. Because the Corps' modeling results are relevant to the matters presented herein, a copy of the June 29, 2005, filing with FERC is appended to this AIR response (Appendix A).

Using the Corps' modeling results, IPC, in conjunction with NOAA Fisheries, subsequently completed an analysis of the effect of changing the outflow temperature from Hells Canyon Dam, by installing and operating a TCS in Brownlee, on the timing of emergence of juvenile fall Chinook below Hells Canyon Dam and the survival of those juveniles at the Lower Granite tailwater. Generally, this analysis concluded that installing a TCS at Brownlee and operating the structure in low flow water years to cool outflows in an attempt to meet the salmonid spawning water quality standard of 13 °C below Hells Canyon Dam offsets any benefit of attempting to influence earlier emergence of juvenile fall Chinook from operating the TCS for spring warming. This analysis, when considered with the other information developed with regard to the operation and effect of installing a TCS at the HCC, leads to the following conclusions: water temperatures cannot be warmed sufficiently in the spring to provide significant benefit to incubating fall Chinook salmon, e.g., the change in emergence timing is relatively modest; operating the TCS to cool outflows in the fall in an effort to meet the existing water quality standard for salmonid spawning actually results in a delay in spring emergence timing, thereby offsetting any benefit of the spring operation; and, finally, the installation and operation of a TCS at Brownlee Dam in an attempt to meet either of these objectives actually results in a lower survival of juvenile fall Chinook through Lower Granite Reservoir.

Based on the Corps' modeling effort and the survival analysis undertaken by IPC and NOAA Fisheries, IPC has concluded that the preferred alternative is to not install a TCS at the HCC. IPC is aware that issues relative to the fall temperature load allocation assigned to the HCC by the Snake River–Hells Canyon TMDL remain unresolved and continues to work with the Oregon Department of Environmental Quality (ODEQ) and Idaho Department of Environmental Quality (IDEQ), in the § 401-certification process, to identify measures or other appropriate procedures for addressing those issues.

In this AIR, IPC offers the basis for its conclusion that a TCS should not be installed at the HCC (a summary of the survival analysis is presented below) and responds to FERC's inquiries relative to the effectiveness of each of the three alternatives to change the existing temperature regime below Hells Canyon Dam. IPC has not, however, devoted the time and effort to address in this AIR issues related to alternatives for augmenting or otherwise ameliorating the effects of operating a TCS at HCC on DO. (This AIR does reflect the dissolved oxygen (DO) levels from operating a TCS without DO augmentation. These DO levels are part of the CE-QUAL-W2 modeling effort, which were included in WQ-2(b) and are also included in this report). There are several reasons for excluding the DO augmentation information. First, because IPC's analysis indicates that the preferred alternative is to not install a TCS at HCC, devoting resources to the augmentation question seemed irrelevant and an unnecessary dedication of resources. Second, and perhaps more importantly, because the AIR focused on the level of DO augmentation necessary to attain DO water quality standards, its breadth raised issues that extend well beyond the responsibility of the HCC for DO, and correspondingly the scope of this proceeding.

IPC continues to explore the responsibility of the HCC for DO issues with IDEQ and ODEQ as part of the CWA § 401-certification process. Related discussions are also occurring in the HCC settlement (SWG) process. A primary focus of these discussions is defining IPC's responsibility for DO downstream of Hells Canyon Dam. In 2003, IDEQ and ODEQ jointly developed the Snake River–Hells Canyon Total Maximum Daily Load (TMDL) (ODEQ and IDEQ 2003) for the Snake River between river miles (RM) 409 and 188. IPC, as well as other stakeholders with property interests adjacent to and upstream from the river segment that is the subject of the TMDL, participated in the TMDL development process. The TMDL contains load allocations for the Hells Canyon Complex (HCC) for various water quality parameters, including DO, but recognizes that DO concentrations in the Brownlee Reservoir and the Snake River are closely linked to, and influenced by, nutrient concentrations. As a consequence, the TMDL, in implementing a watershed approach, assigned total phosphorus load allocations to pollutant sources for the Snake River upstream of the HCC (RM 409–335) and a DO load allocation for Brownlee Reservoir (RM 335–285). However, as the TMDL was primarily focused on conditions in, and upstream from, Brownlee Reservoir, it did not specifically address DO conditions in the Snake River downstream of Hells Canyon Dam. As part of the 401-certification process and the complementary SWG process, IPC, ODEQ, and IDEQ have been attempting to determine an appropriate DO allocation for the HCC at Hells Canyon Dam. These efforts continue and will form the basis for the manner in which IPC addresses DO issues in its revised § 401 application, which is scheduled to be submitted to the DEQs later this year.

2. RESPONSE

2.1. CE-QUAL-W2 Modeling

The water quality modeling methods and results provided in WQ-2(b) provide much of the required information for WQ-2(c). The reader is referred to WQ-2(b) for a more detailed explanation of the modeling, methods, and results. In WQ-2(b), the CE-QUAL-W2 water quality model was set-up and run for the StopL, Gattun, and 35T for both proposed and OP-2 reservoir operations as well as for the Low, Medium-Low, Medium, Medium-High, and High water years. Each scenario was run several times to optimize the operation of each structure to best obtain the temperature targets given in WQ-2(a). Reservoir aeration was also incorporated into the model runs as described in IPC's response to AIR WQ-1.

2.1.1. Water Quality Scenarios

2.1.1.1. The Current Condition Water Quality Scenario (Current Conditions)

In WQ-2(b), all of the above mentioned scenarios were run with two different water quality scenarios. The first scenario was run using the current condition water quality inflows from the Snake River and current condition sediment oxygen demand (SOD) settings. The water quality inflow data used for current conditions were based on the best available data that best represented the actual inflowing conditions into Brownlee reservoir during each of the specific water years (different conditions were used for different water years). The SOD values were determined during model calibration in which the SOD values were set so the model best predicted DO concentrations as compared to measured field data.

2.1.1.2. The TMDL Water Quality Scenario (TMDL Conditions)

Simulations were also performed using inflowing conditions representative of long-term upstream water quality improvements and implementation of IPC's 1,150 ton DO allocation as required by the Snake River-Hells Canyon TMDL (IDEQ and ODEQ 2003). Long-term TMDL improvements were modeled for all the representative years using calculations described in Myers et al. 2003. A total phosphorus (TP) concentration target of 70 µg/L has been established for the upstream reach of the Snake River as part of the TMDL (IDEQ and ODEQ 2003). Dissolved phosphorus and organic phosphorus were reduced in the

Brownlee Reservoir model inflows to simulate how the reservoir would respond to the TP target. With inflow water quality improvements and the associated decrease in organic matter (OM) loading as contemplated by the TMDL, SOD should also decrease over the long term. The proposed TP reduction and resulting SOD improvements were simulated to assess the reservoir's response to potential long-term water quality improvements in inflow.

To simulate the TP target, dissolved phosphorus and organic phosphorus (organic matter, including algae) were reduced from the baseline boundary conditions such that inflowing TP levels did not exceed 70 µg/L. As watershed management actions are implemented to meet the target, total organic matter (TOM) loads and sedimentation are expected to decrease. As loads decrease and existing TOM decays through natural processes, SOD decreases. Response to these long-term improvements was simulated by reducing SOD to 0.1 g O2/m2/day throughout the reservoir. This SOD is more typical of naturally occurring SOD levels (Cole and Wells 2002). For the lower reservoirs, discharge from the upstream reservoir was used as the inflow boundary condition and SOD was reduced to Brownlee levels (0.1 g O2/m2/day).

2.1.2. Results

The Hells Canyon hourly outflow temperatures and DO for the three selected structures, five representative water years, and two operational scenarios for current conditions are shown in

Figures 1–30, and for TMDL conditions are shown in Figures 31–60. Semi-monthly plots (February, April, June, August, October, and December) of simulated temperature and DO isopleths in Brownlee reservoir for each of the three structures, two operational scenarios, five representative years (1992, 1994, 1995, 1999, and 1997) for both current and TMDL conditions are included in Appendices B and C, respectively.

Overall, in WQ-2(b) it was determined that the most significant factor influencing the effectiveness of the various structures was the reservoir operations and hydrologic conditions in a given year and their effect on outflow conditions from Brownlee reservoir. All of the structures have greater effectiveness in the low water years than in high water years. Also, all structures were more effective for cooling summer and fall outflows when using proposed operations rather than OP-2 operations. Further conclusions are given below.

Spring Warming:

- Overall, there was little difference in spring warming potential between the structures.

- Regardless of the structure selected, spring warming is only likely to occur in the lower flow years after the month of March.

Ability to meet the fall target:

- With both proposed and OP-2 operations, the fall target was obtained with the Gattun and 35T structures in all modeled water years. The fall target was obtained with the StopL in all modeled years except the medium-high flow year.

Summer Cooling:

- The relative effectiveness of each structure to cool the outflows in the summer is dependent upon the extent that the structures are used to address the fall target. The greater the emphasis that is placed on cooling outflow in the fall, the less cool water is available for cooling outflow in the summer.

Dissolved Oxygen:

- Overall, the simulated trends in DO results appear to be logical providing a general indication of the conditions that would occur if a structure were constructed. Results show that the greater cooling potential available with the Gattun and 35T cause lower downstream DO. Furthermore, operation of the structures can be used to increase summer downstream DO while still meeting the fall temperature objective. Because accessing a high percentage of low DO cooling water is necessary to reach the fall target, DO levels may be adversely affected during the fall period.

2.2. Emergence and Survival of Juvenile Fall Chinook Salmon

2.2.1. Modeling Purpose

As originally contemplated, the purpose of the TCS evaluation was to determine whether installation of a TCS at Brownlee Dam would 1) influence fall water temperatures below HC Dam by meeting the salmonid spawning criteria, 2) allow conditions below HC Dam to warm earlier in the spring to accelerate emergence timing, and 3) as a result of earlier emergence, allow fish to pass through Lower Granite Reservoir earlier with presumably better conditions for migration or result in larger (older) juveniles at the time of migration. For the purpose of the evaluation, both a StopL and a Gattun were evaluated and compared to base (Base) conditions with no TCS in place. These two structures were chosen from the alternatives presented in the AIR WQ-2 to represent the likely range of outcomes of all of the various TCS alternatives because none of the other structures offered any greater opportunity to meet the targets.

As part of the ongoing HCC settlement process, and as part of the analysis of the efficacy of a TCS, it was determined that it would assist in the evaluation of the TCS alternatives to obtain an analysis of the impacts of the various control structures at Brownlee Dam on water temperatures in the lower Snake River between the Anatone gage and the Lower Granite Reservoir tailwater. IPC arranged to have the Corps undertake a modeling effort to address that issue. On June 29, 2005, IPC submitted the results of the modeling completed by the Corps to FERC. The purpose of the Corps' modeling was to evaluate potential changes in water temperature at the Lower Granite tailwater resulting from two different temperature control structures (TCS) at Brownlee Dam. Subsequent to the receipt of the Corps' modeling, NOAA Fisheries and IPC used the modeling results to analyze the effect of installing and operating a TCS at Brownlee on the emergence and survival of juvenile fall chinook downstream of Hells Canyon Dam. In this analysis, three components of the modeling effort and their corresponding effect on juvenile fall chinook salmon were considered: 1) emergence timing relative to spring warming as a result of a TCS in place, 2) emergence timing relative to meeting the states of Oregon and Idaho salmonid spawning criteria of 13 °C on October 23rd, and 3) juvenile fall chinook survival at the Lower Granite Tailwater relative to temperature and flow.

2.2.2. Juvenile Fall Chinook Emergence and Survival

Emergence timing may influence fall Chinook salmon survival relative to the timing of when smolts arrive at Lower Granite Reservoir. Connor et al. (2003) concluded earlier emerging smolts arrive at Lower Granite Reservoir earlier and generally experience better conditions for survival through the reservoir to the Lower Granite Dam tailwater. They developed a model, influenced by both flow conditions and water temperatures, for juvenile fall chinook salmon survival through Lower Granite Reservoir.

2.2.2.1. Emergence

Emergence timing of incubating fall chinook salmon is influenced by thermal unit accumulation[1] from the point of fertilization. Typically, approximately 1,000 thermal units accumulate in an incubating fall chinook alevin before it emerges from the redd environment. To compare emergence timing, a median

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[1] A thermal unit is a daily average temperature of 1 degree Celsius (above 0 degrees). For example, if the daily average temperature is 10 C, then 10 thermal units have accumulated. If the following daily average temperature is also 10 C, then over the two days, 20 thermal units have accumulated.

spawn date was calculated from a cumulative daily redd construction distribution developed from spawn years 1993 to 2003 (Figure 61). The median spawn date of the distribution is November 4. Thermal units were calculated from the Base, StopL, and Gattun modeled data sets to estimate the date of emergence.

The evaluation of emergence resulted in the two temperature control structures delaying emergence timing. The StopL resulted in a 5-day delay in emergence relative to Base conditions, and the Gattun resulted in a 1-day delay in emergence relative to Base conditions. The result had the opposite effect of the desired outcome of earlier emergence. When comparing thermal unit accumulations, it is evident that cooling water in the fall to meet the salmonid spawning criteria of 13 °C counteracts any benefit gained by accelerating spring warming with either TCS. For example, during the low flow year of 1992, thermal units lost in the fall by meeting the state standard was 78.6 thermal units (Stop L) and 29.4 thermal units (Gattun), whereas the gain in the spring by earlier warming provided an increase of only 28.8 thermal units (StopL) and 23.9 thermal units (Gattun), for an over all net loss of accumulated thermal units of 49.8 thermal units (StopL) and 4.9 thermal units (Gattun).

2.2.2.2. Survival through Lower Granite

Survival to the Lower Granite Tailrace for juvenile fall chinook salmon was estimated under the three model conditions (Base, StopL, Gattun) using a survival model developed by Connor et al. (2003)[2]. The model is based on flow and water temperature conditions at the tailwater of Lower Granite Reservoir combined in a single equation as follows:

$$\text{Survival} = 140.82753 + 0.02648\,(\text{Flow};\ \text{cms}) - 7.14437(\text{Temp};\ \text{C}).$$

To apply this equation, average flow and average temperature conditions were estimated using output from the Corps' Lower Granite Reservoir CE-QUAL W2 model during two periods of the juvenile fall chinook outmigration period: 1) the time period between the 10th and 50th percentiles of the juvenile fall chinook outmigration distribution and 2) the time period between the 50th and the 90th percentile of the juvenile fall chinook outmigration distribution (Table 1).

During the early 1990's, including 1992 and 1995 water years, naturally produced juvenile fall chinook were relatively low in abundance. Since that time, numbers of naturally produced fall chinook salmon have increased significantly. There was concern in this analysis that the outmigration periods of 1992 and 1995 were so small, that they may not adequately represent the smolt outmigration distribution of a low

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[2] The approach in applying Connor et al. 2003 for estimating survival in this analysis was suggested by Ritchie Graves, NOAA Fisheries, as a method of assessing the potential for a TCS to enhance fall Chinook salmon smolt survival through Lower Granite Reservoir.

and medium water year for modeling purposes. To better represent the smolt outmigration period for a low and medium water year, it was decided that the smolt outmigration years of 2001 and 1998 would be used to represent a low and medium year smolt outmigration distribution, respectively (Table 1).

Results of the survival equation suggest that the temperature control structures would likely result in lower survival rates relative to the base case (Table 2). This result is primarily because summer water temperatures coming out of the Hells Canyon Complex are warmer with a TCS in place than the Base case (colder water is stored during summer months). These warmer conditions continue down stream to influence water temperatures at the Anatone gage and then to the tailwater of Lower Granite Reservoir. This warming in water temperatures resulted in slightly higher average water temperatures during the two outmigration periods analyzed relative to smolt survival. Slightly higher water temperatures resulted in a reduction in survival relative to the base case of no temperature control structures.

These results are without consideration to the delay in emergence timing as a result of a TCS in place. Delays in emergence / migration timing would potentially result in shifting the time periods of the smolt outmigration later or result in smaller fish migrating at the same time. A later emergence in this analysis would potentially expose fish to slightly warmer conditions and potentially lower flow in Lower Granite thereby potentially decreasing survival further. Smaller juveniles would also likely have higher mortality rates as they migrated through the free-flowing Hells Canyon reach and Lower Granite reservoir.

2.2.3. Summary of TCS and Fall Chinook Survival Analysis

The results of this modeling effort indicate several factors to consider about the effectiveness of installing a TCS at Brownlee Dam.

1) In low flow years, operating a TCS to cool Hell Canyon outflows to meet the salmonid spawning standard of 13 °C identified by the states of Oregon and Idaho offsets any potential benefit that may result from operating a TCS in the following year to warm outflows to encourage earlier emergence. In short, temperatures cannot be warmed early enough in the spring to gain benefit to incubating fall Chinook salmon. Fall cooling to meet the states salmonid spawning standard will result in delayed emergence timing.

2) In low flow years, because the TCS alternatives were modeled to ensure meeting the fall standard, colder water was stored during summer months, resulting in warmer conditions passing downstream into Lower Granite Reservoir. These warmer conditions resulted in slightly warmer outmigration conditions, which slightly decreased survival estimates for juvenile fall chinook salmon passing through Lower Granite Reservoir. It is important to emphasize that modeling for fall cooling allowed optimization of water storage to meet the fall standard and minimize summer

warming. This optimization was possible because with a modeled data set, we had perfect knowledge of future conditions and volume of cold water required to meet the fall standard. However, in practice, actual operation of a TCS to meet the fall temperature criteria would not have the benefit of such optimization and would likely result in operating the structure conservatively to ensure that a sufficient volume of cool water was retained in the reservoir to meet this need. This would likely result in an extension and possible increase of summer temperatures downstream relative to the modeling results. Therefore, the negative results on juvenile fall Chinook salmon migration survival predicted by the modeling are likely conservative and potentially underestimate the negative effect of a TCS on fall Chinook salmon survival. In medium flow years, a TCS makes little difference to fall Chinook salmon emergence timing or survival through Lower Granite Reservoir relative to Base conditions.

2.3. Potential Effects on Ammonia Levels, pH Levels, and Concentrations of Mercury and Organo-Chlorine Compounds

2.3.1. Reservoir Processes

As outlined in WQ-2(b), it is hypothesized that a temperature control structure would raise the elevation of the thermocline present in Brownlee Reservoir between March and November. Raising the thermocline in Brownlee Reservoir would modify the thermal structure and alter physical, biological and chemical processes in the reservoir from what occurs currently. A major factor driving the in-reservoir thermal structure is the depth (i.e., thickness) of the epilimnion. Under current conditions, the epilimnion in Brownlee reservoir is deep and is strongly controlled by the physical configuration of the power intake channel from which the penstocks draw water. Simulations using the CE-QUAL-W2 model with the three TCS's, suggests that the epilimnion would become considerably shallower, the thermocline would become stronger, and anoxic conditions in the metalimnion and hypolimnion (present in current conditions) would exist closer to the surface. With the elevated thermocline there is more potential for periodic mixing of epilimnetic and metalimnetic waters and movement of anoxic water and other undesirable products into upper layers of Brownlee Reservoir. An increase in the elevation of the thermocline could also cause the upstream end of the metalimnion to move further upstream into shallower water and change processes in the transition zone of the reservoir from what currently occurs.

The release of cold water from the reservoir will affect the discharge levels of ammonia, mercury, organochlorines, and pH. However, it is difficult to describe what these effects are because there is uncertainty about how the altered thermal structure would change levels of these constituents in the various strata of the reservoir. The following qualitative discussion describes potential changes in discharge levels of these constituents based on general knowledge of reservoir processes.

2.3.2. Ammonia Processes

A major pathway for ammonia production is heterotrophic bacterial decomposition of organic matter where ammonia is generated as a primary end product. Under anoxic conditions in the water and sediments, bacterial nitrification of ammonia to nitrate and nitrite ceases and ammonia accumulates. When overlying water is anoxic, the capacity of sediments to absorb ammonia is greatly reduced and ammonia is released (Wetzel 2001). Accumulation of ammonia (and other anoxic products, including inorganic phosphorus and dissolved metals) throughout the year in the hypolimnion and deeper areas of the transition zone results as a combination of these processes. Large inflowing organic nitrogen loads are transformed in Brownlee reservoir, resulting in the retention of organic nitrogen and export of ammonia (Myers et al. 2003). Ammonia levels in the discharge from Hells Canyon Dam closely mirror levels in Brownlee powerhouse outflows and show some seasonal patterns with peaks in spring and late fall. These patterns coincide with periods of high inflow, reservoir drawdown, and fall turnover, which all result in redistribution of nutrients accumulated in the water column and sediments.

Ammonia will accumulate in the hypolimnion through the season and water drawn from the deeper hypolimnetic water directly would have high ammonia levels. Similar to current conditions, there would be temporal and spatial gradients of ammonia levels vertically and longitudinally through the reservoir, through the season. Ammonia levels (coinciding with anoxic conditions) often increase early in the deeper transition zone and gradually increase downstream in the colder hypolimnion. Also, vertical patterns of highest ammonia levels in the metalimnion and near the sediments of the hypolimnion (coinciding with anoxic conditions) will likely still be seen. With a raised and potentially stronger thermocline the accumulation of ammonia in the metalimnion could occur earlier in the season and be more intense. This means that water drawn from the hypolimnion directly (potentially the Gattun, and 35T) would increase discharge ammonia less if operated early in the season (e.g., June). Water drawn from the hypolimnion directly to cool temperatures in the fall would have higher levels of ammonia. Water drawn from the very bottom of the hypolimnion (Gattun) would have the highest levels and potentially disturb and mobilize sediment. A StopL would gradually access the metalimnetic water that could also have high ammonia levels. It is recognized that actual effects on discharge ammonia levels would be dependant on the volume of cool water (with high ammonia levels) mixed with surface water (with lower ammonia levels) and actual levels of ammonia in both waters.

Flow year (high, medium, low) has a large effect on in-reservoir thermal structure. Hypolimnetic temperatures are controlled in part by the extent of spring drawdown for flood control. Hypolimnetic temperatures are generally warmer and will cause ammonia to accumulate more quickly in high flow years with larger spring drawdown. Warmer hypolimnetic temperatures also mean less cooling potential and more volume needed to control temperatures. Therefore, for discharge ammonia levels, cooling temperatures in the fall in a high flow year may be the worse case scenario, while cooling temperatures in the early summer in a low flow year may be less extreme.

2.3.3. Mercury Processes

The complex cycling of mercury (Hg) among its many pools and forms in aquatic systems makes even a qualitative evaluation of effects of temperature control scenarios difficult. Inorganic mercury (InHg) and highly toxic, bioaccumulative methylmercury (MeHg) compounds are partitioned among sediment, water, and biota pools in both organic/inorganic and dissolved/particulate forms. The majority of InHg is typically stored in sediments (Meili 1997). Concentrations of MeHg and proportions of MeHg to InHg depend on the balance of methylation, demethylation, and chemical stabilization in the system. MeHg is formed by methylation of InHg in the presence of organic matter. Methylation is thought to be a microbial process highly dependent on methanogenic and sulfate-reducing bacteria in anoxic conditions, although it can also occur in oxic conditions (Miskimmin et al. 1992). Demethylation, which is also controlled directly by microbial activity or abiotically by sunlight, is highest in oxic photic zones (Meili 1997).

Organic matter concentrations and cycling exert strong control on the transport and transformations of Hg in aquatic systems. Concentrations of MeHg and total Hg typically increase with the concentration of dissolved organic carbon (Driscoll et al. 1994). Other important parameters influencing the cycle include concentrations and redox states of iron, manganese, chloride, and sulfur compounds.

Methylation appears highest in layers of the water column and sediments with steep redox gradients and high microbial activity (i.e., the metalimnion of eutrophic lakes and top centimeters of sediment). Oxic sediments can be a sink for InHg and MeHg while anoxic sediments can be a source. A buildup of MeHg is often seen in anoxic water where conditions slow demethylation and anoxic sediments increase MeHg release.

Based on the cycling of mercury it is speculated that any anoxic water discharged for temperature control could potentially increase discharge mercury levels. Methylation and demethylation rates are unknown. Many of the same in-reservoir patterns as ammonia are likely, and the effects of flow year similar. Water drawn from the very bottom of the hypolimnion (Gattun) could potentially have the highest levels. Since mercury is strongly associated with sediments disruption, mobilization of sediments could cause the largest increases.

2.3.4. Organochlorine Compounds

Similar to mercury, organochlorine compounds are strongly associated with sediments. Processes causing sediment disturbance and redistribution may make organochlorine compounds more available for biological accumulation.

2.3.5. Processes Affecting pH

In natural waters, pH is governed mainly by interaction of H+ ions arising from dissociation of H2CO3 (carbonic acid) and from OH ions produced during hydrolysis of HCO3- (bicarbonate) and from organic decomposition (Wetzel 2001). Carbonic acid is formed from hydration of dissolved CO2 where equilibrium exists with CO2, H2CO3, and CO32- (carbonate). When this equilibrium is shifted by removal of CO2 (e.g., from photosynthesis) or addition of CO2 (e.g., microbial respiration), pH can be shifted. Vertical patterns of pH in eutrophic waters can be strong due to photosynthetic removal of CO2 in the photic zone (raising pH) and CO2 generation from heterotrophic decay of organic matter, nitrification of ammonia, and oxidation of sulfide (lowering pH). These processes, combined with other decomposition processes, result in a decrease in pH in anoxic waters such as those in the metalimnion or hypolimnion. These patterns are especially pronounced in Brownlee reservoir due to high inflowing organic loads and high primary productivity.

2.4. Implementation Schedule for Alternatives

The reconnaissance level engineering assessment of selective withdrawal alternatives done by Washington Group International (WGI) estimated construction durations for the StopL and Gattun of between 25 and 30 months, and for the 35T, approximately 66 months. IPC estimates that it would take approximately 24 months to design, model, test, final design, and contract for any of these alternatives. Based on the above projections, IPC estimates that it would take approximately 4 years to design and construct the selective withdrawal StopL or Gattun, and approximately 7 years to design and construct the 35T.

2.5. Detailed Estimate of Design, Construction, and Operation Costs

Table 3 lists estimated costs for the StopL, Gattun, and the 35T. The energy loss costs for each of the alternatives that are shown in Table 3 have been revised since submittal of IPC's response to AIR WQ-2 Part (a) based on more detailed estimates of the costs. The estimated design, construction, and maintenance costs of each of the alternatives shown in Table 3 are unchanged from the estimated costs provided in IPC's response to AIR WQ-2 Part (a). The design of any of the alternatives would be refined prior to construction, however, it is not expected that such design refinements would significantly change the expected construction cost.

2.5.1. Estimated Direct Construction Costs

The direct construction cost estimates for each of the alternatives were prepared by Washington Group International (WGI) based on the concept plans and text descriptions shown in Appendix A of AIR WQ-2 Part(a). WGI's detailed cost estimate for each alternative is shown in Appendix B of AIR WQ-2 Part (a). These estimates are unchanged from IPC's response to WQ-2 Part (a).

2.5.2. Estimated Indirect Construction Costs

Indirect construction costs are composed of two separate costs—the cost of reservoir drafts to accommodate construction of the selective withdrawal structures, and the Allowance for Funds Used During Construction (AFUDC) for each of the structures. These cost estimates are unchanged from IPC's response to WQ-2 Part (a).

The estimated costs of reservoir drafts for construction were derived using a spreadsheet that calculated an estimated value of the power lost due to low reservoir elevation each hour of the medium flow year, with monthly peak and off-peak hourly power value estimates for 2005. The duration, depth, and time of year of reservoir drafts necessary to accommodate construction of each of the selective withdrawal structures was based on the concept plans and text descriptions shown in Appendix A of AIR WQ-2(a).

The estimated AFUDC for each of the alternatives was based on the predicted construction cost and duration of each of the structures from the text descriptions of the alternatives shown in Appendix A. An annual AFUDC rate of 7.24% was used to estimate the interest that would be capitalized for each of the alternatives.

2.5.3. Estimated Lost Power, Operational, and Maintenance Costs

Estimated annual lost power costs resulting from the existence and operation of each of the selective withdrawal structures are shown in Table 3. These estimates were developed using a variety of methods, mainly based on published energy loss equations by which the energy loss at specific flows are calculated based on the structural characteristics of the selective withdrawal structure. Because hydraulic modeling has been done for a structure similar to the StopL, which provided some empirical flow versus energy loss data, energy loss calculations for the StopL are considered more accurate than those for the Gattun and 35T.

The estimated lost power costs for the StopL and the Gattun have been re-calculated since submission of IPC's response to WQ-2 Part (a). The changes in these estimates resulted from refining the operations of the structures using the CE-QUAL-W2 model to optimize the operations of the structure for optimal temperatures. The new annual costs were calculated using the same methods as outlined in WQ-2(a). The energy loss estimates for the 35T are unchanged from prior estimates because the expected energy losses via the 35T are assumed to be independent of the water depth from which the powerhouse flows are extracted.

The projected O&M costs for each of the selective withdrawal alternatives are expected to be relatively minor in comparison to the other costs associated with the selective withdrawal alternatives, and have not been changed from the estimates provided in IPC's response to WQ-2 Part (a). The estimated O&M costs for each of the facilities were based on estimates of the amount of labor and parts necessary to operate and maintain each facility each year.

The annual O&M estimates were escalated at a current trend forecast rate of consumer price inflation (2.5%). To annualize the values, the 30-year escalated stream of expenses was averaged. Annual estimates for property insurance and property taxes were included in the annual cost estimates as well. All of the expense components for each alternative are listed in Table 4.

2.5.4. Estimated Total Costs

The 30-year total and annualized costs for each of the selective withdrawal structures include estimates for the following items that were mentioned previously: operation and maintenance expenses, property taxes, insurance costs, and lost energy (opportunity) costs. In addition to these cost components, the annual cost of capital for each alternative is included in the overall cost estimates listed in Table 5. The annual cost of capital represents levelized costs over an assumed 30-year period, and is IPC's estimated annual revenue requirement. A discount rate of 7.20%, per IPC's 2004 Integrated Resource Plan was used to calculate the levelized cost of capital for the various selective withdrawal structures.

2.6. Effects on Project Generation and Dependable Capacity

None of the alternatives would materially reduce the project dependable capacity, because each of the alternatives has been designed to be able to pass the full hydraulic capacity of the powerhouse at any time of year. Project generation would be reduced by each of the alternatives due to energy losses. The estimated value of this lost generation is shown in the estimated lost power costs.

2.7. Conclusions

From the modeling completed for the three structures and various scenarios using CE-QUAL-W2, it was determined that, overall, there was little difference in spring warming potential between the structures and that regardless of the structure selected, spring warming is only likely to occur in the lower flow years after the month of March. Also, with both proposed and OP-2 operations, the fall target was obtained with the Gattun and 35T structures in all modeled water years. The fall target was obtained with the StopL in all modeled years except the medium-high flow year.

In low flow years, operating a TCS to cool Hells Canyon outflows to meet the salmonid spawning standard of 13 °C identified by the states of Oregon and Idaho offsets any potential benefit that may result from operating a TCS in the following year to warm outflows to encourage earlier emergence. Temperatures cannot be warmed early enough in the spring to gain benefit to incubating fall Chinook salmon. Fall cooling to meet the state's salmonid spawning standard will result in delaying emergence timing. Further, in low flow years, because the TCS alternatives were modeled to ensure meeting the fall standard, colder water was stored during summer months, resulting in warmer conditions passing downstream into Lower Granite Reservoir. These warmer conditions resulted in slightly warmer outmigration conditions, which slightly decreased survival estimates for juvenile fall chinook salmon passing through Lower Granite Reservoir.

A temperature control structure would raise the elevation of the thermocline and change the thermal structure of the entire reservoir. This would alter physical, biological and chemical processes in the reservoir from what currently occurs. With the elevated thermocline there is more potential for periodic mixing of epilimnetic and metalimnetic waters and movement of anoxic water and other anoxic products into upper layers. Also, if cool water is withdrawn it will likely be anoxic, and there is a potential for increased levels of anoxic products in the Brownlee outflows. There is also a potential to disturb mercury that is stored in the sediments if water is withdrawn from the bottom of the reservoir.

Based on the results from the detailed modeling effort undertaken by IPC and NOAA Fisheries, IPC has concluded that the preferred alternative is to not install a TCS at the HCC. IPC is aware that issues relative to the fall temperature load allocation assigned to the HCC by the Snake River–Hells Canyon TMDL remain unresolved and continues to work with ODEQ and IDEQ, in the § 401-certification process, to identify measures or other appropriate procedures for addressing those issues.

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Table 1. Dates associated with the time periods of the 10th, 50th and 90th percentiles of the juvenile fall Chinook salmon outmigration during 1998 and 2001.

	Date		
Water Year	**10th PTL**	**50th PTL**	**90th PTL**
2001 (Low Flow)	24 June	7 July	13 August
1998 (Med Flow)	21 June	9 July	25 July

Table 2. Modeled mean flow (cms), mean temperatures (C) and survival (percent) of juvenile fall Chinook salmon at Lower Granite Tailwater associated with Base case (no Temperature Control Structure), Stop Log Weir (Stop L), and Gated Weir with tunnel (Gattun) during two periods of the smolt outmigration distribution (10th–50th percentile; 50th–90th percentile) and combined (10th–90th percentile).

	1992 (Low Flow)			**1995 (Med Flow)**		
	10–50 ptl	**50–90 ptl**	**Combined**	**10–50 ptl**	**50–90 ptl**	**Combined**
Mean Flow (cms)	592.1	678.0		2060.2	1365.1	
Mean Temp (C)						
Base	19.6	17.6		16.5	18.4	
Stop L	20.3	18.1		16.7	18.6	
Gattun	20.1	17.8		16.7	18.5	
Survival						
Base	16.3	33.1	24.7	77.3	45.8	61.5
Stop L	11.2	29.8	20.5	76.2	43.8	60.0
Gattun	12.6	32.0	22.3	76.3	44.7	60.5

Table 3. Costs of the Stop Log Weir, Gated Weir and Tunnel, and 35 kcfs Tower.

Alternative	Estimated Direct Construction Cost	Estimated Indirect Construction Cost	Estimated Annual Lost Power and O&M Costs (Notes 2 and 3)	Estimated Annual Cost (30 year) (Note 4)
Stop Log Weir	$24,000,000	$3,700,000 lost power during construction. $2,200,000 allowance for funds used during construction	Low Flow Year (1992): $170,000 Median Low Flow Year $229,000 Median Flow Year (1995): $610,000 Median High Flow Year $1,014,000 High Flow Year (1997): $1,259,000 Avg of 5 tested years: $656,400.	$3,700,000
Gate Weir and Tunnel	$48,000,000	$3,700,000 lost power during construction. $8,200,000 allowance for funds used during construction	Low Flow Year (1992): $181,000 Median Low Flow Year (1994): $274,00 Median Flow Year (1995): $613,000 Median High Flow Year (1999): $1,017,000 High Flow Year (1997): $1,269,000 Avg of 5 tested years: $670,800	$7,000,000
35 kcfs Tower	$286,000,000	Conceptual construction plan assumes that no special reservoir draft would be needed for construction. A 2-month draft at elev 2020 in late fall would cost apprx $8,200,000 in lost power. $66,200,000 allowance for funds used during construction	Low Flow Year (1992): $460,000. Median Low Flow Year (1994): $660,000 Median Flow Year (1995): $1,260,000 Median High Flow Year (1999): $1,660,000 High Flow Year (1997): $2,060,000 Avg of 5 tested years: $1,220,000	$ 40,600,000

Note 1: All Year 2005 costs.

Note 2: For consistency, the same monthly peak and off-peak power costs have been used in WQ-2(c) as were used in WQ-2(a).

Note 3: The O&M costs for the Stop Log Weir, Gated Weir and Tunnel, and 35 kcfs Tower weir were estimated as $30,000, $30,000, and $60,000 per year, respectively. The O&M cost was assumed the same for all water years.

Note 4: The estimated annual costs are made up of the annual average expenses plus the levelized cost of capital for each of the selective withdrawal alternatives.

Table 4. Expenses in millions of dollars (MM) for alternatives directed by FERC.

	Expense Components				Totals
Alternative	30-Year O&M and Lost Power	30-Year Property Taxes	30-Year Insurance	30-Year Total Expenses	Average Annual Expenses
Stop Log Weir	20.1	6.3	0.8	27.3	0.9
Gated Weir and Tunnel	20.5	11.9	1.6	34.0	1.1
35 Kcfs Tower	37.5	67.3	8.9	113.6	3.8

Table 5. Overall costs in millions of dollars (MM) for alternatives directed by FERC.

No.	Cost of Capital			Expenses		Total
Alternative	Total Investment (including AFUDC)	Present Value Cost of Capital	Levelized Cost of Capital	30 Year Total Expenses	Average Annual Expenses	Annualized Costs
Stop Log Weir	26.2	33.3	2.7	27.3	0.9	3.7
Gated Weir and Tunnel	56.2	71.4	5.9	34.0	1.1	7.0
35 Kcfs Tower	352.2	447.8	36.8	113.6	3.8	40.6

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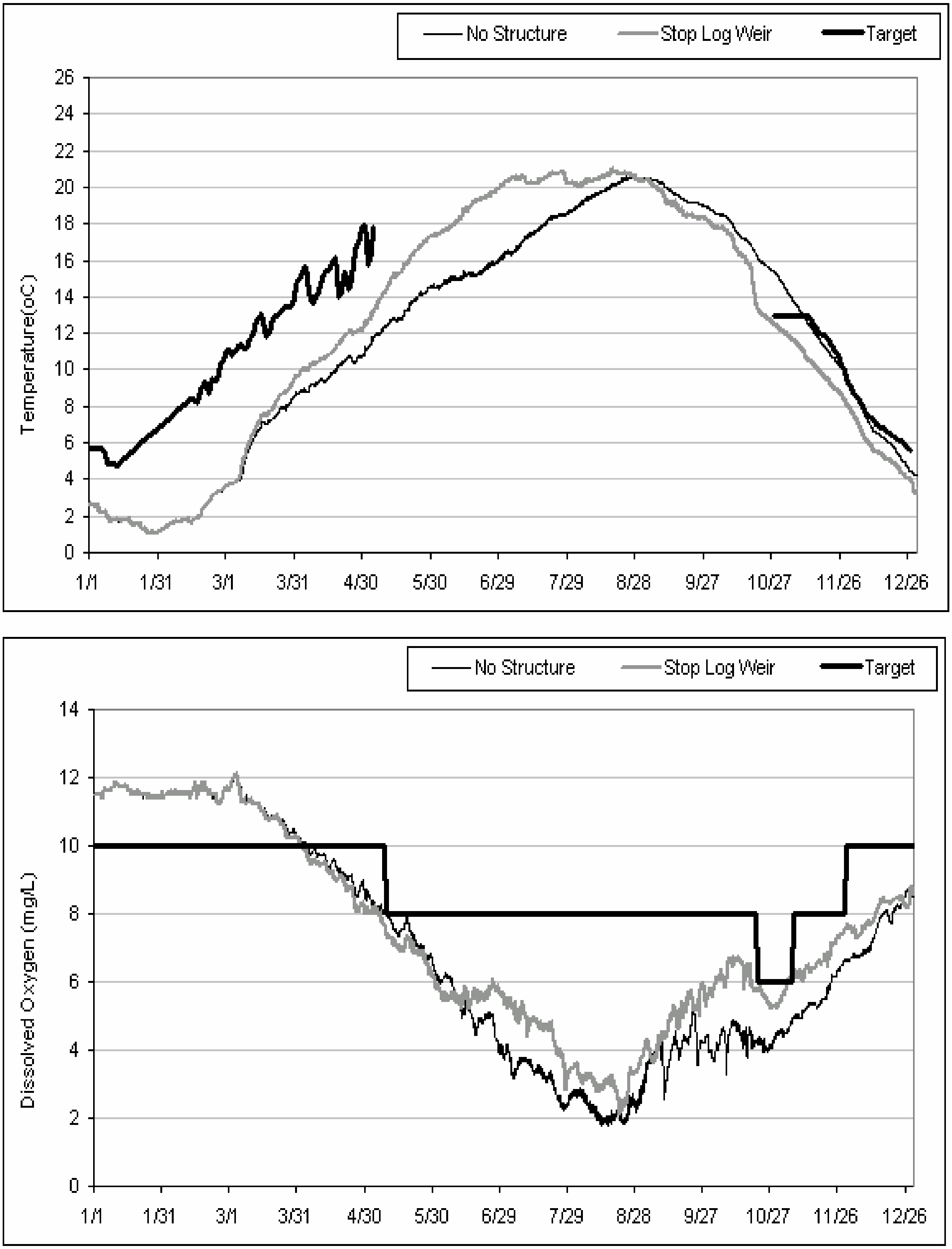


Figure 1. Low Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the current conditions model setup and proposed reservoir operations.

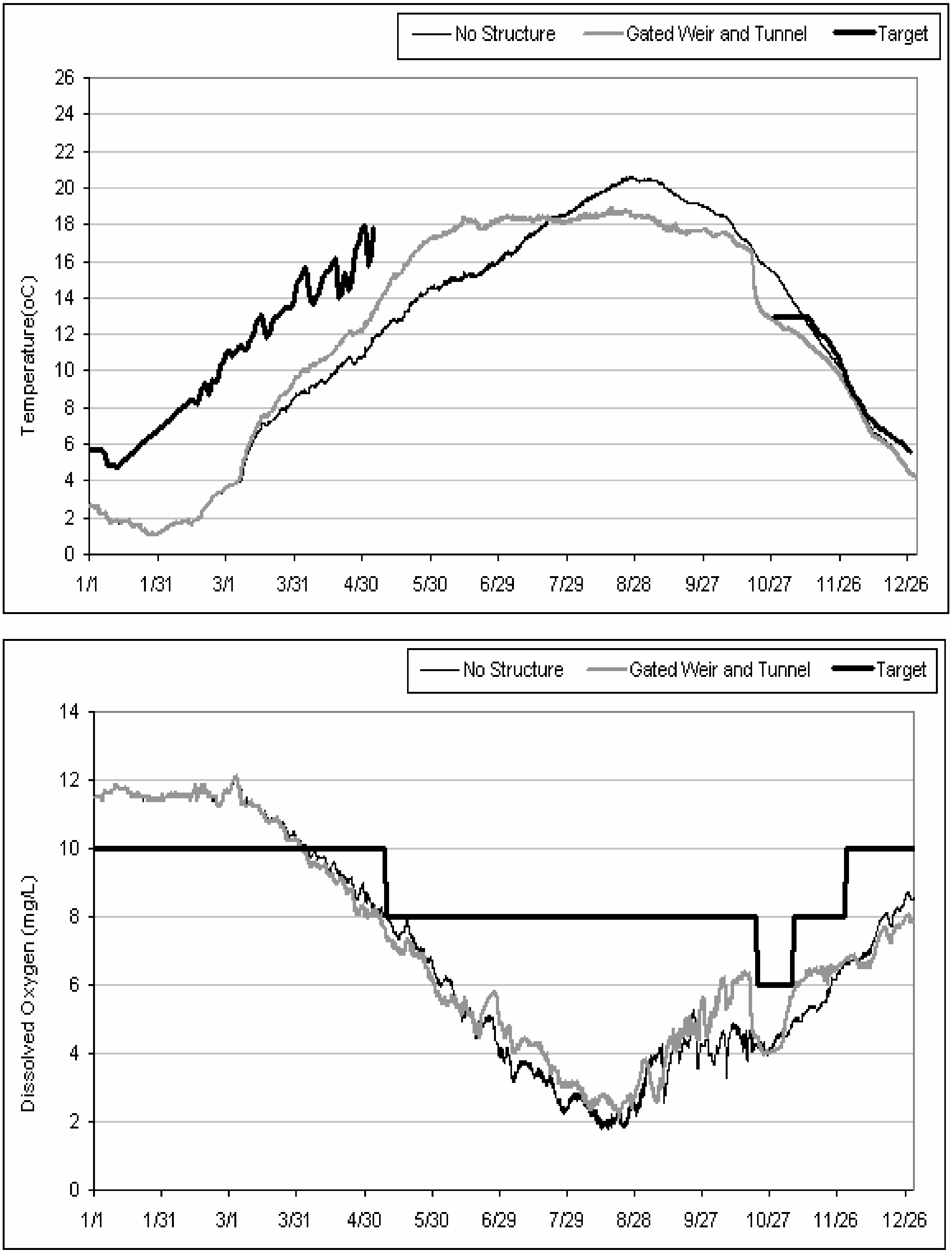


Figure 2. Low Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the current conditions model setup and proposed reservoir operations.

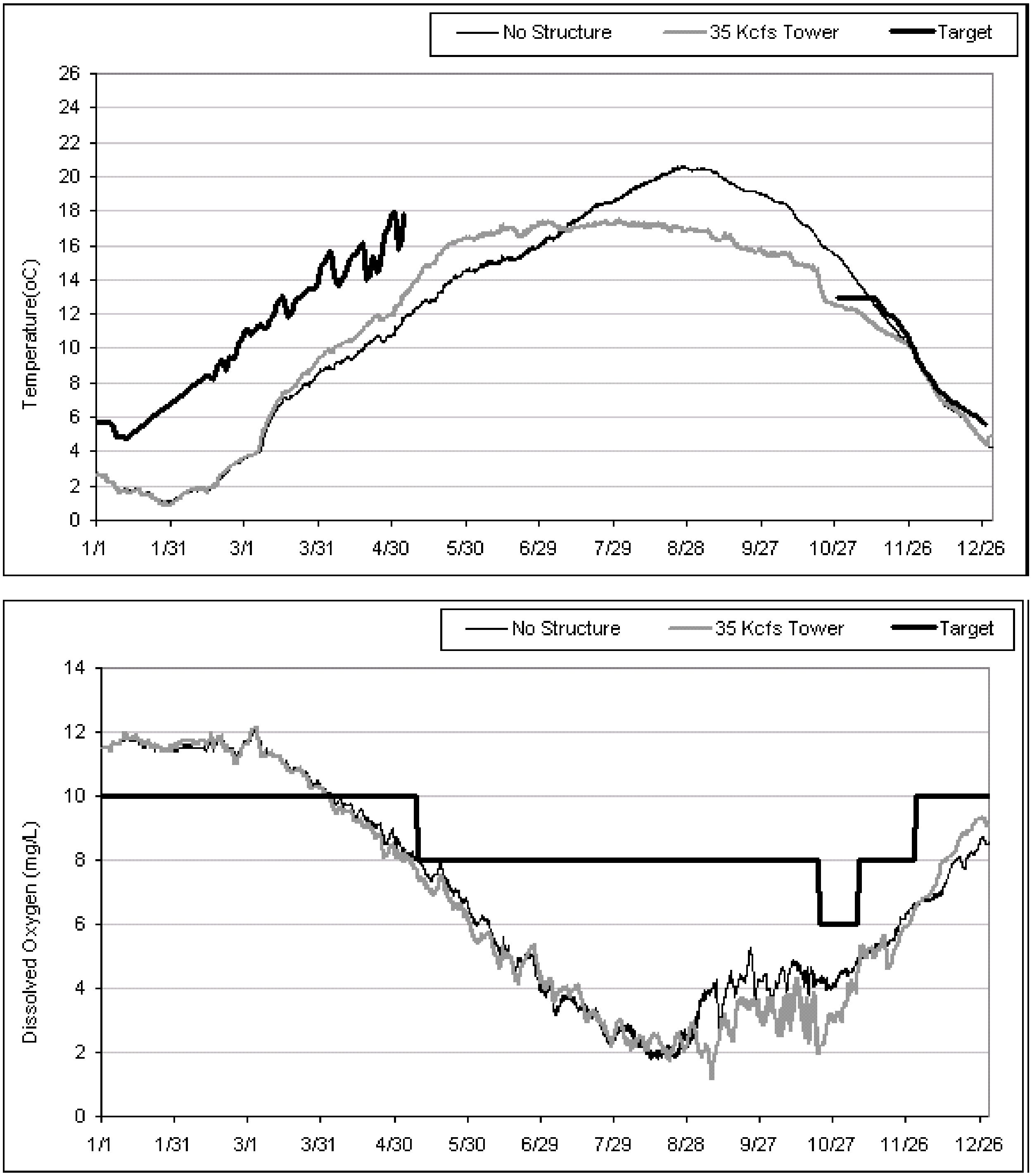
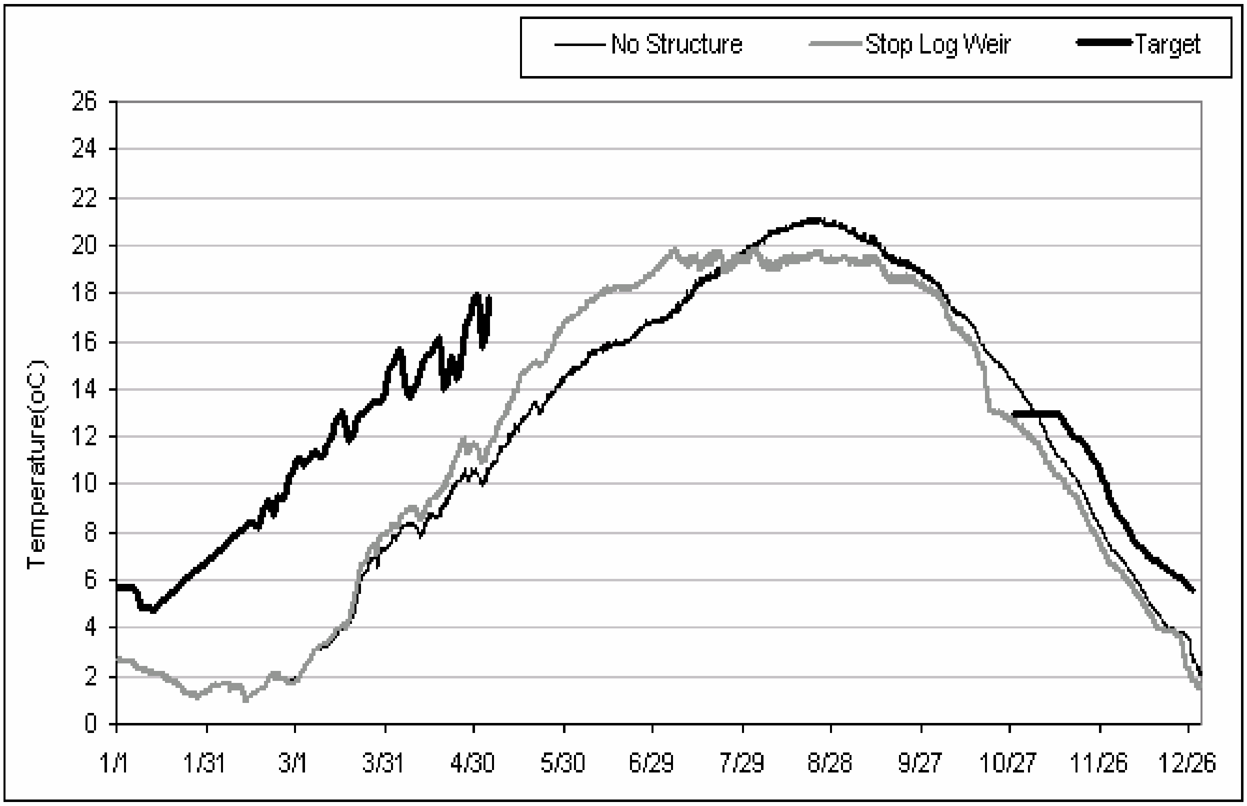


Figure 3. Low Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the current conditions model setup and proposed reservoir operations.



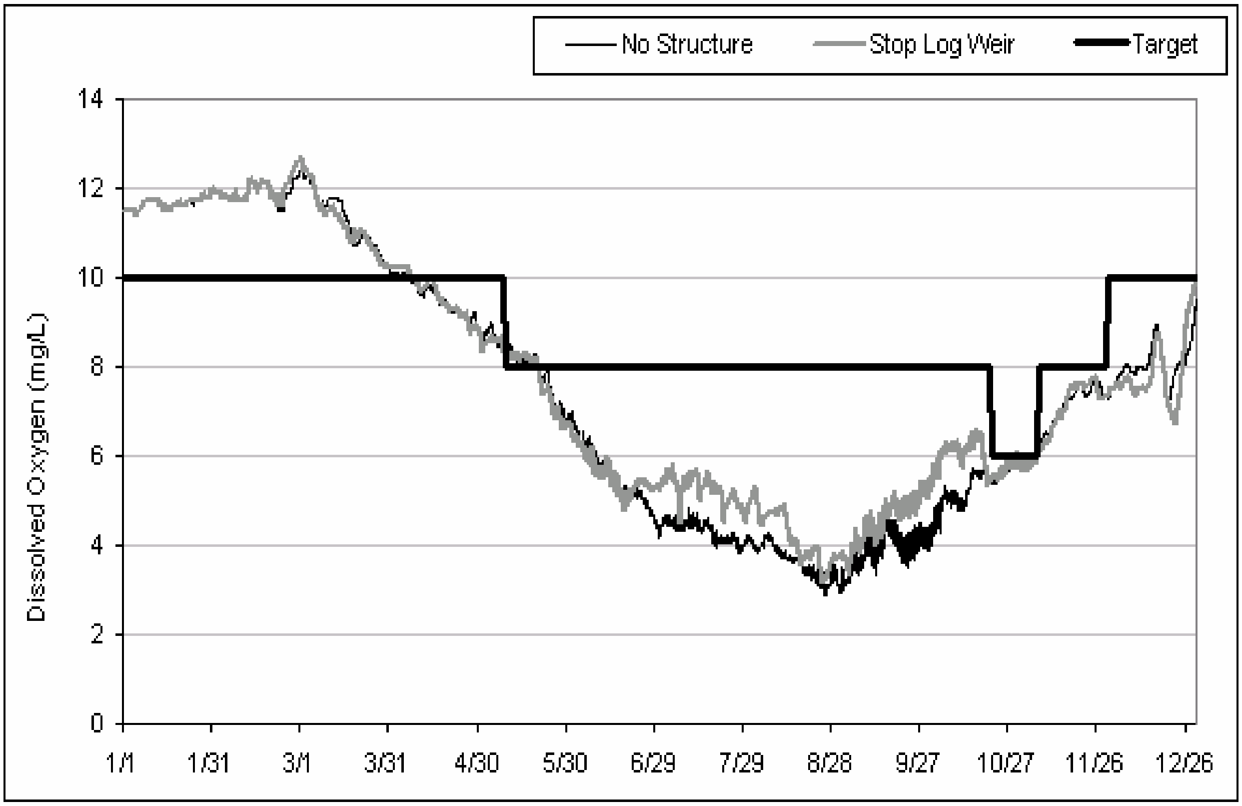
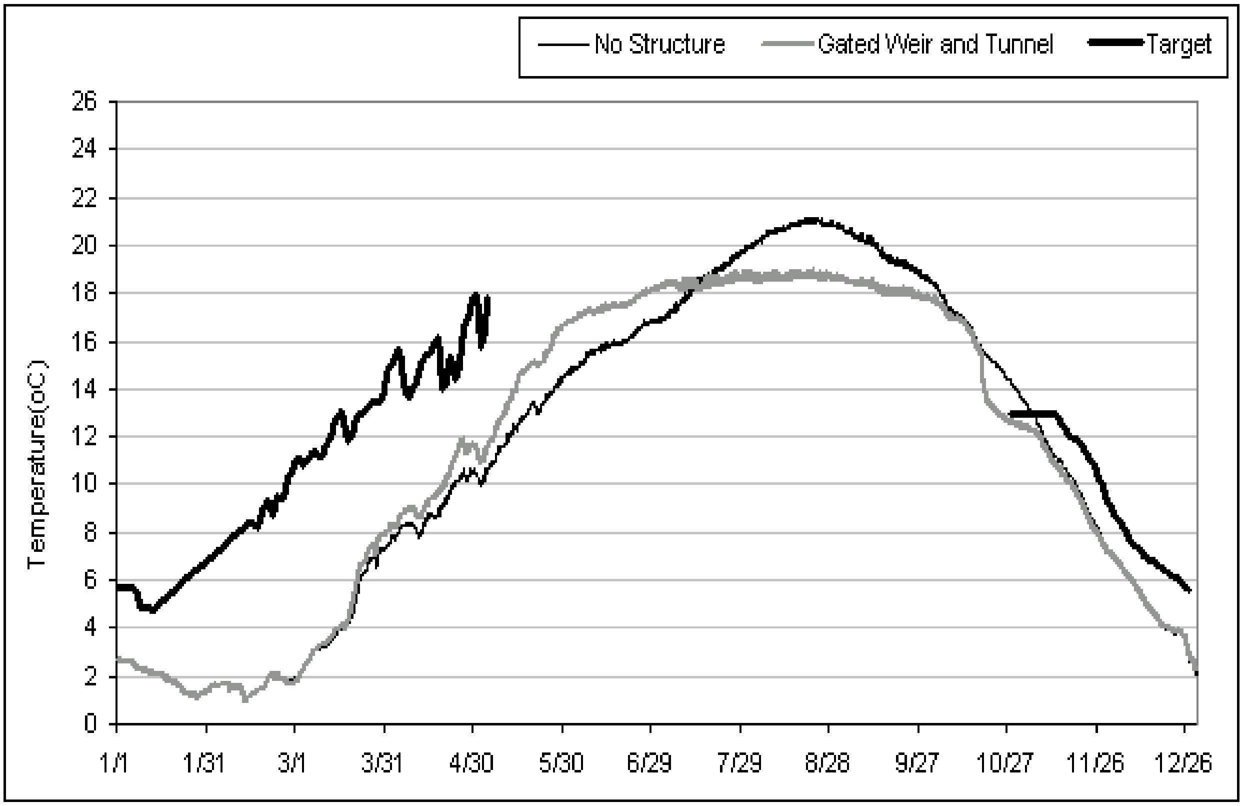


Figure 4. Medium-Low Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the current conditions model setup and proposed reservoir operations.



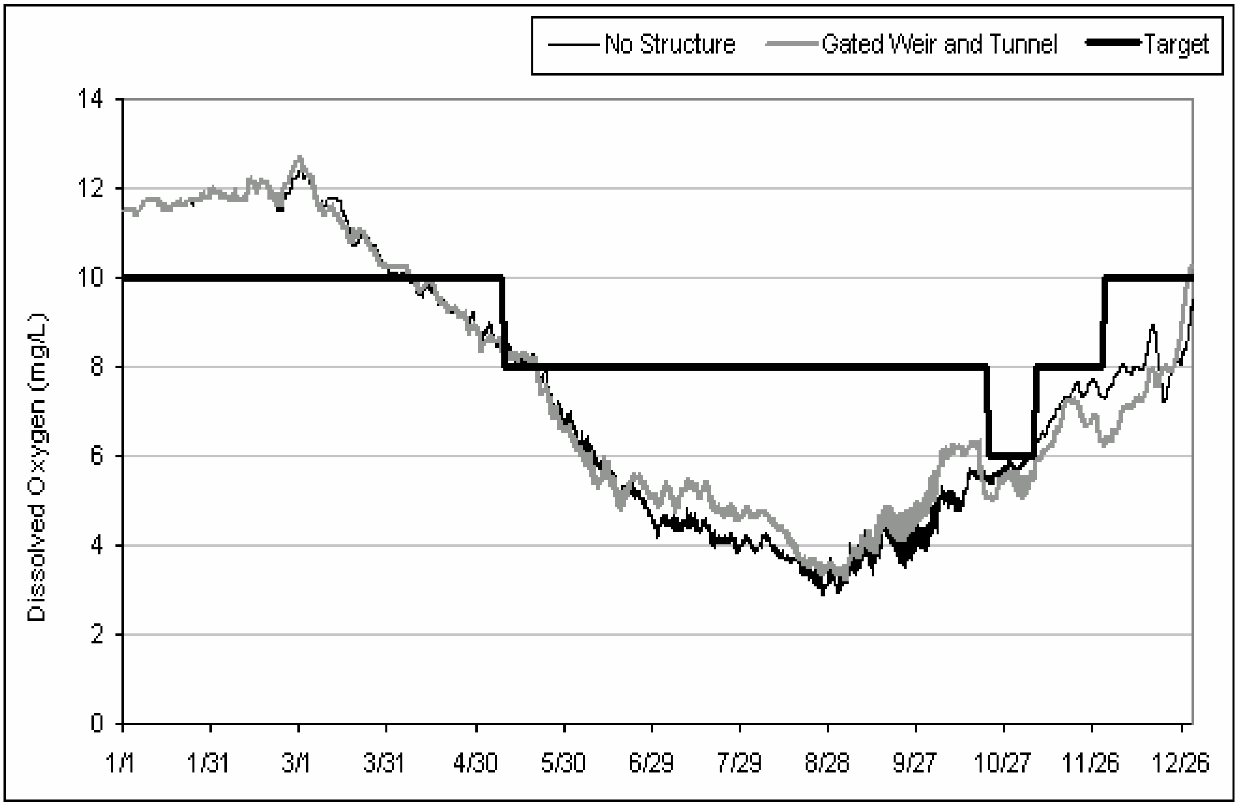


Figure 5. Medium-Low Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the current conditions model setup and proposed reservoir operations.

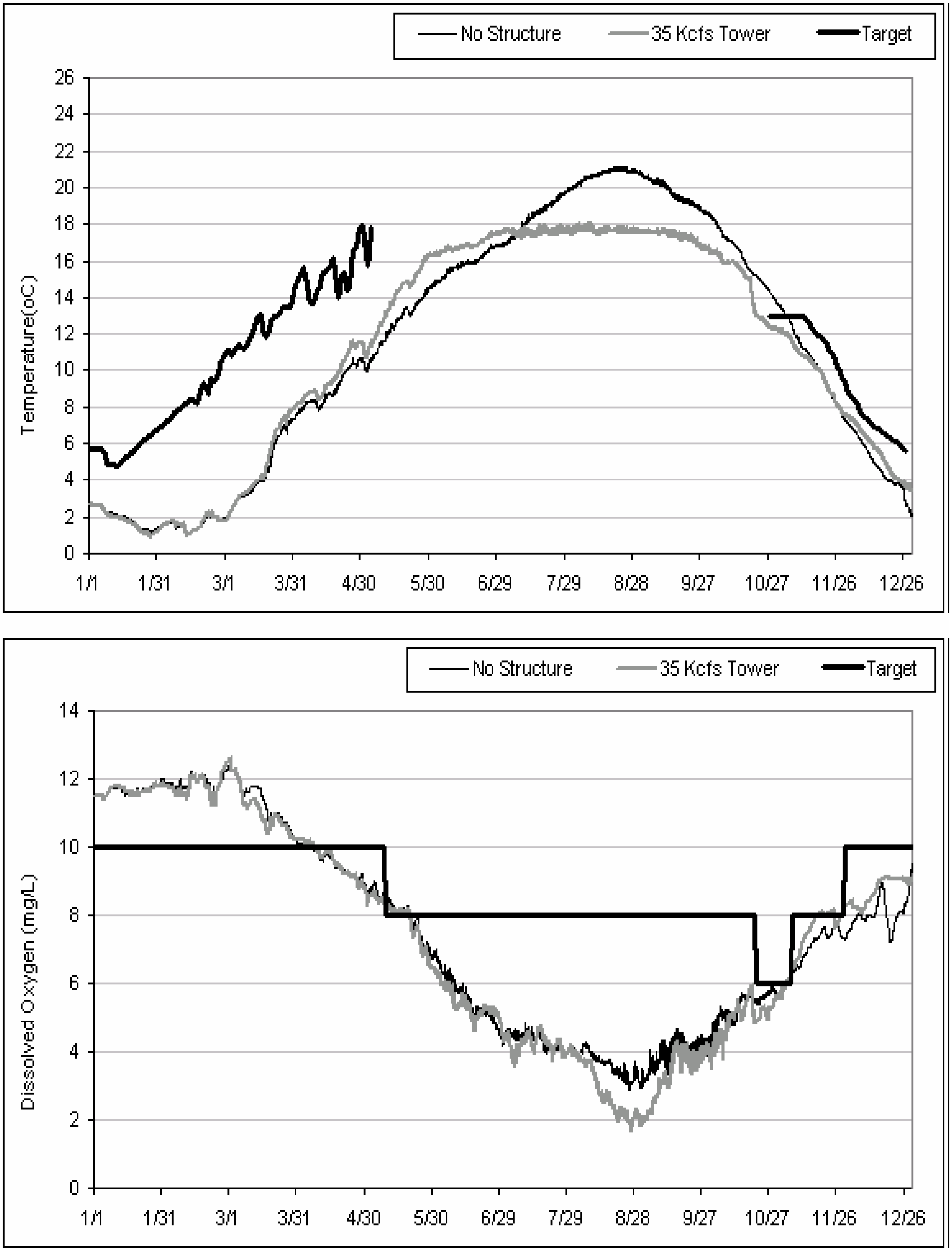
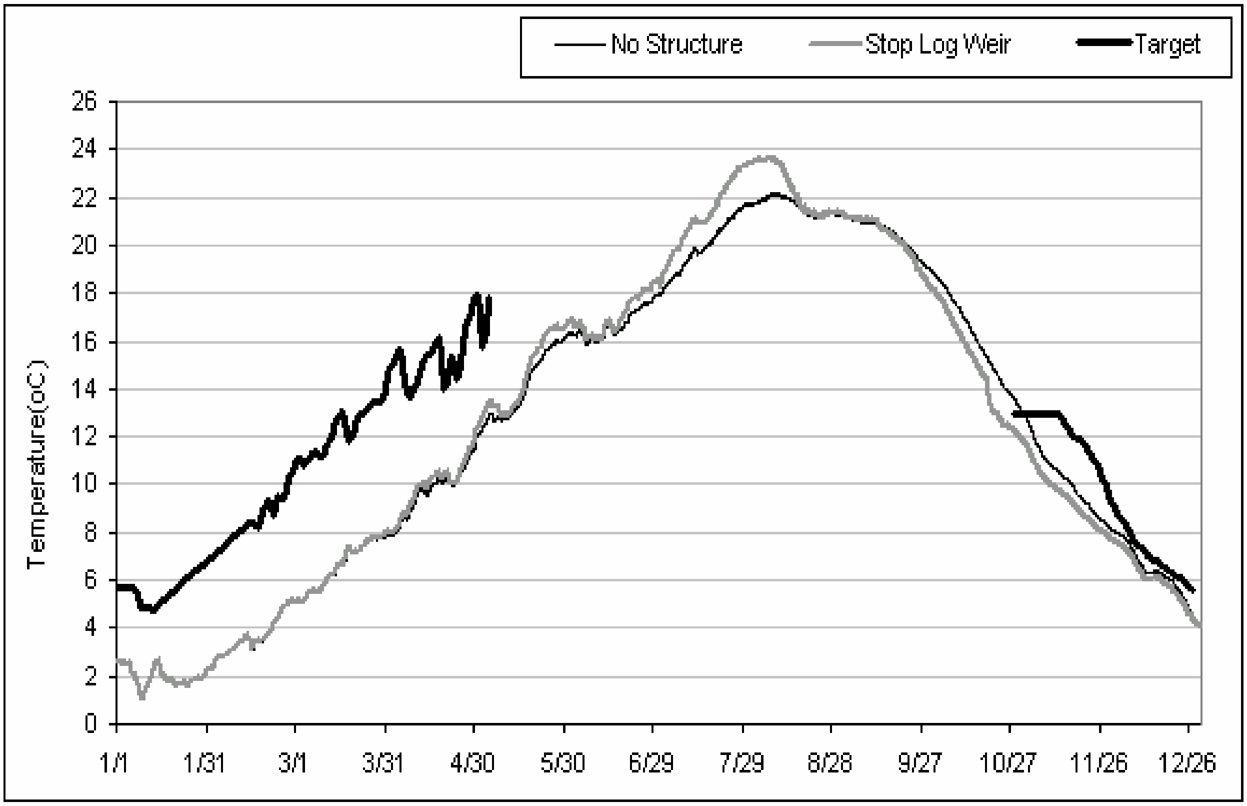


Figure 6. Medium-Low Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the current conditions model setup and proposed reservoir operations.



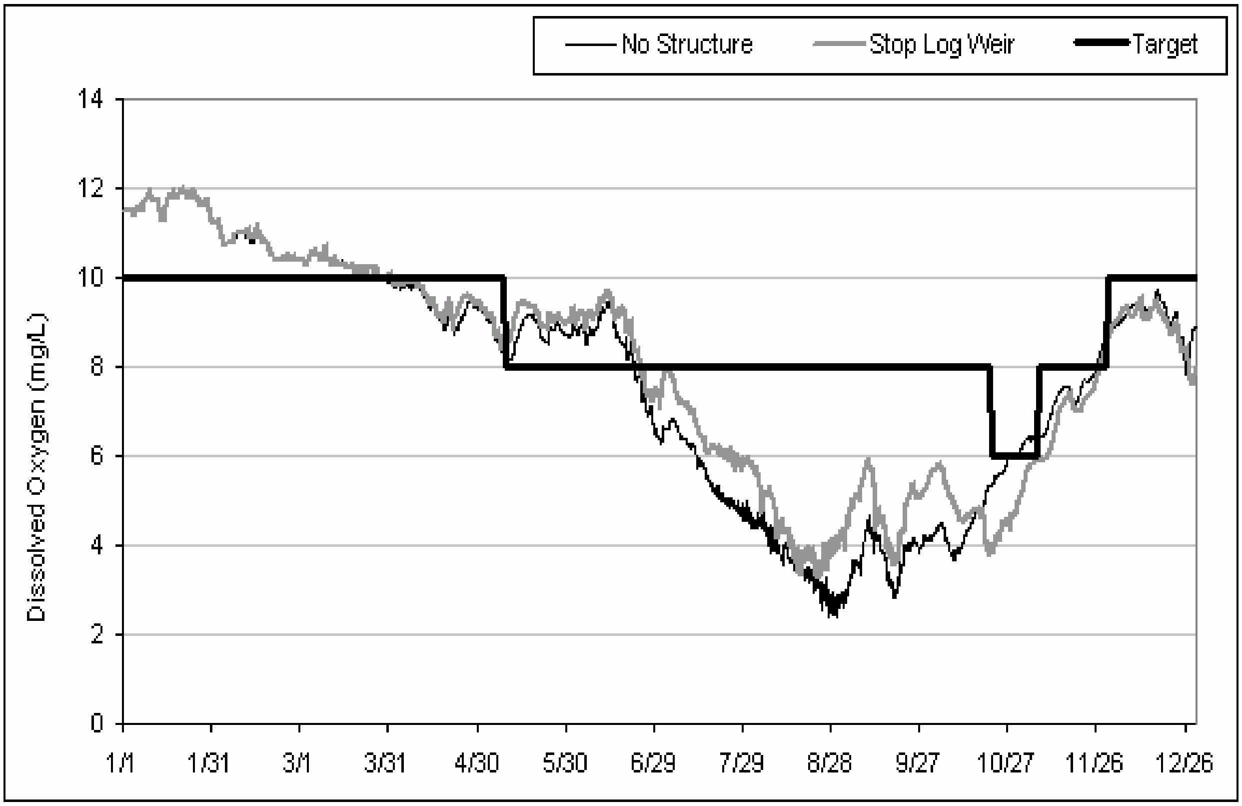
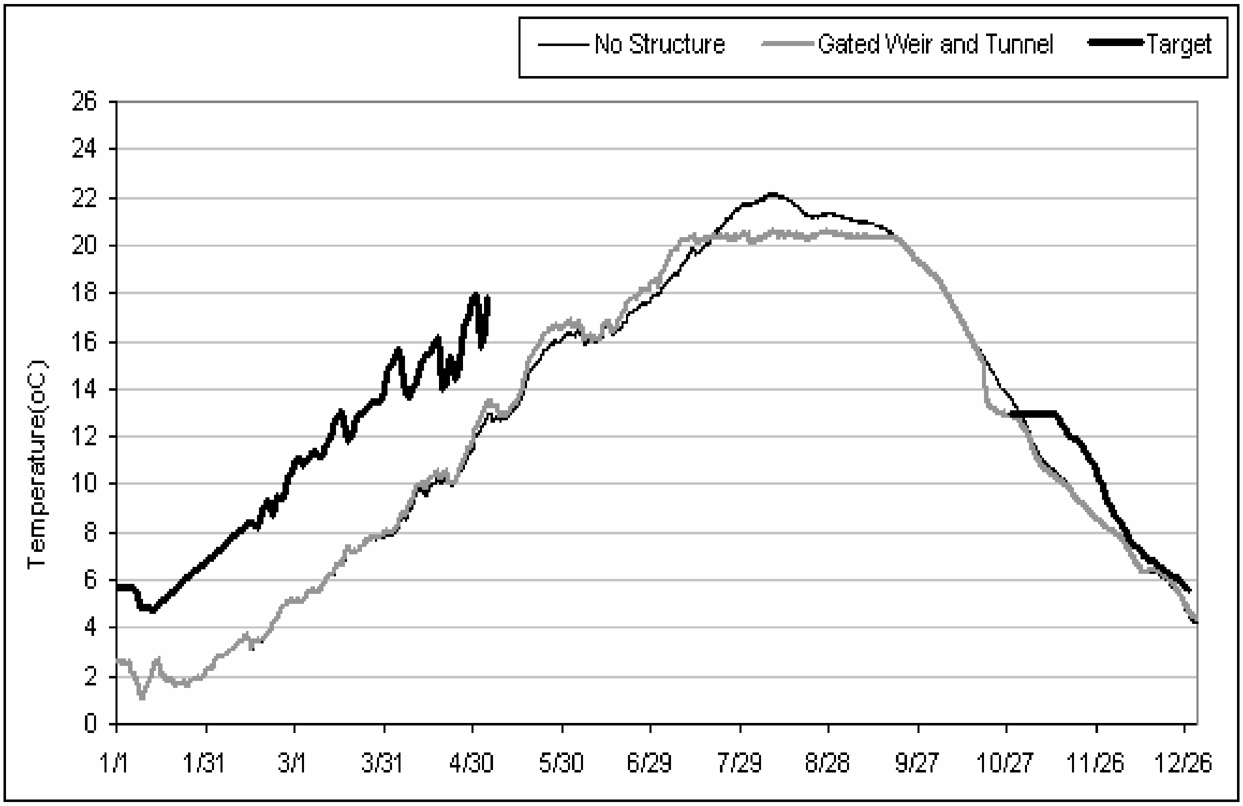


Figure 7. Medium Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the current conditions model setup and proposed reservoir operations.



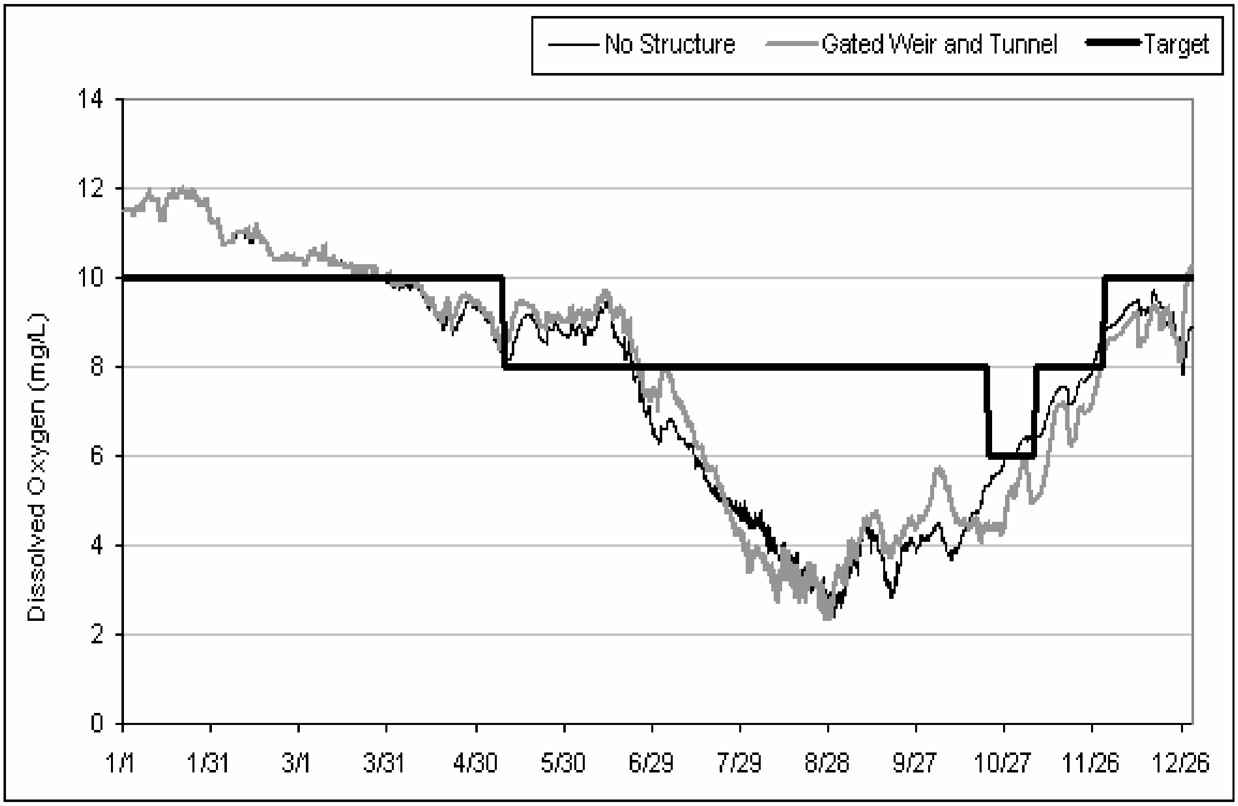
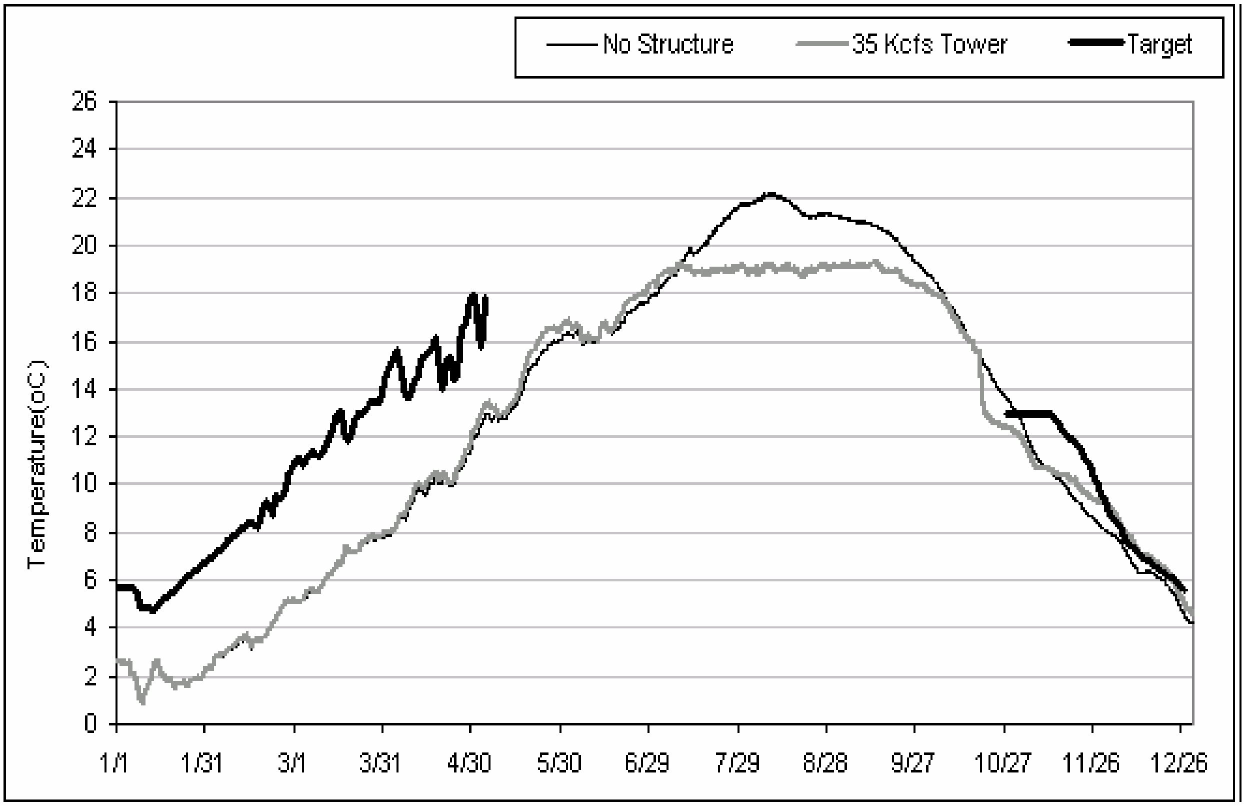


Figure 8. Medium Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the current conditions model setup and proposed reservoir operations.



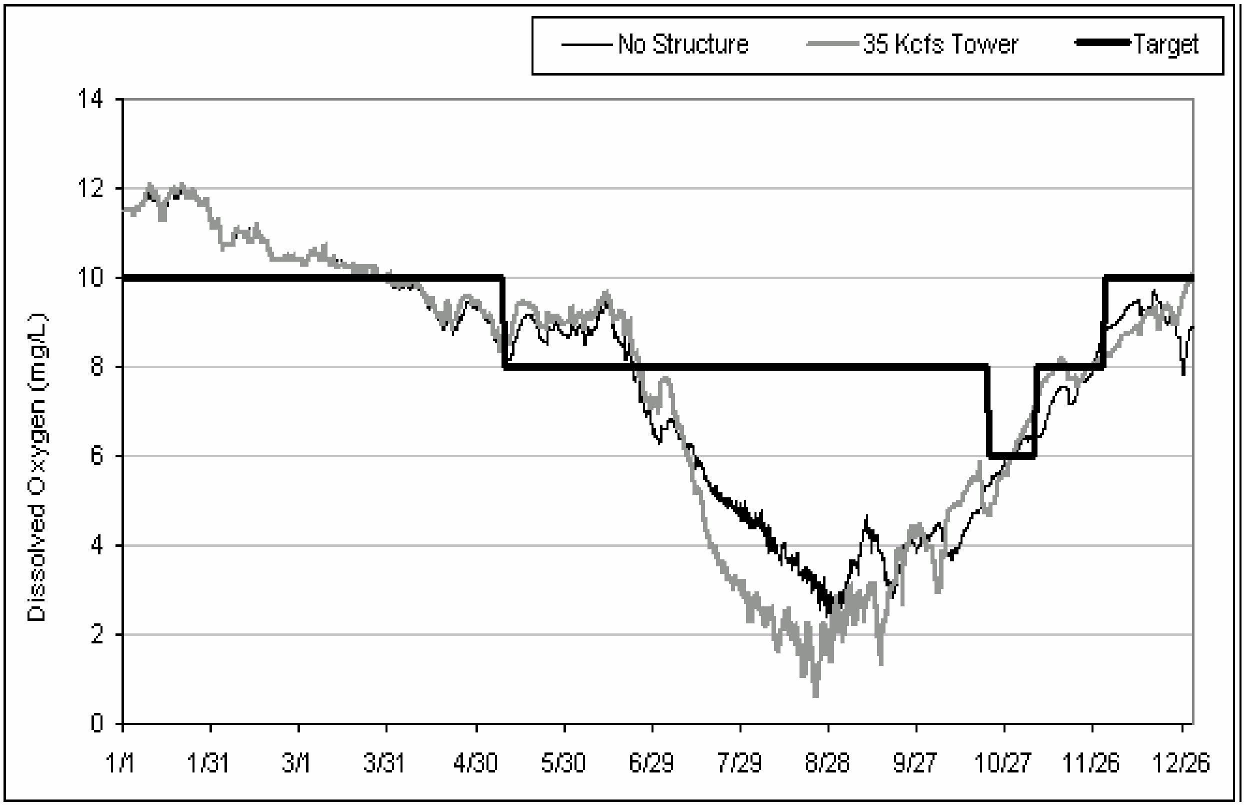
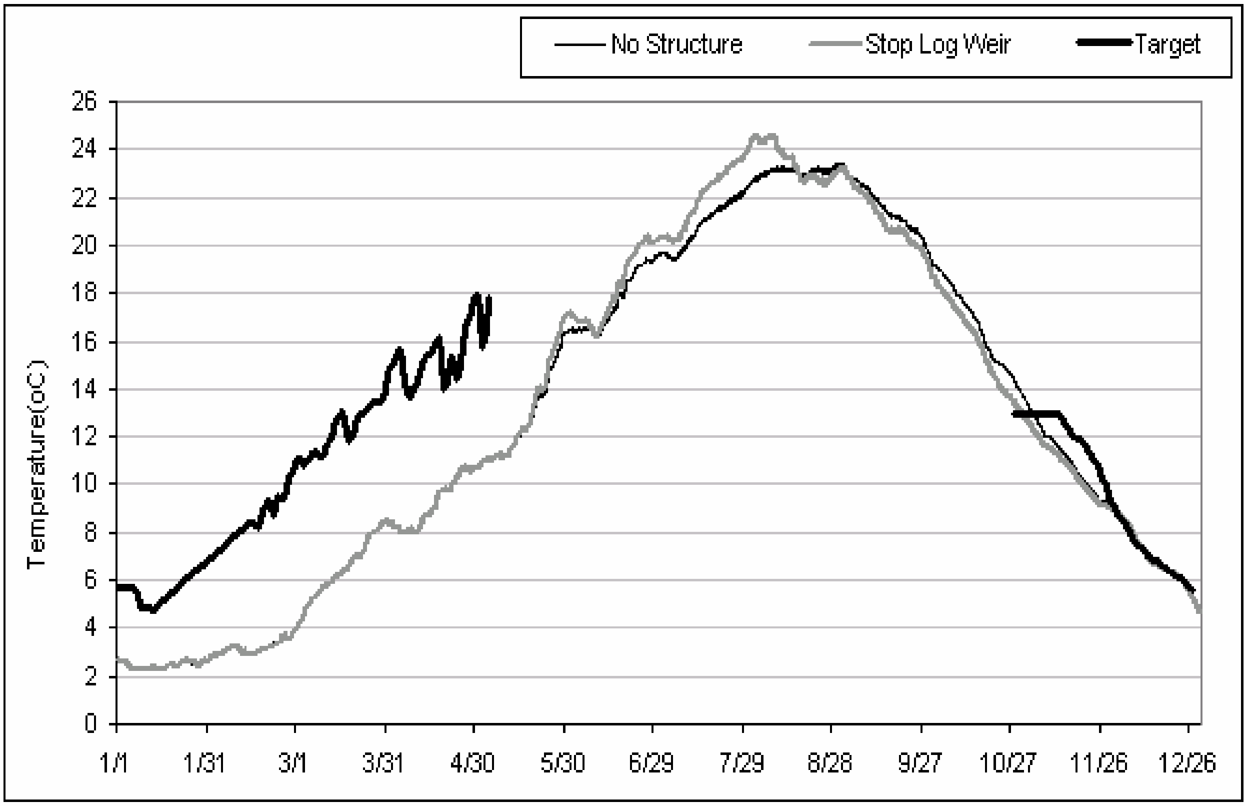


Figure 9. Medium Water Year hourly Hells Canyon outflows for the 35kcfs Tower and Base (No Structure) using the current conditions model setup and proposed reservoir operations.



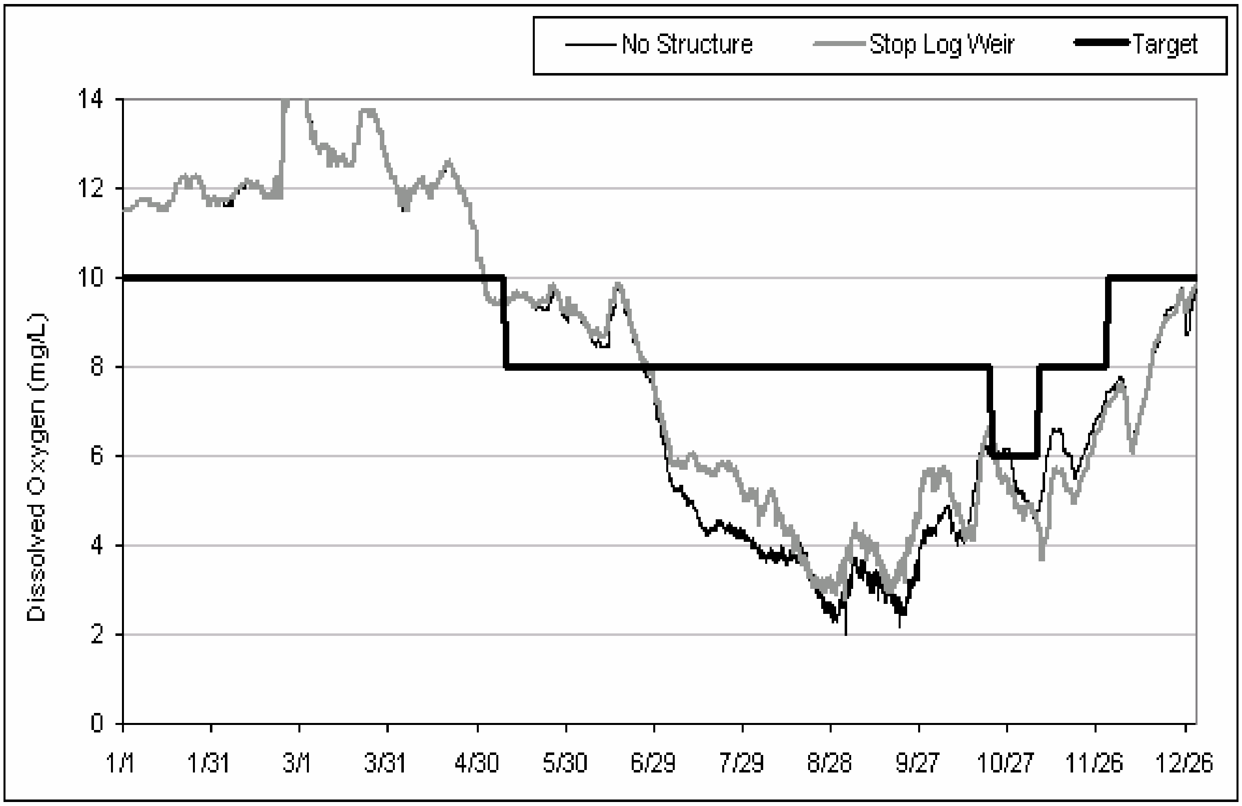
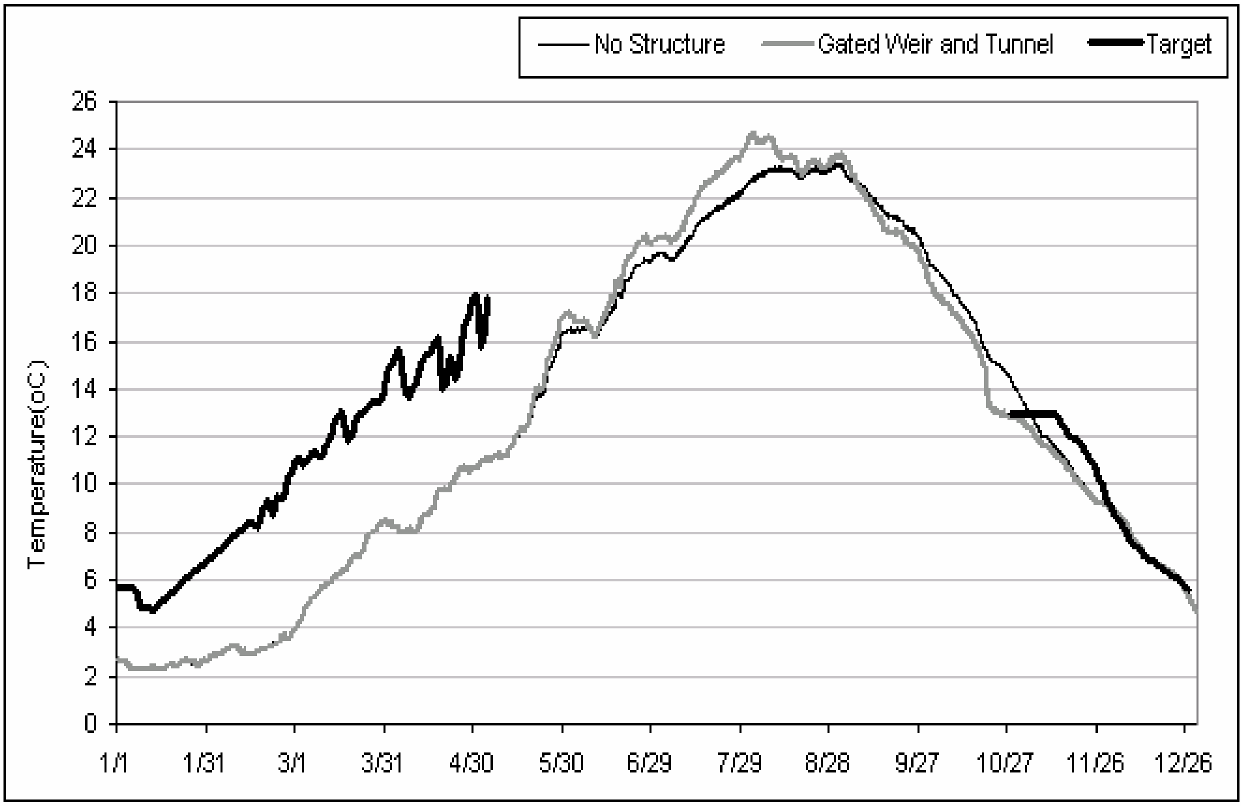


Figure 10. Medium-High Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the current conditions model setup and proposed reservoir operations.



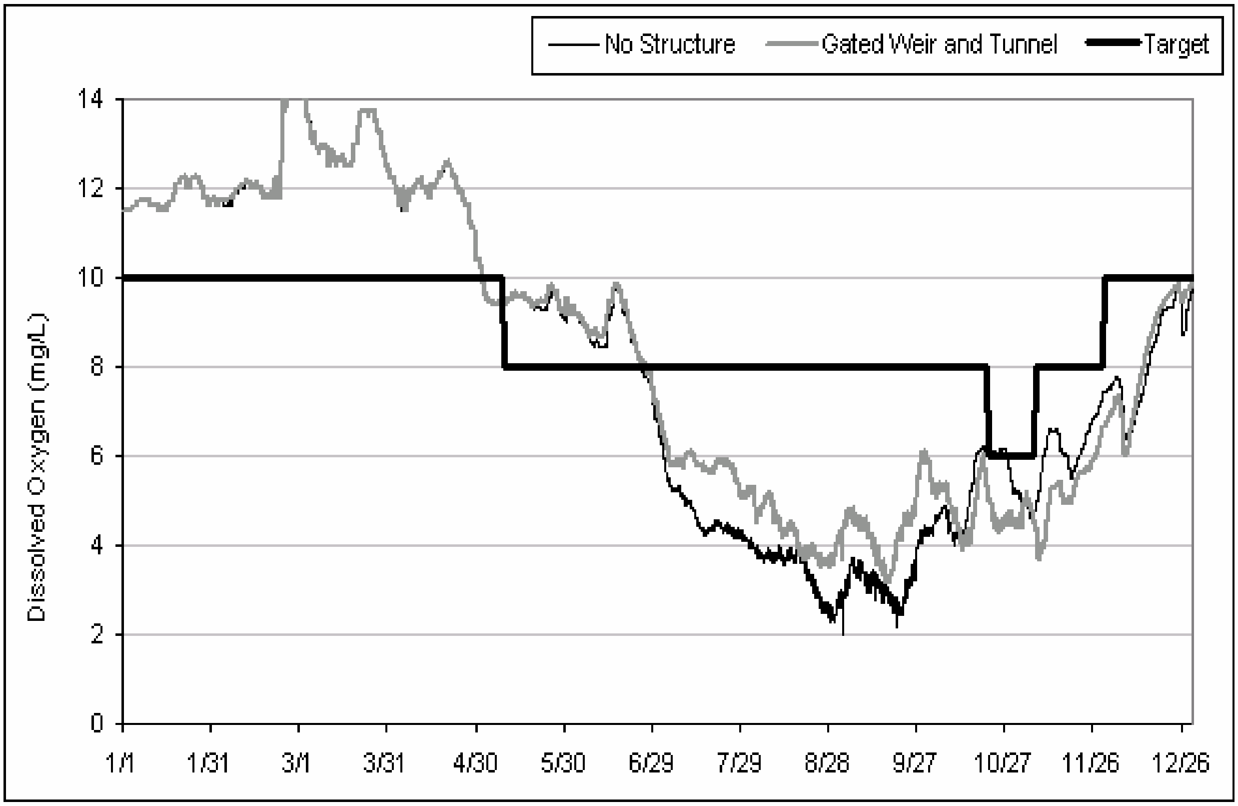


Figure 11. Medium-High Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the current conditions model setup and proposed reservoir operations.

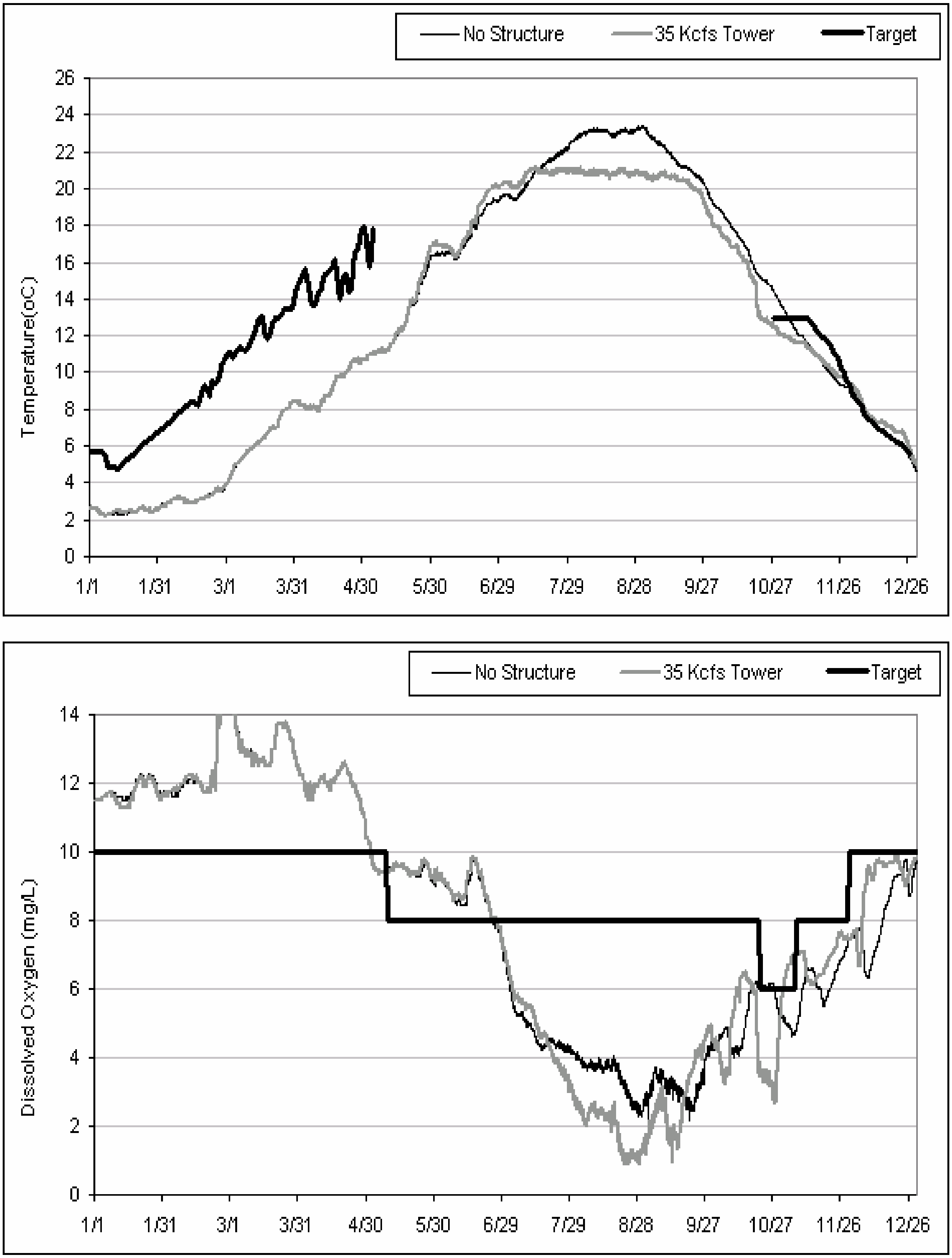


Figure 12. Medium-High Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the current conditions model setup and proposed reservoir operations.

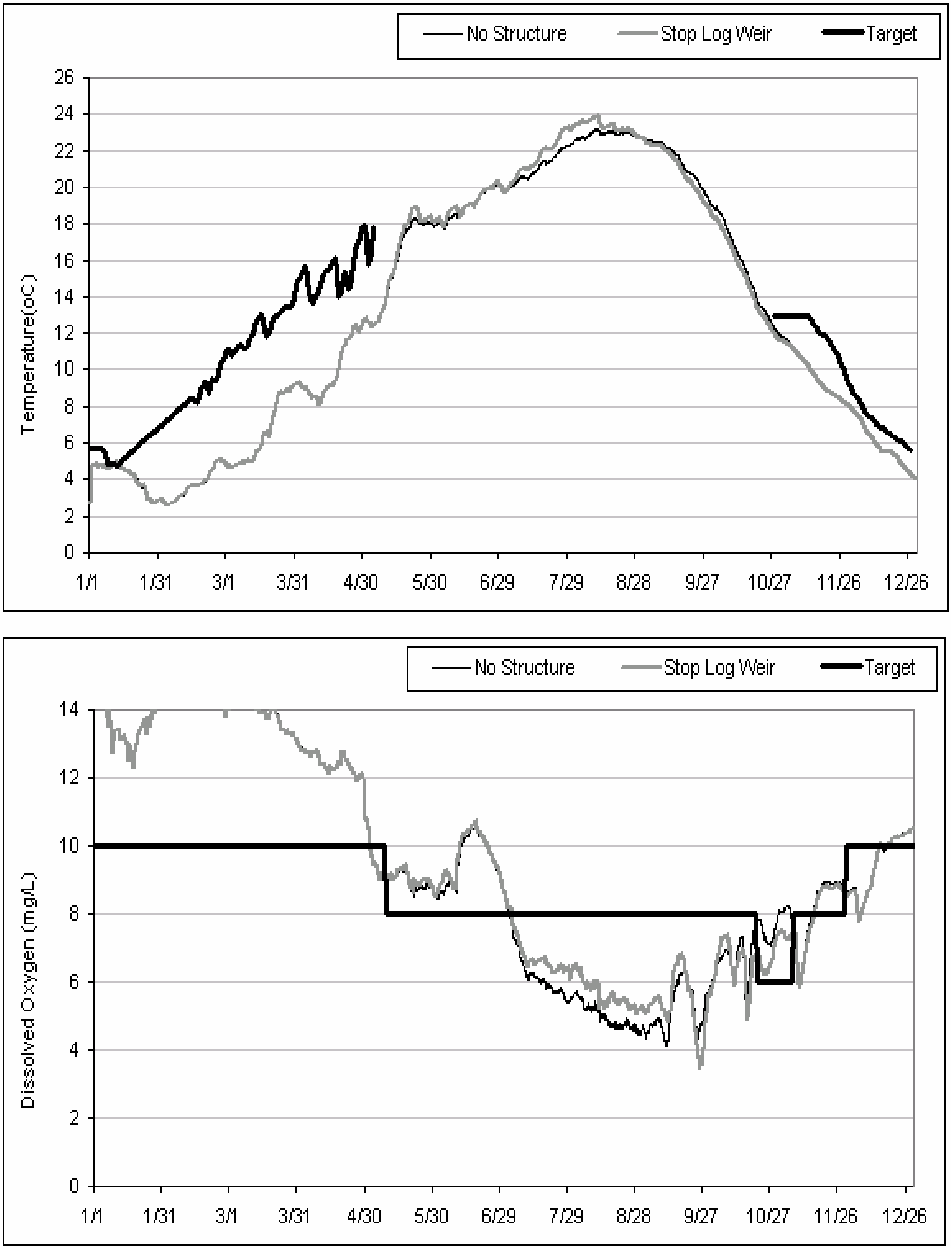
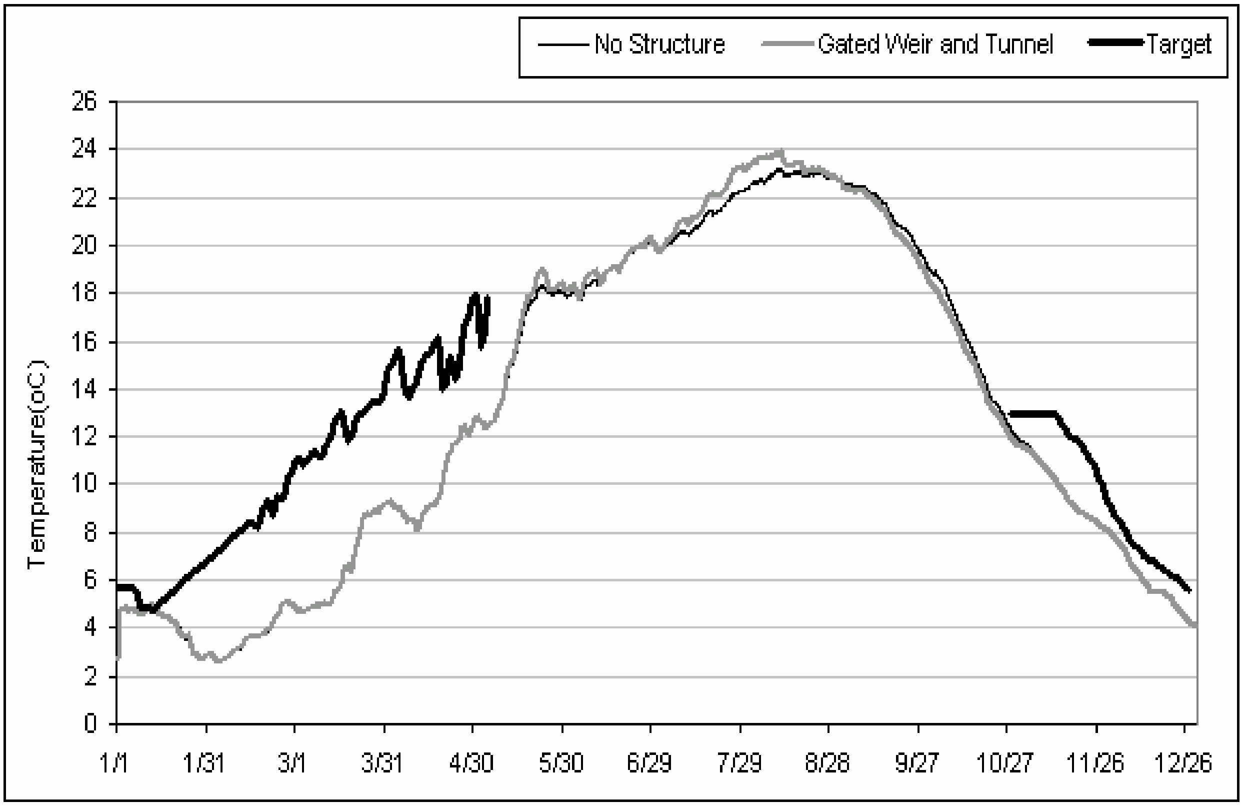


Figure 13. High Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the current conditions model setup and proposed reservoir operations.



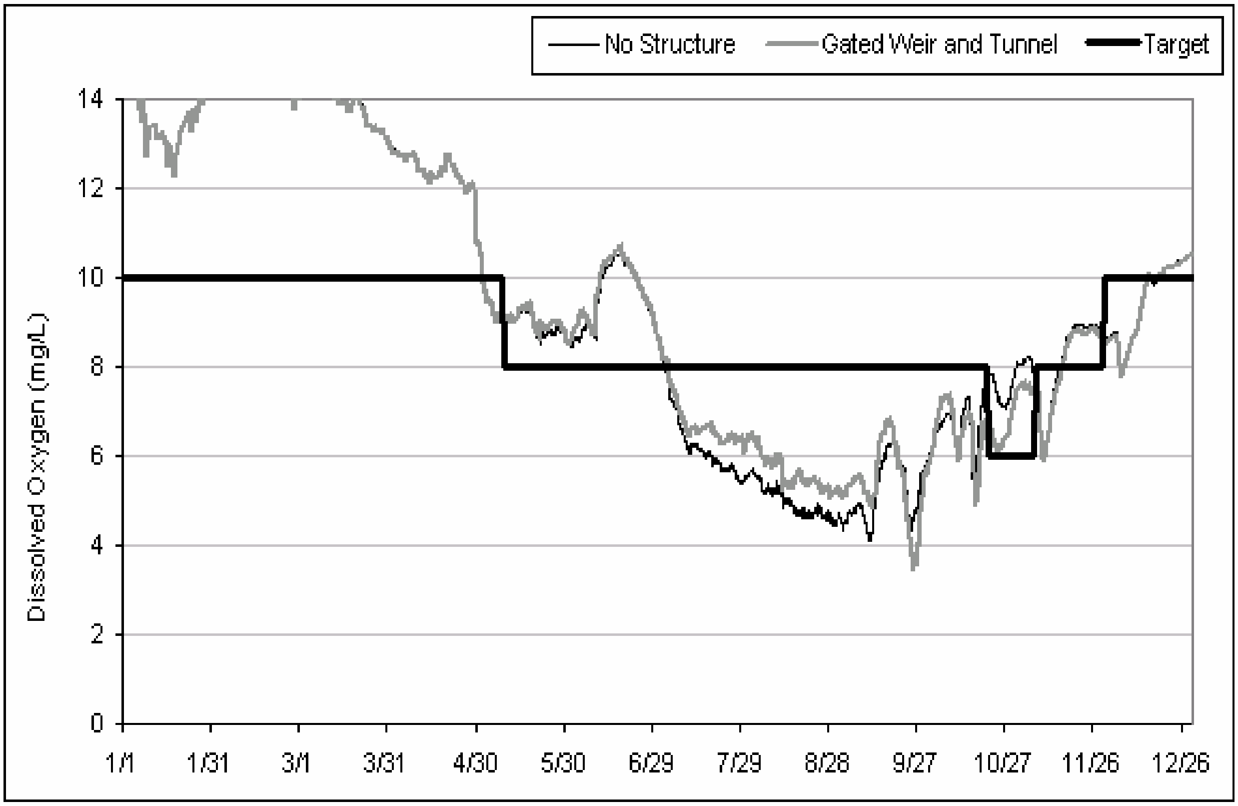


Figure 14. High Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the current conditions model setup and proposed reservoir operations.

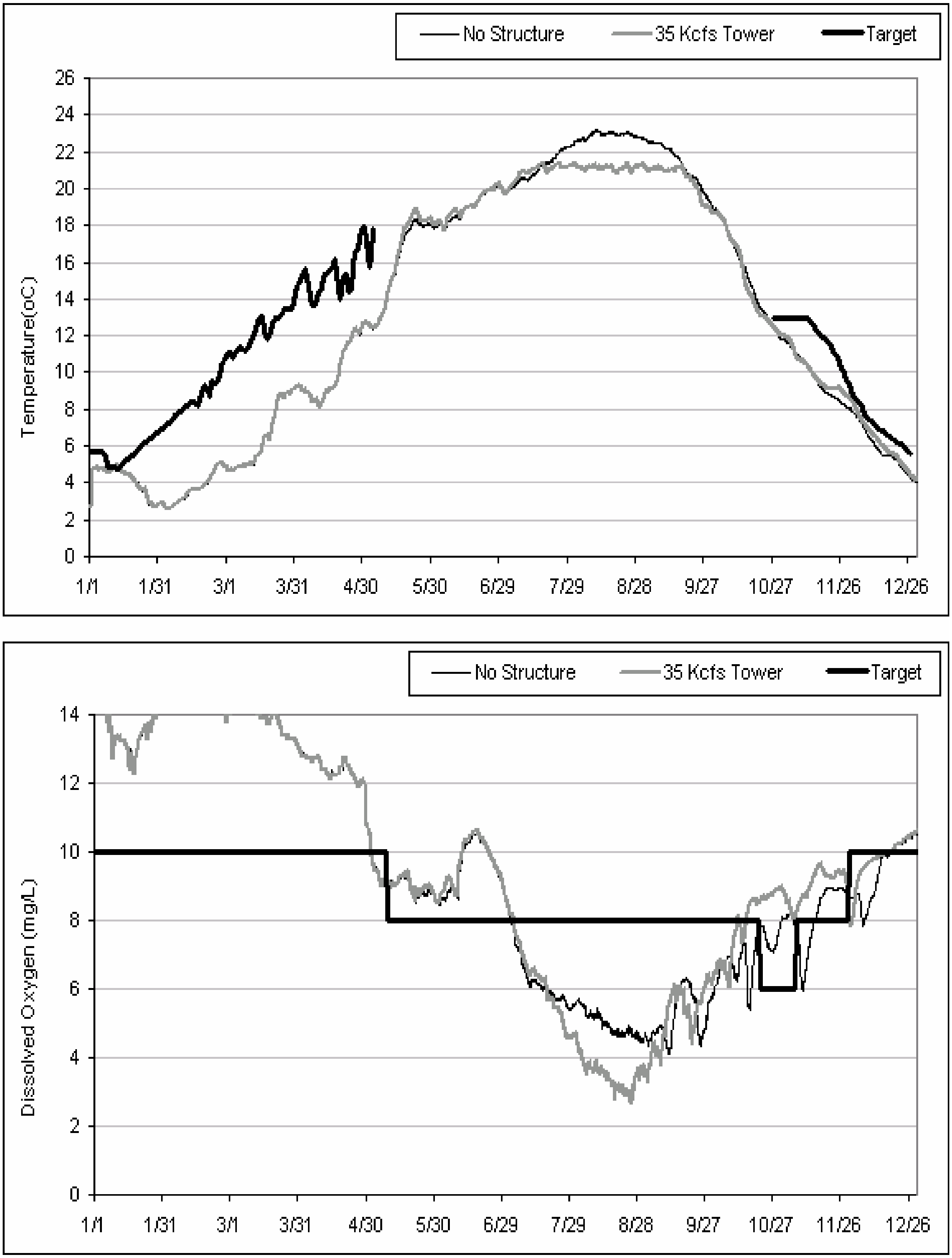
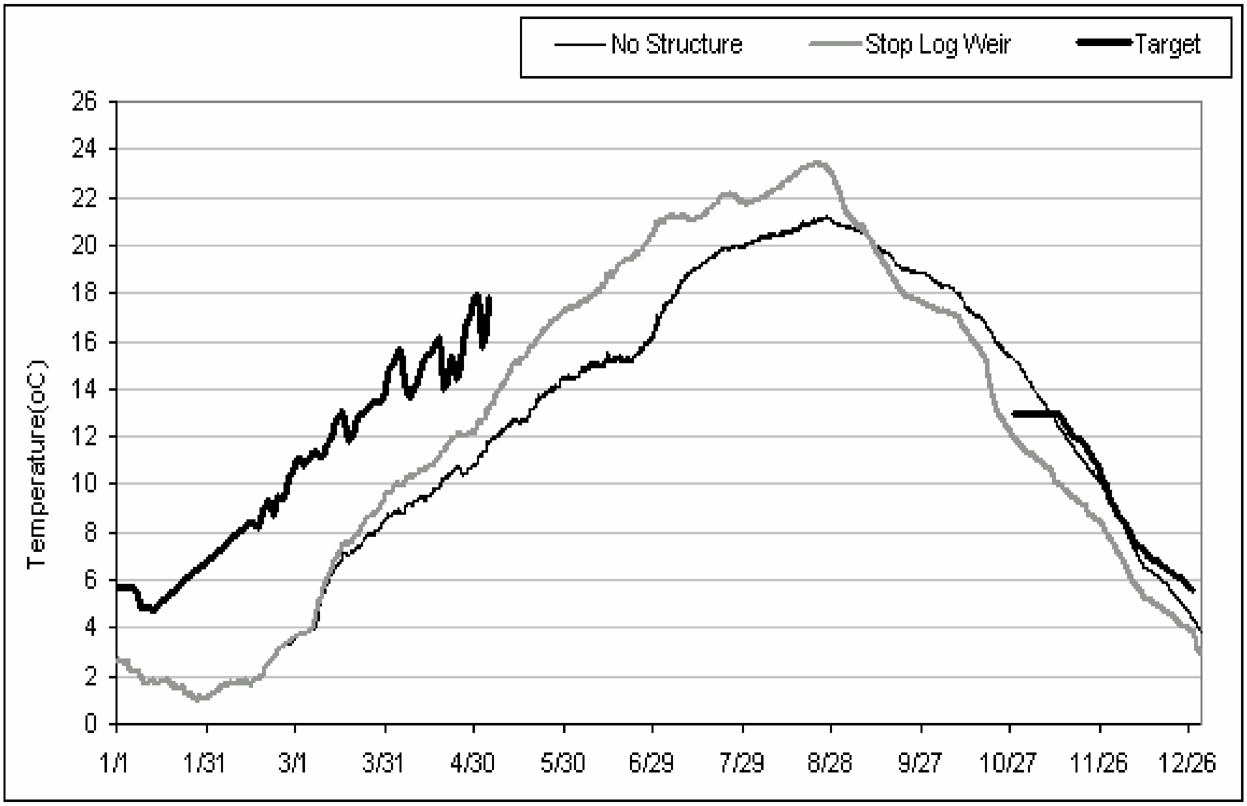


Figure 15. High Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the current conditions model setup and proposed reservoir operations.



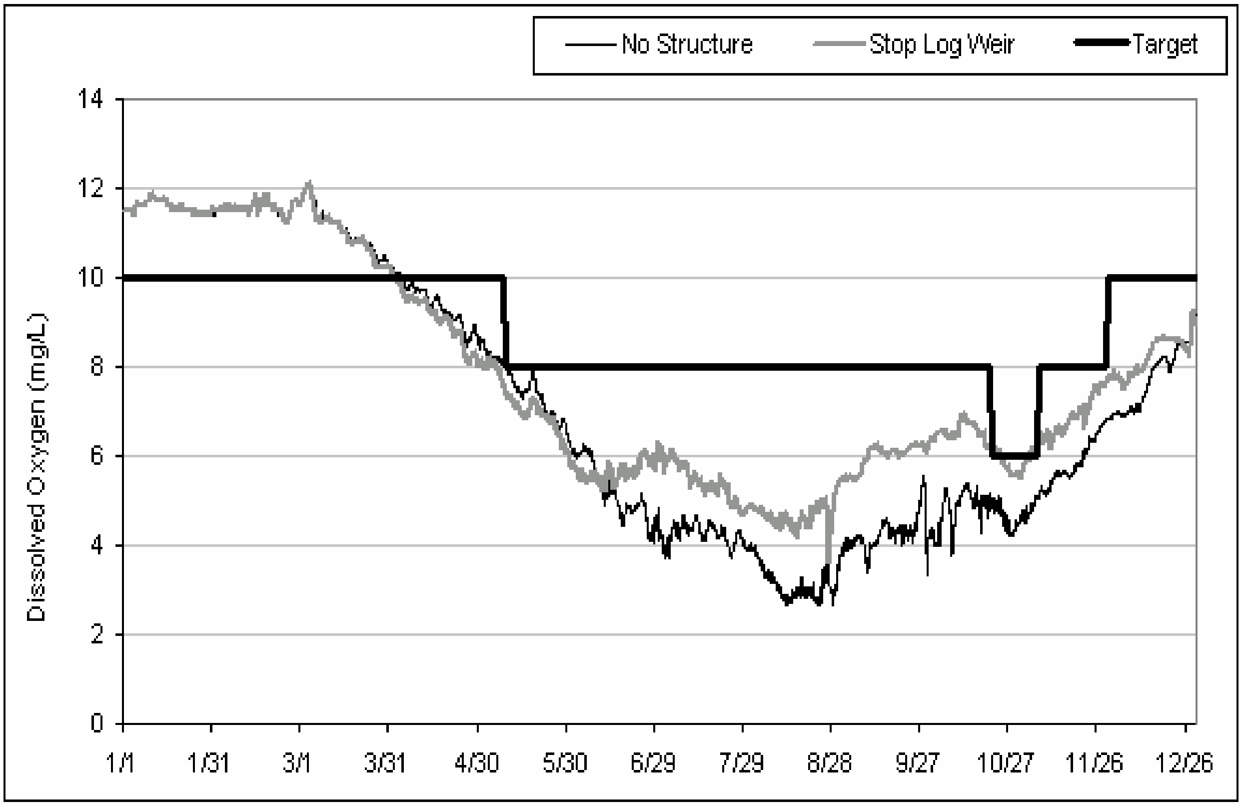
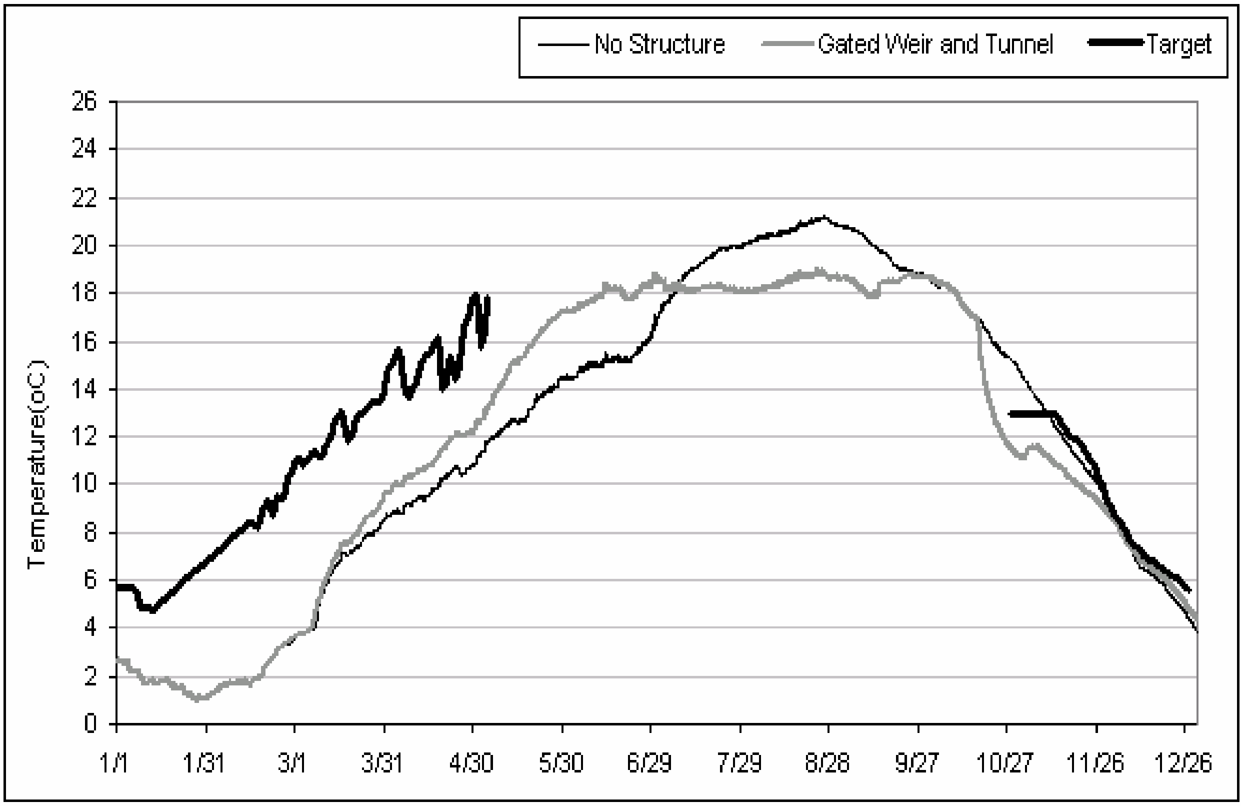


Figure 16. Low Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the current conditions model setup and OP-2 reservoir operations.



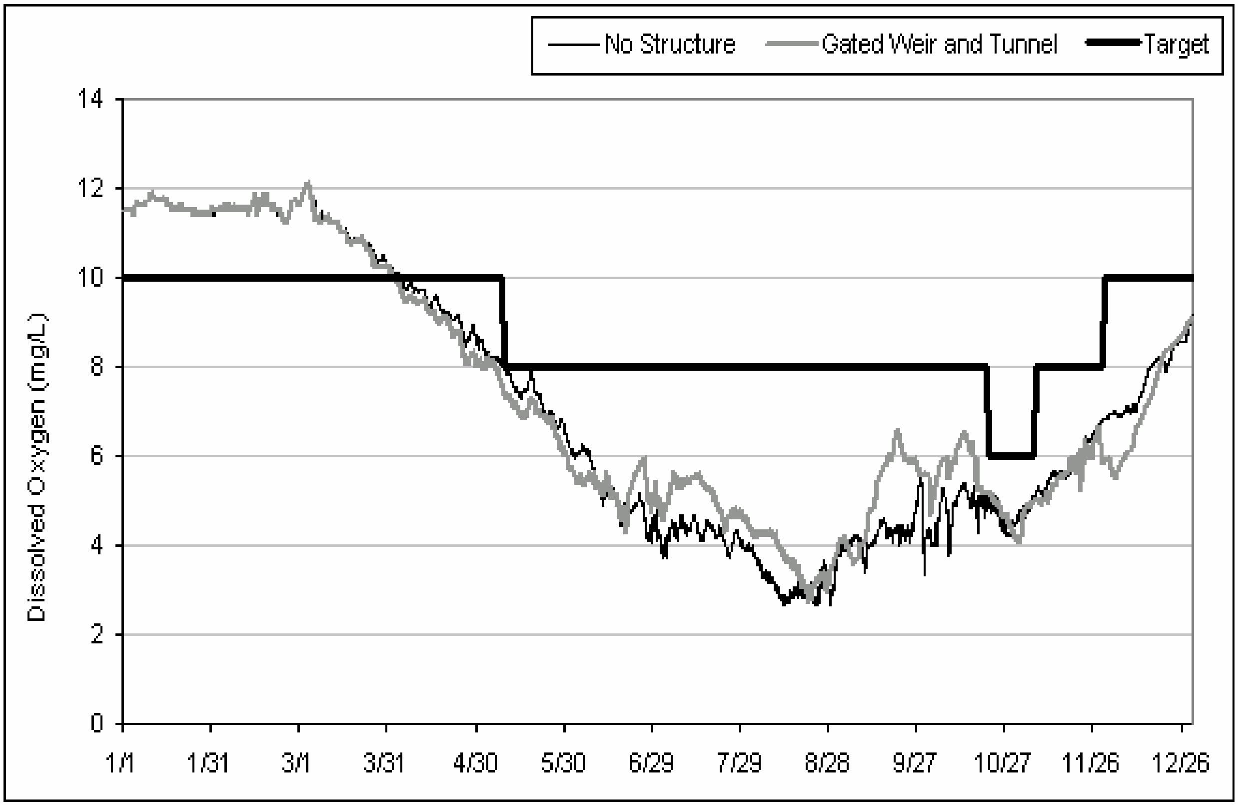
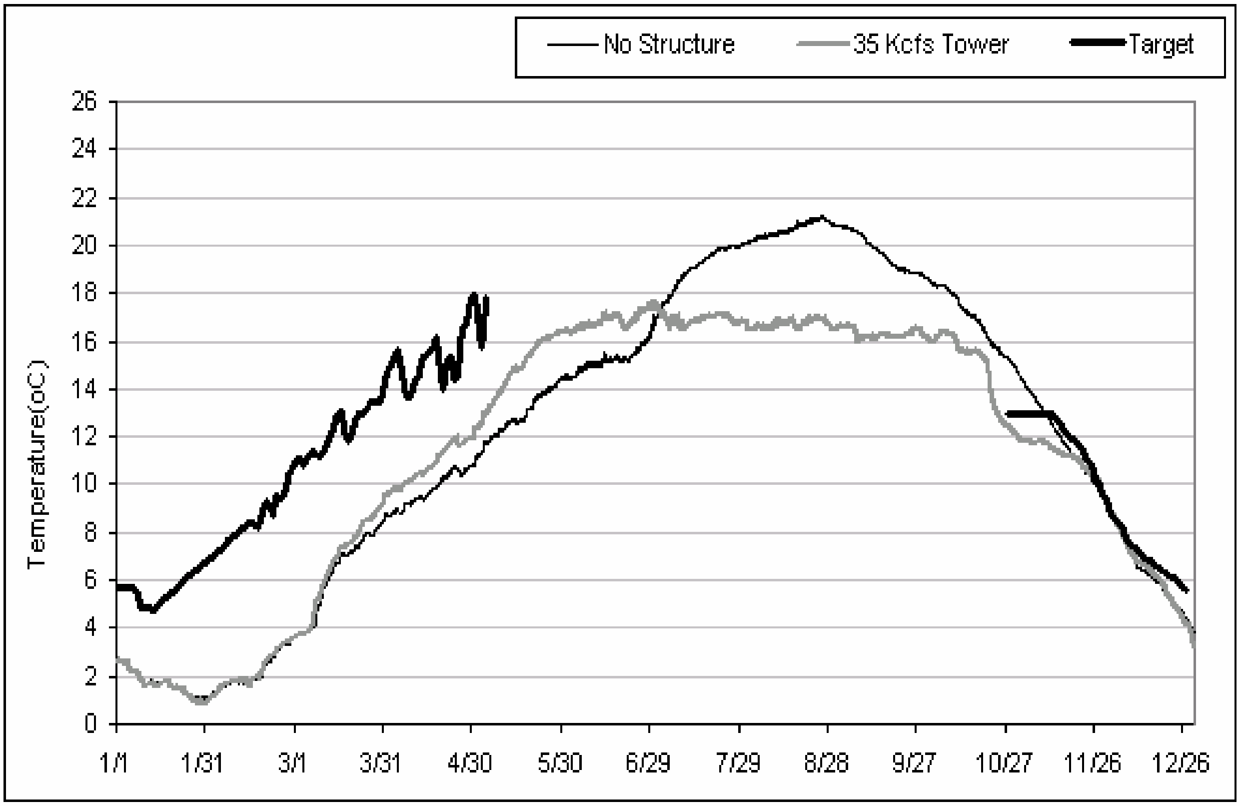


Figure 17. Low Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the current conditions model setup and OP-2 reservoir operations.



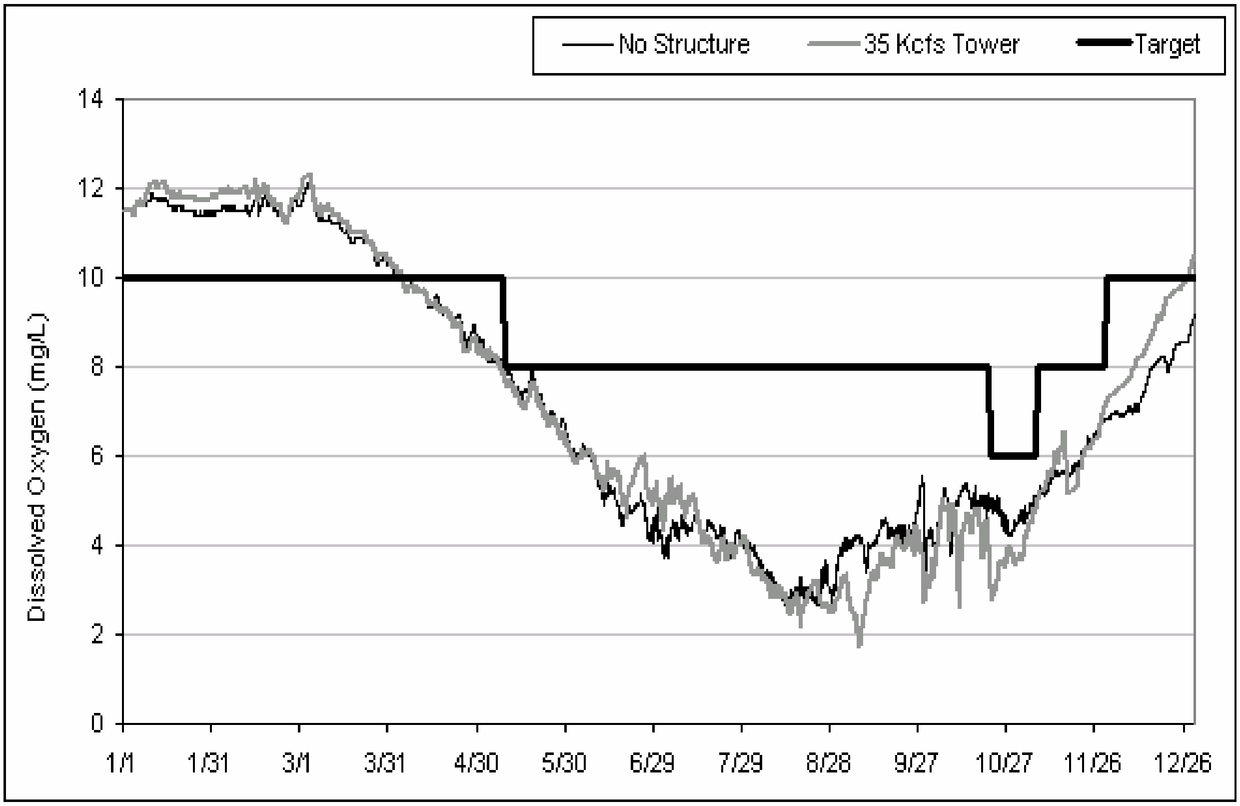
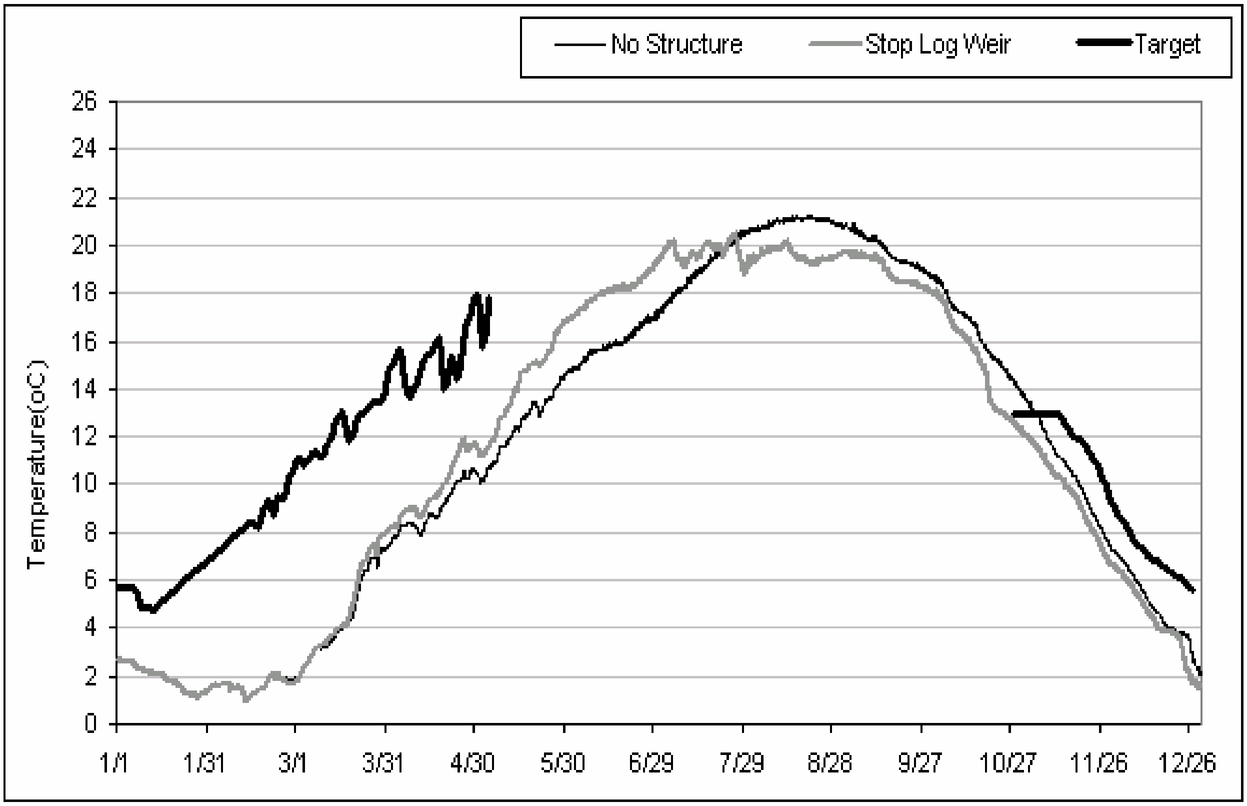


Figure 18. Low Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the current conditions model setup and OP-2 reservoir operations.



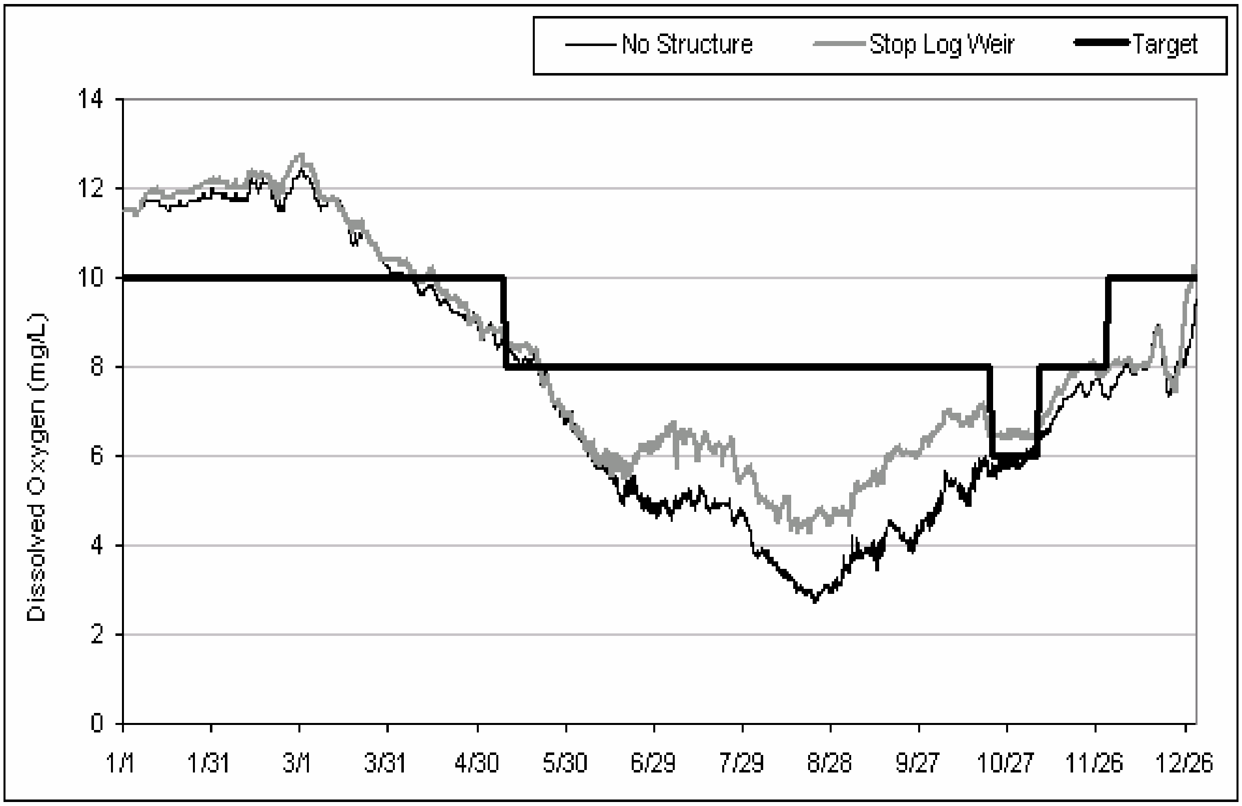


Figure 19. Medium-Low Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the current conditions model setup and OP-2 reservoir operations.

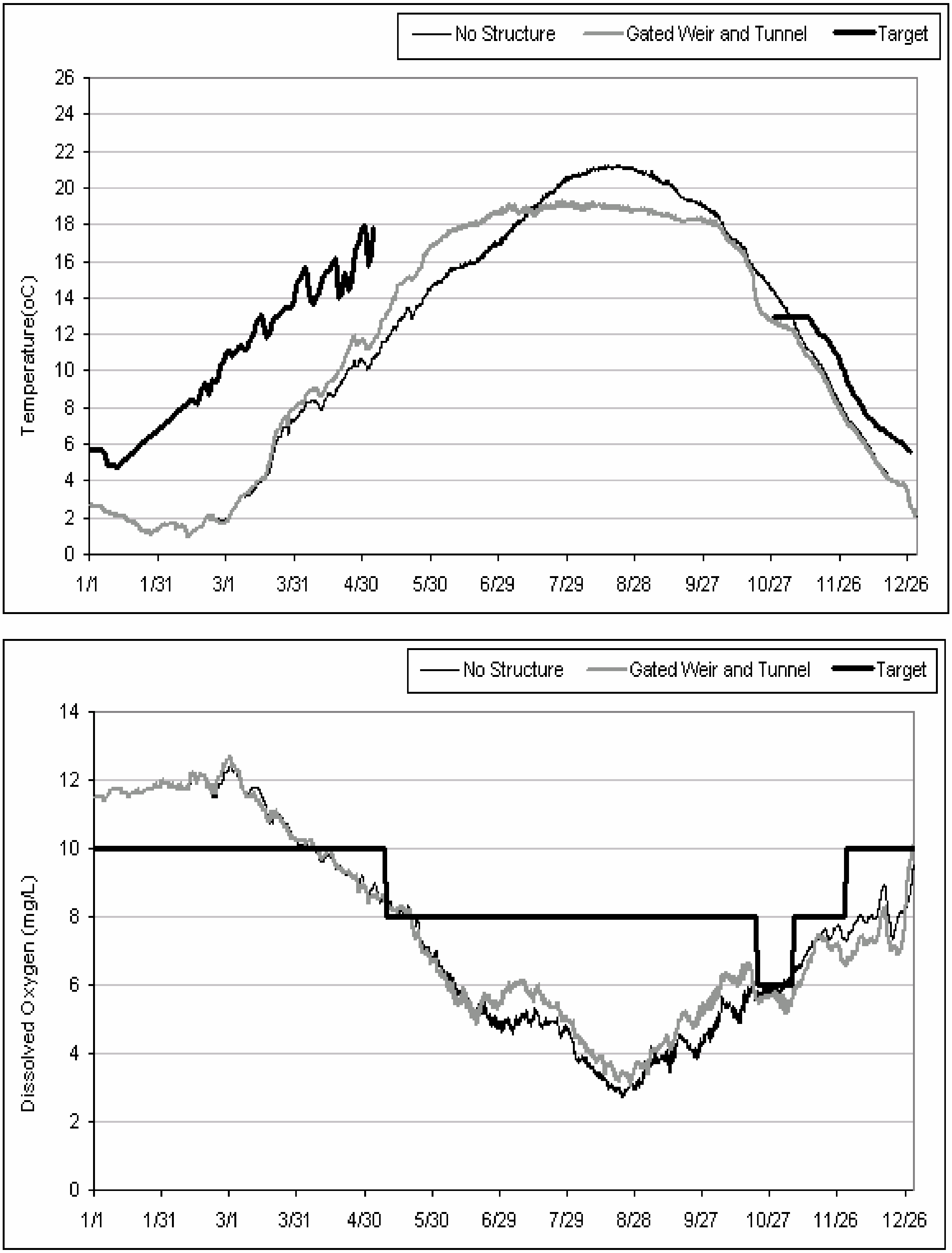
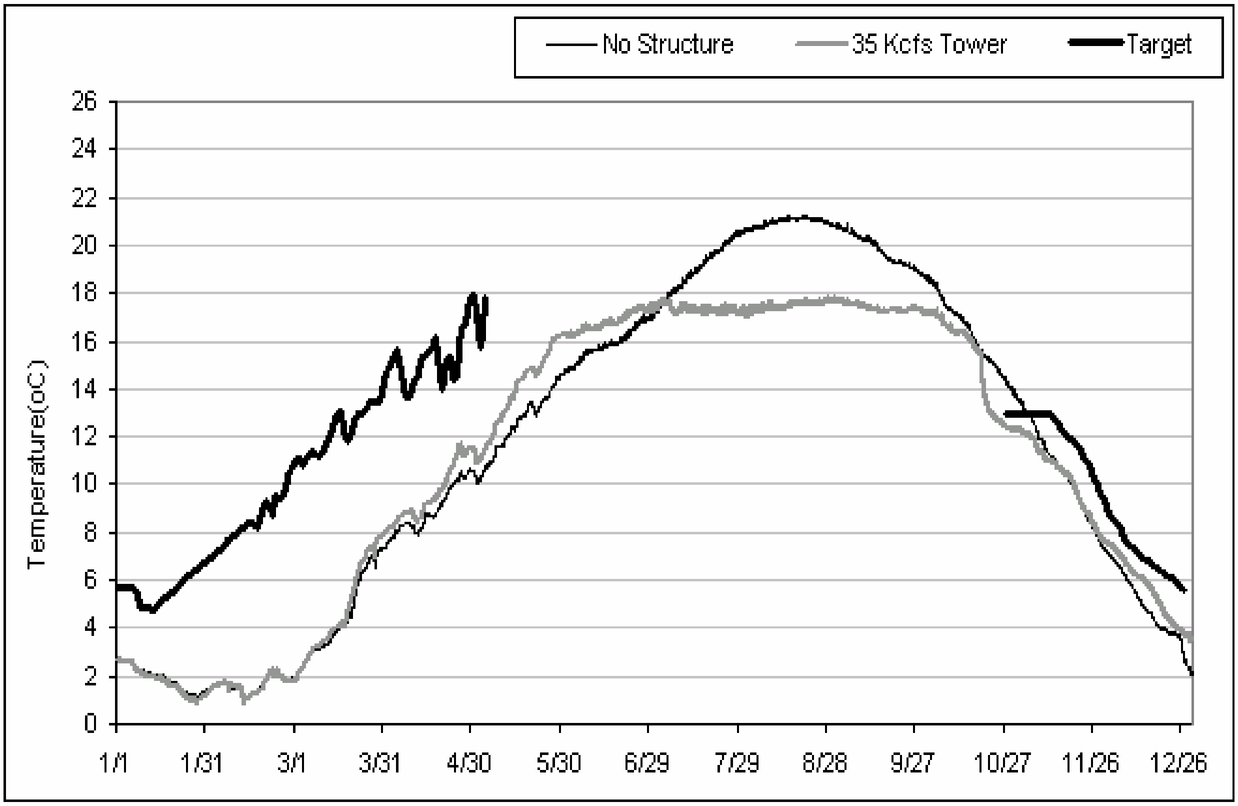


Figure 20. Medium-Low Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the current conditions model setup and OP-2 reservoir operations.



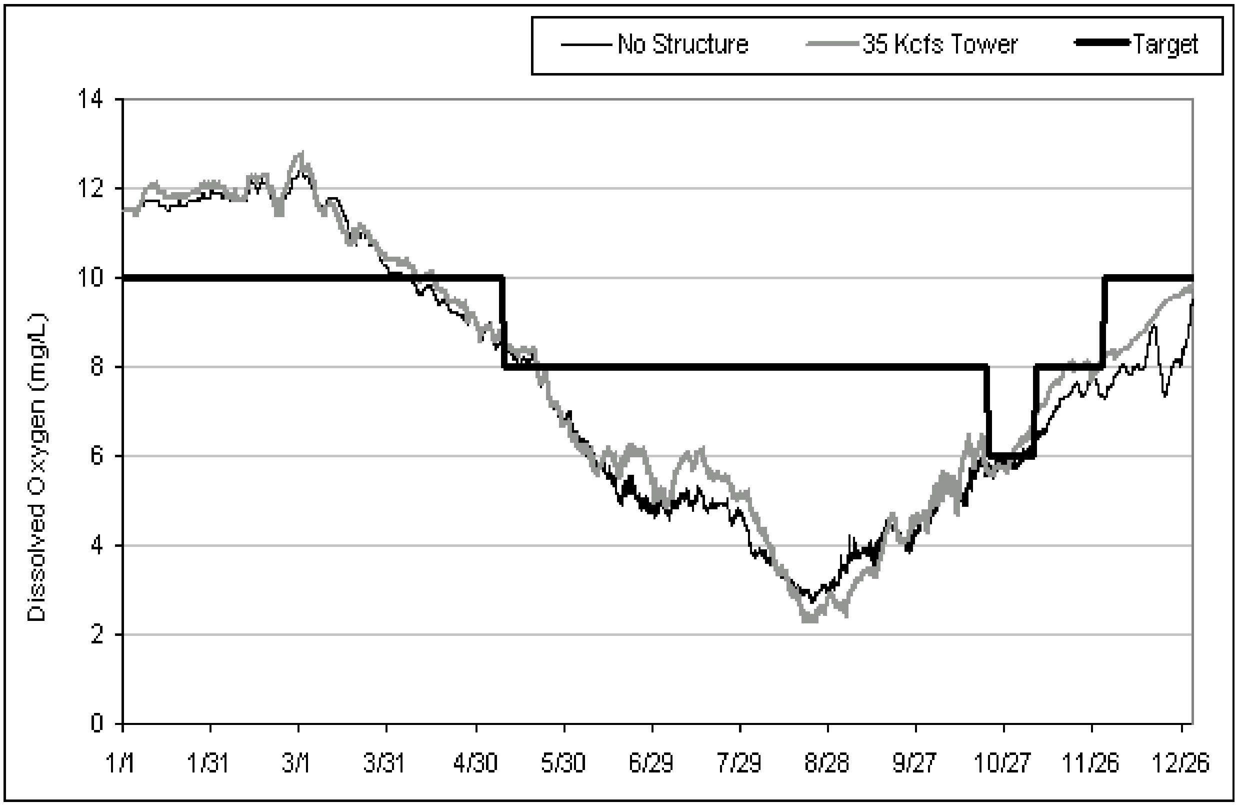
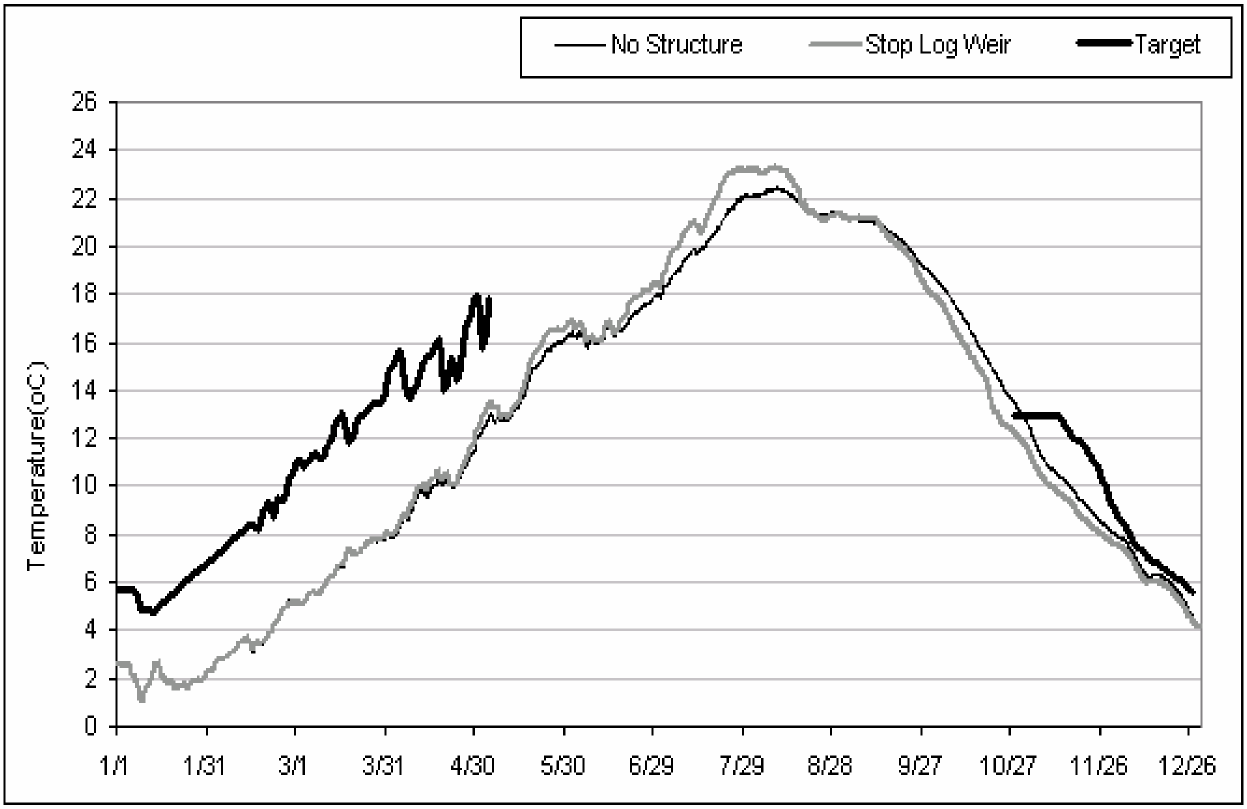


Figure 21. Medium-Low Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the current conditions model setup and OP-2 reservoir operations.



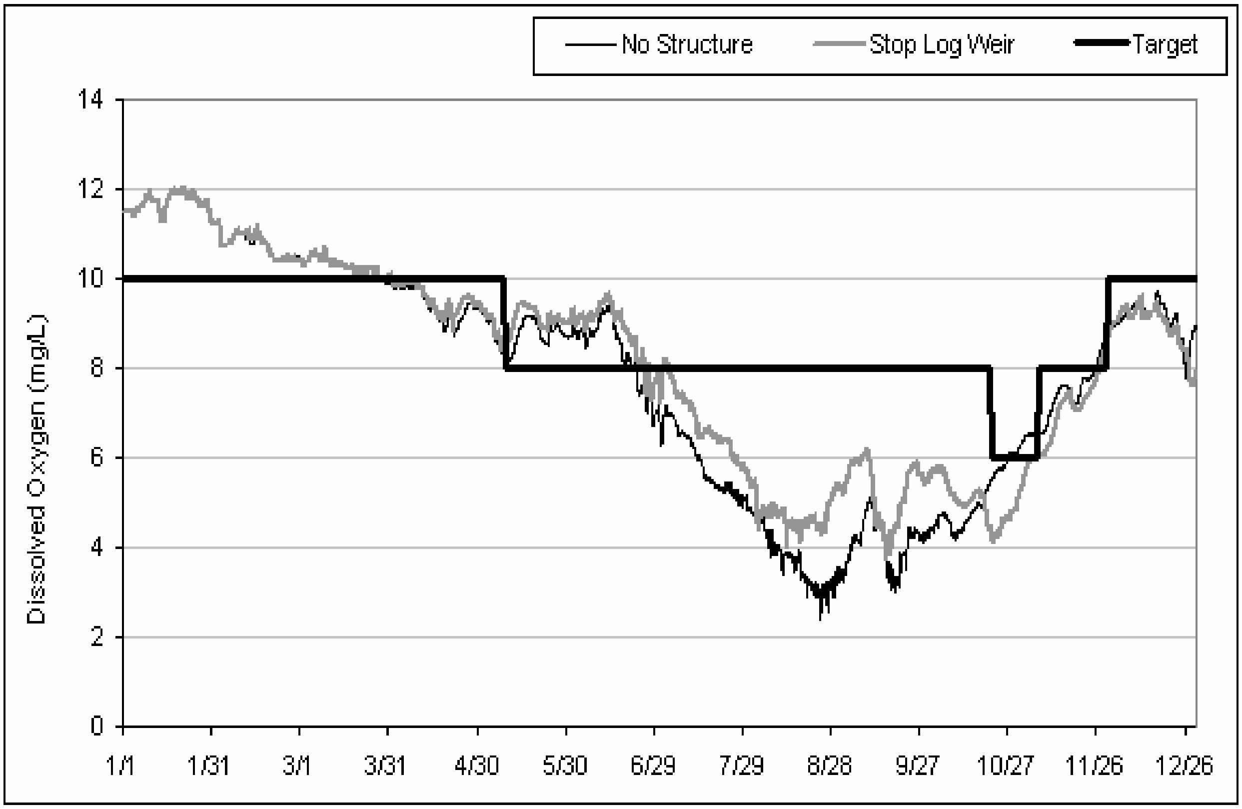


Figure 22. Medium Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the current conditions model setup and OP-2 reservoir operations.

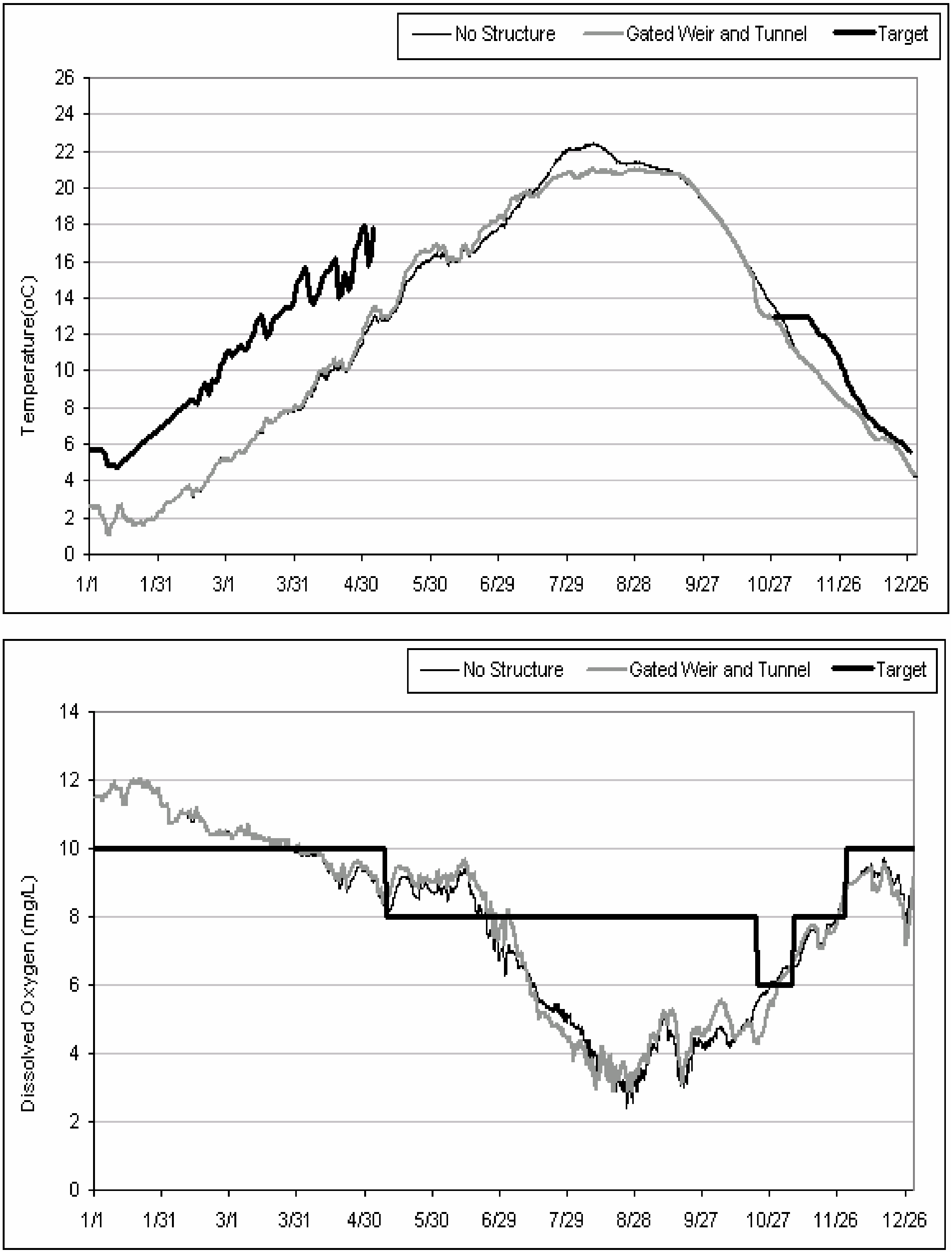
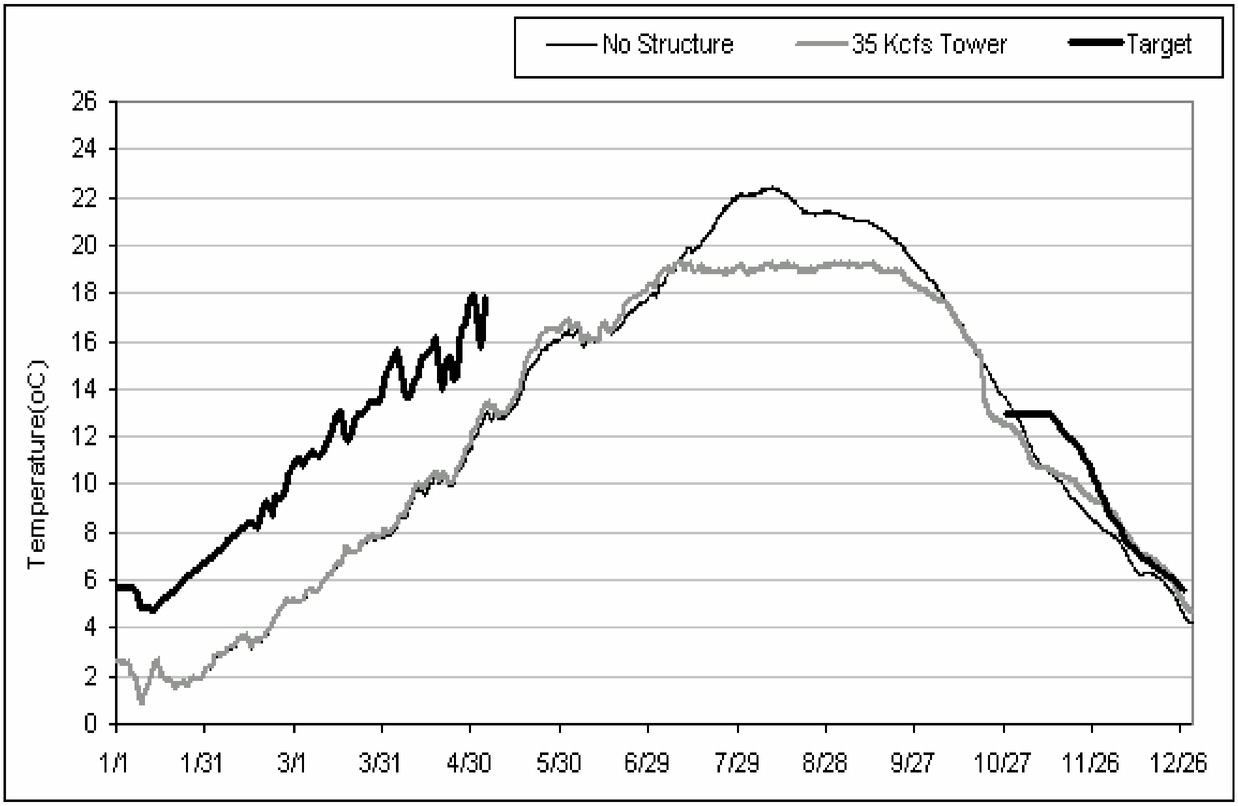


Figure 23. Medium Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the current conditions model setup and OP-2 reservoir operations.



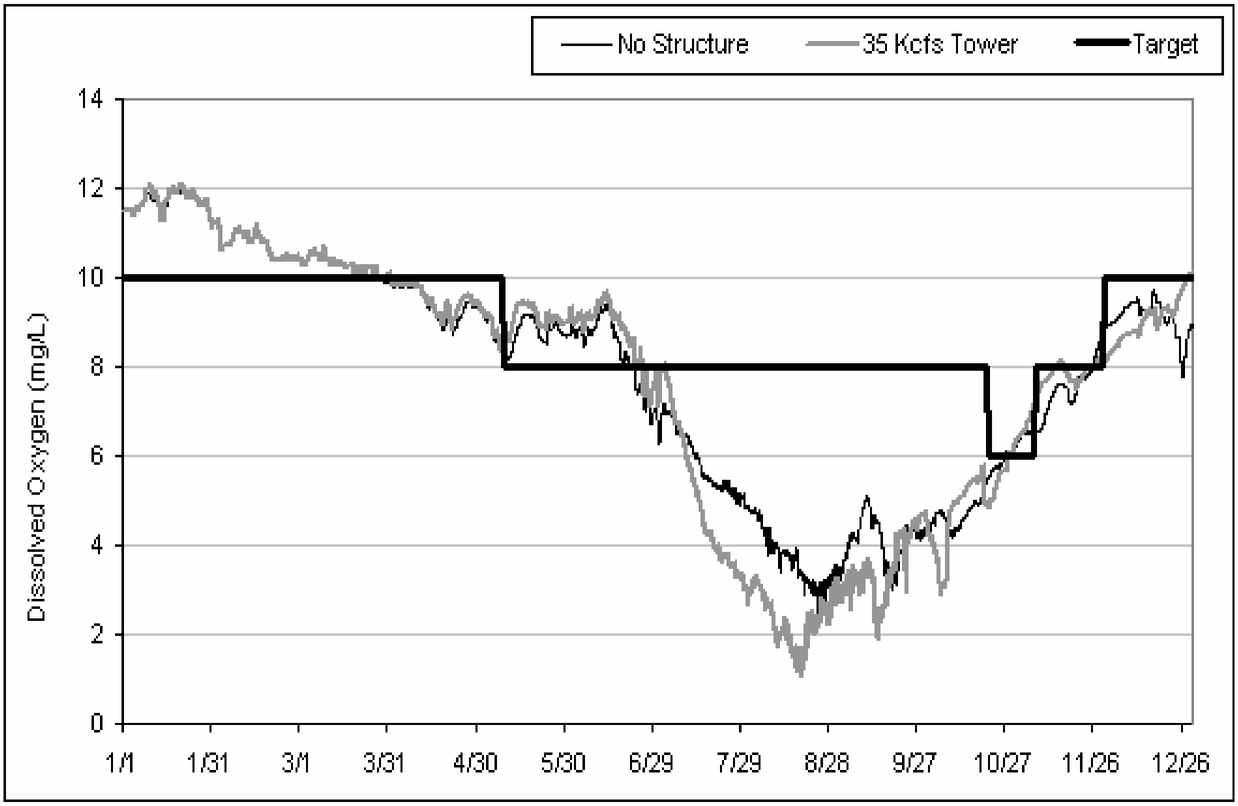


Figure 24. Medium Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the current conditions model setup and OP-2 reservoir operations.

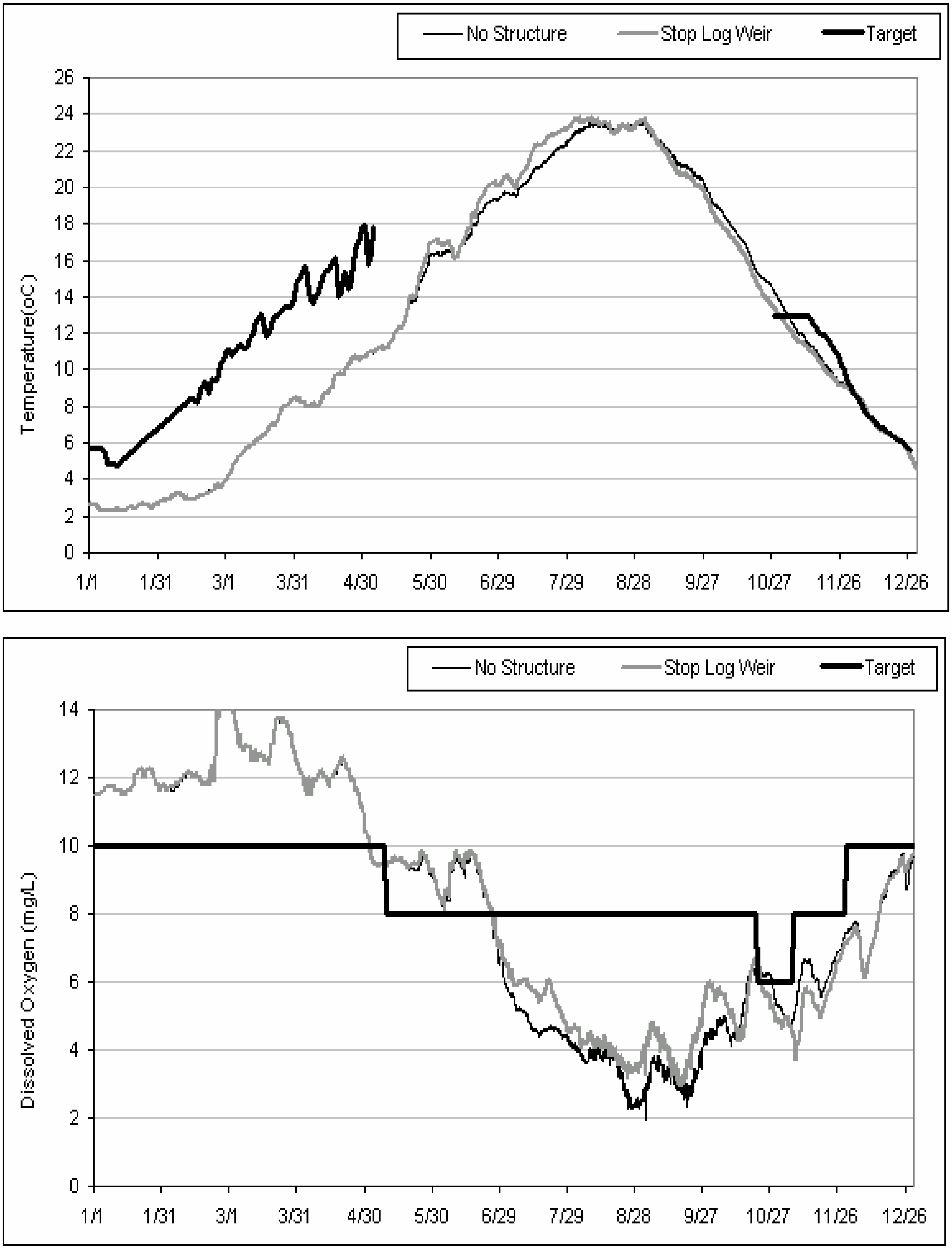
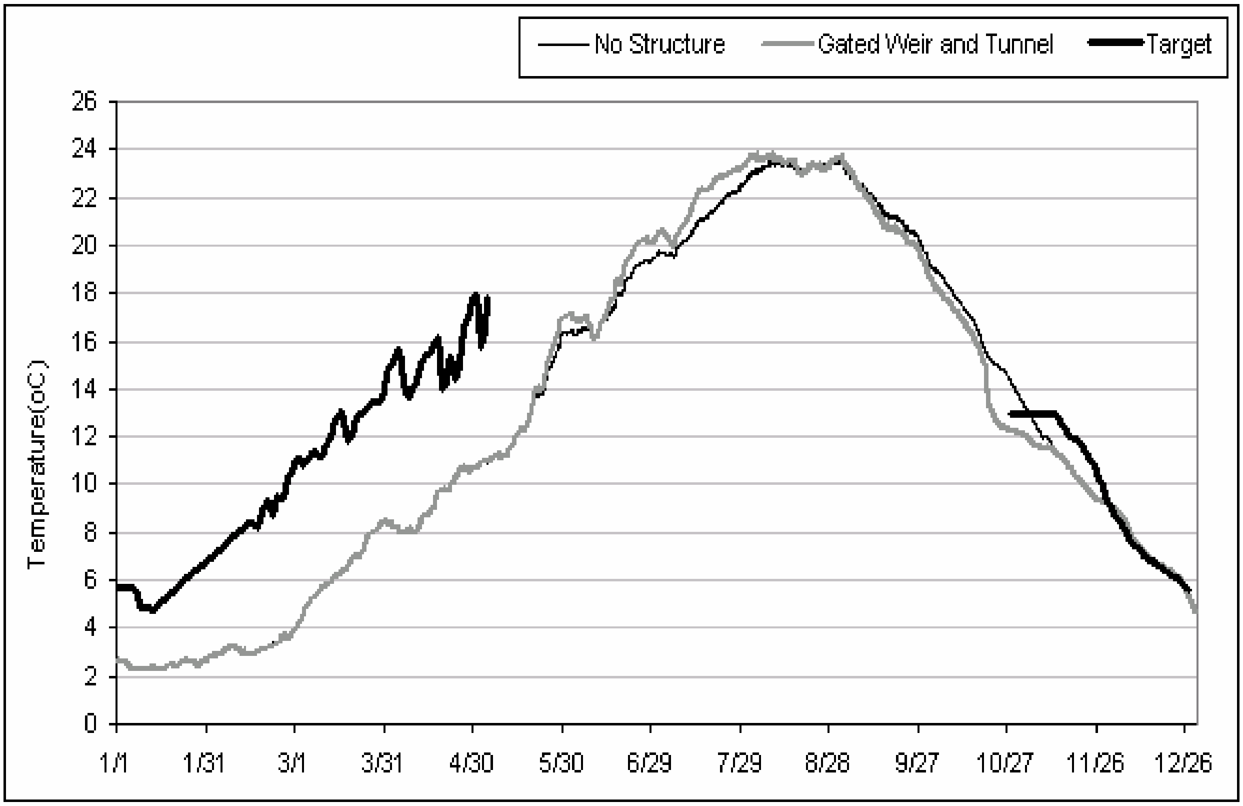


Figure 25. Medium-High Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the current conditions model setup and OP-2 reservoir operations.



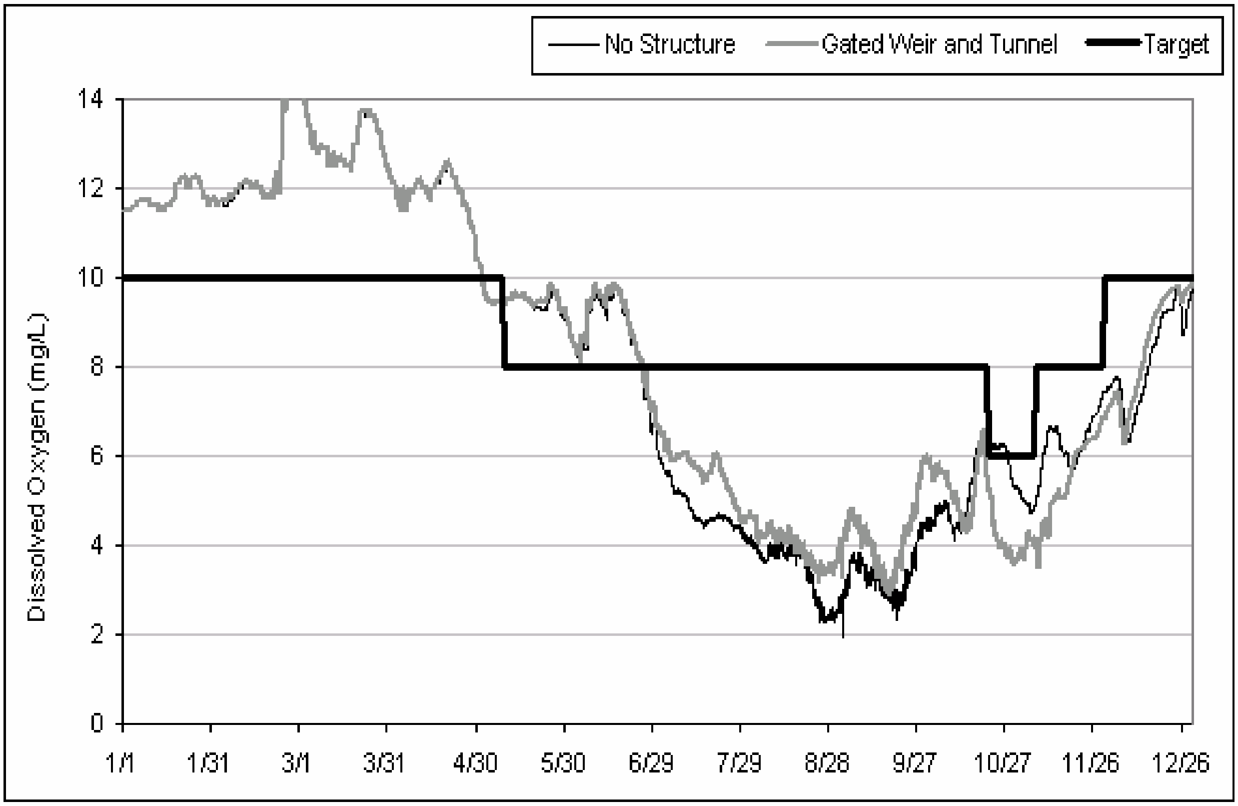
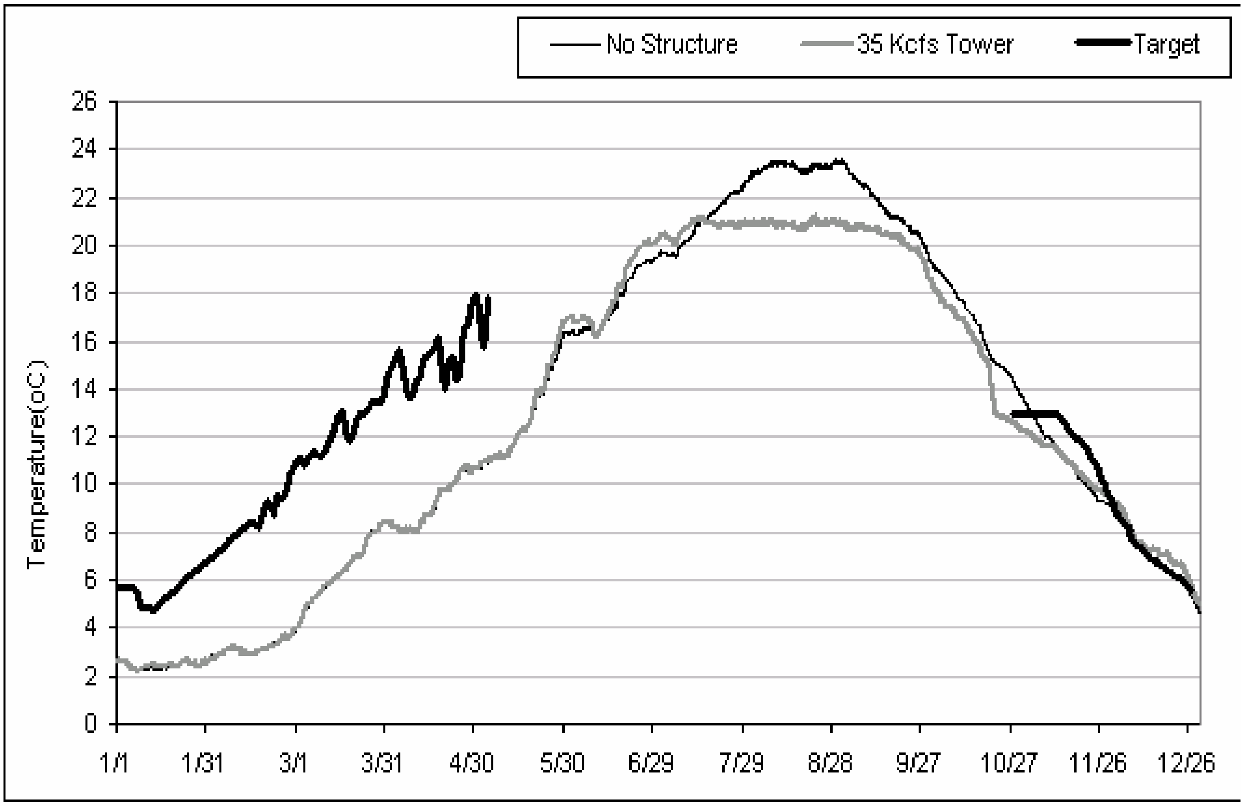


Figure 26. Medium-High Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the current conditions model setup and OP-2 reservoir operations.



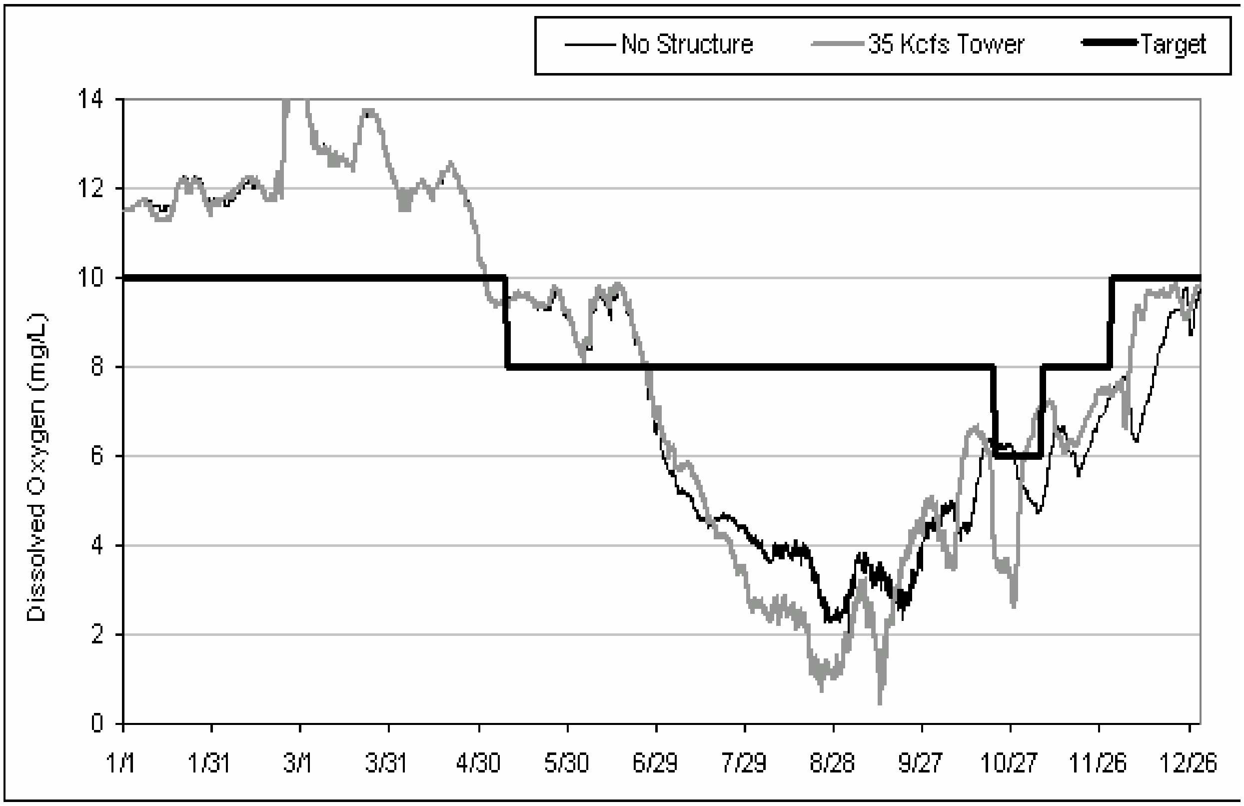
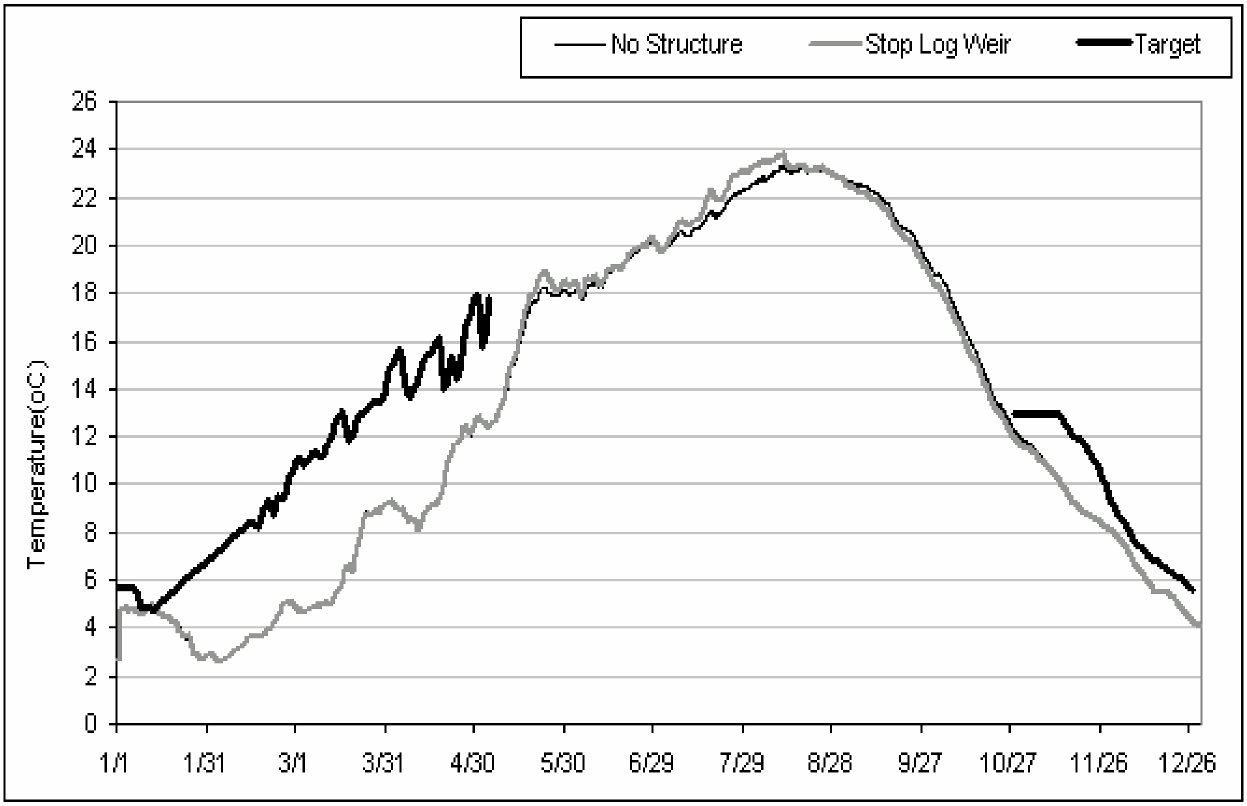


Figure 27. Medium-High Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the current conditions model setup and OP-2 reservoir operations.



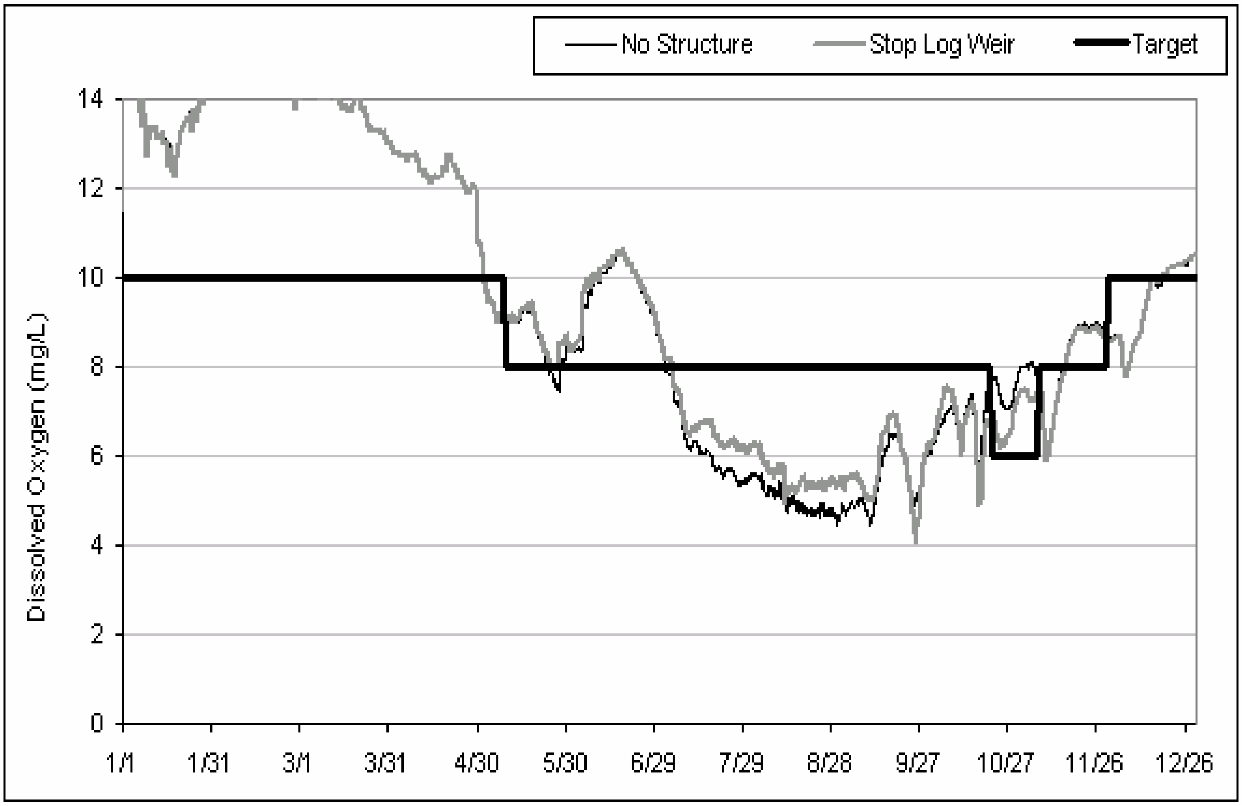
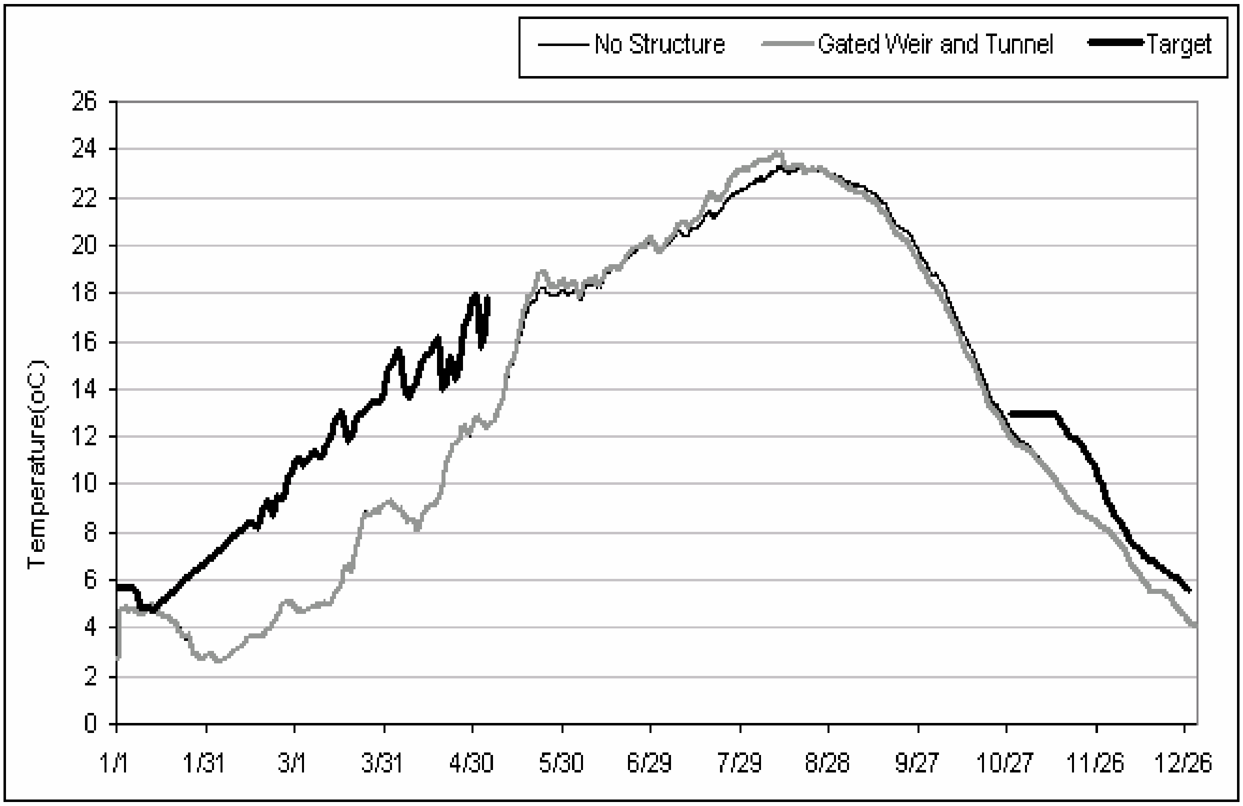


Figure 28. High Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the current conditions model setup and OP-2 reservoir operations.



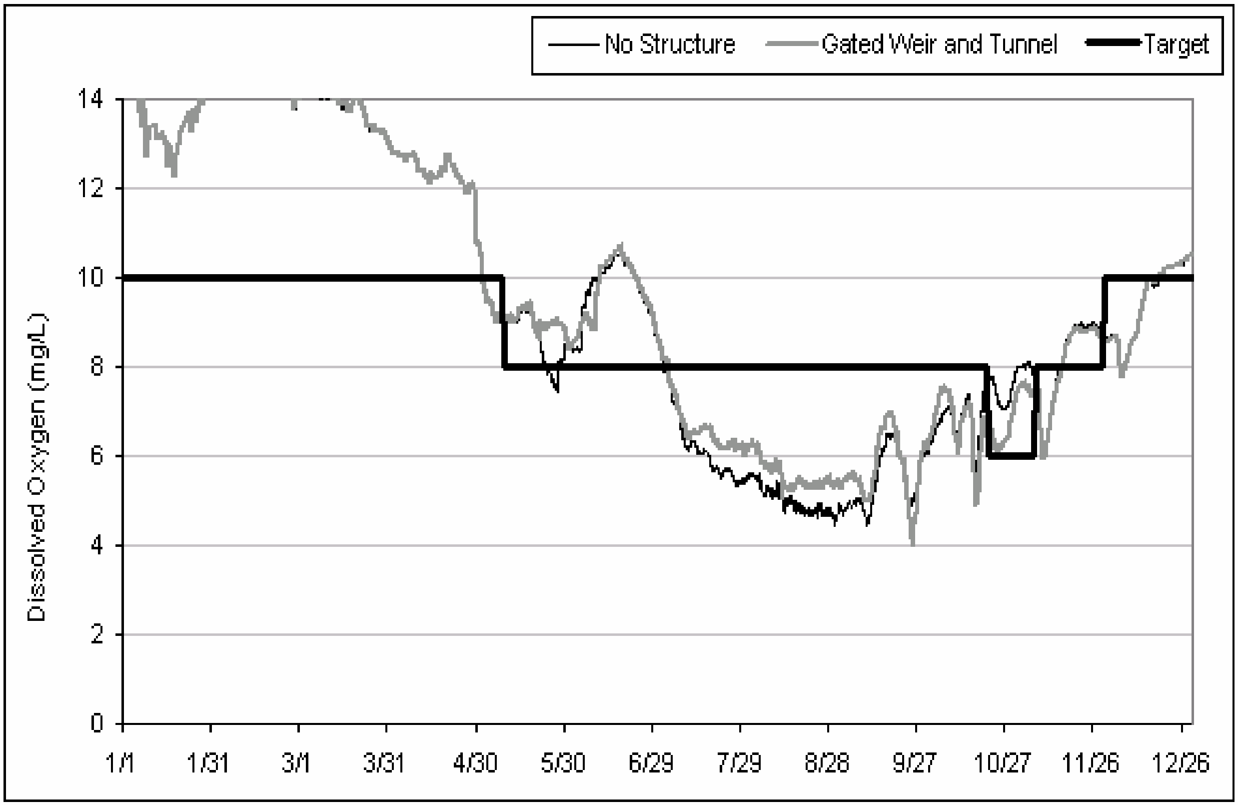
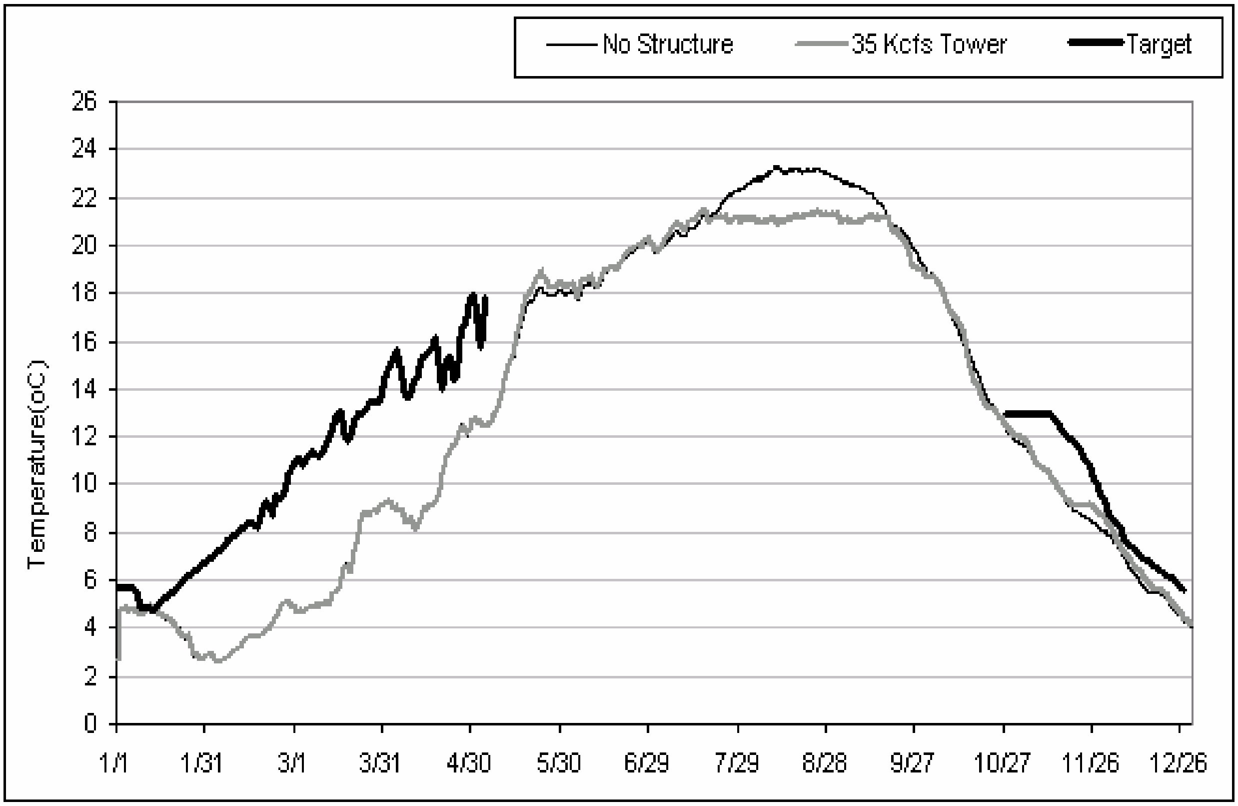


Figure 29. High Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the current conditions model setup and OP-2 reservoir operations.



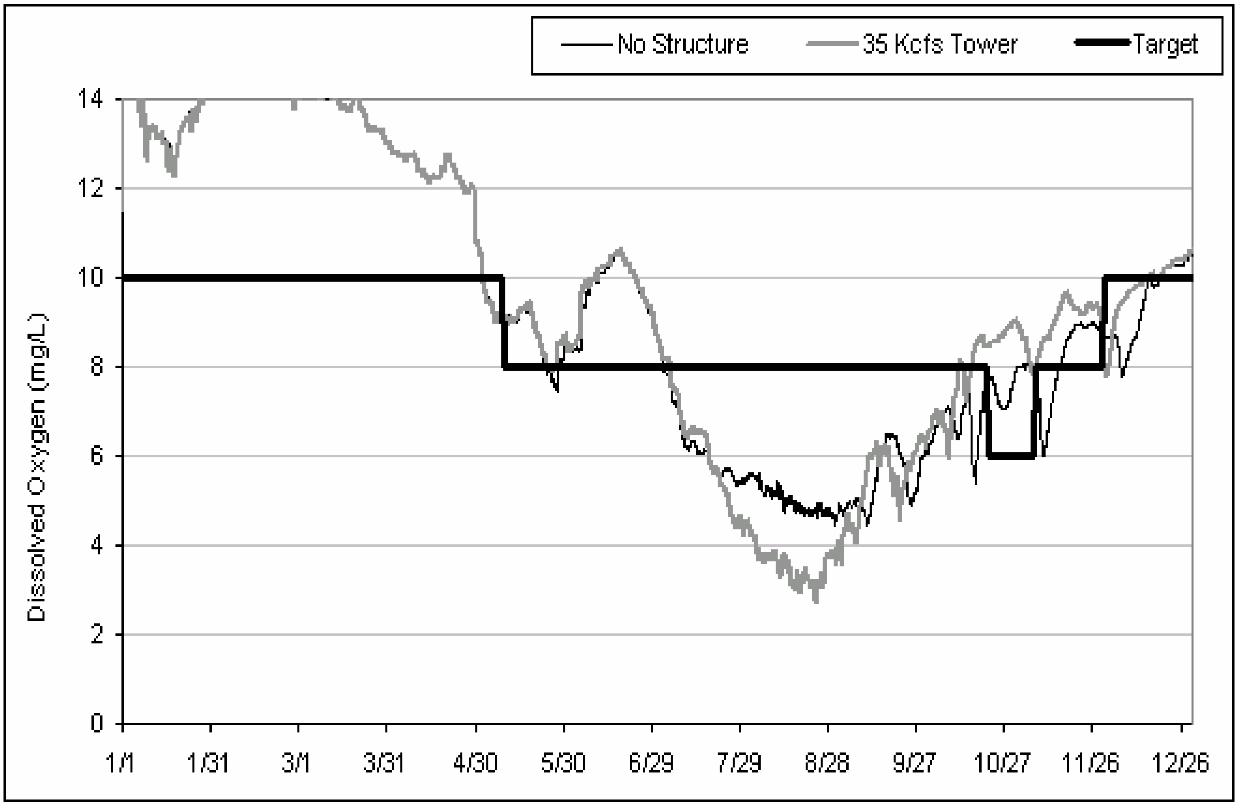
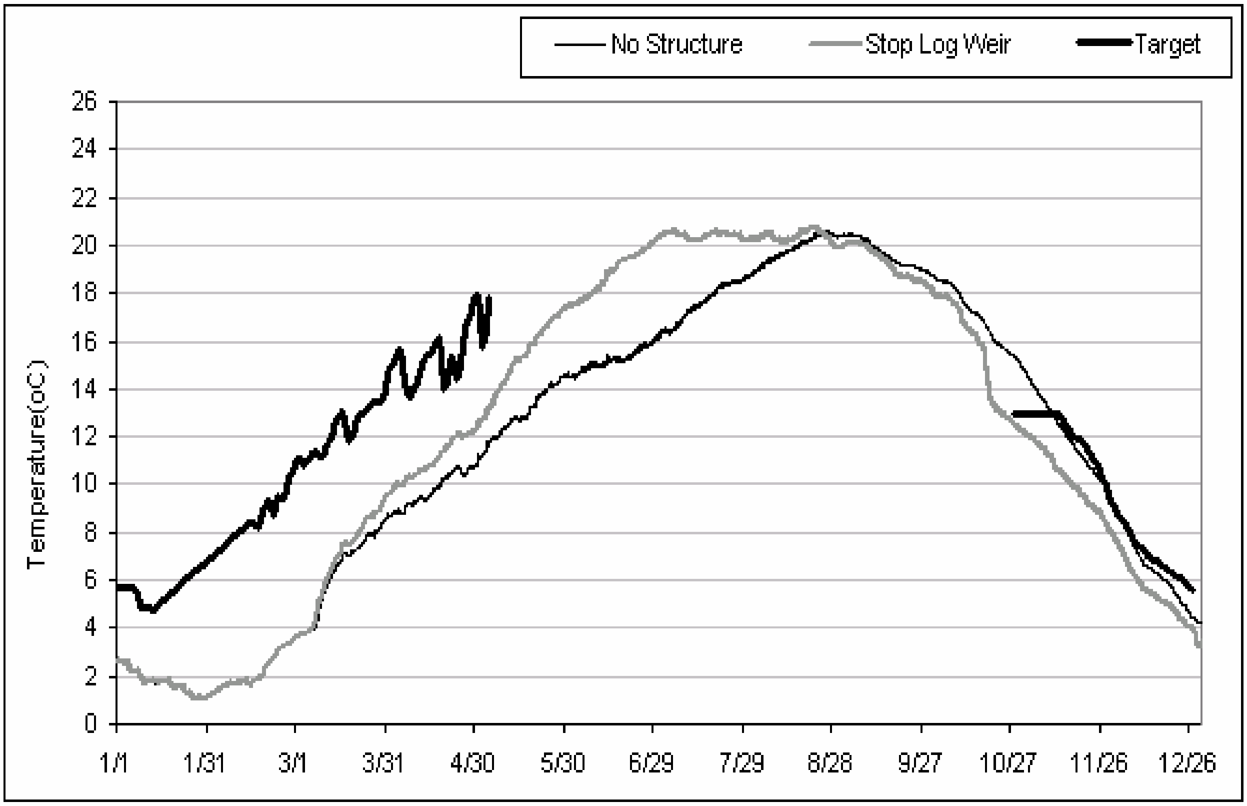


Figure 30. High Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the current conditions model setup and OP-2 reservoir operations.



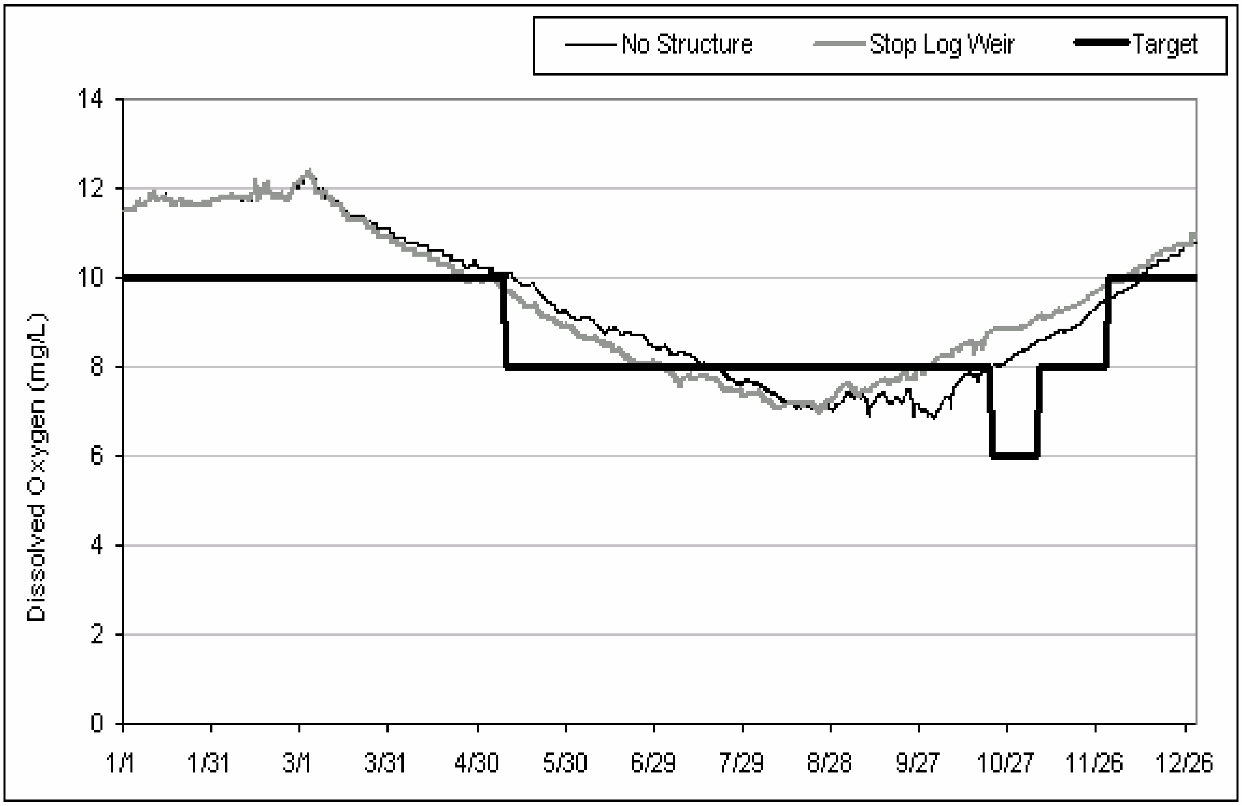


Figure 31. Low Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the TMDL conditions model setup and proposed reservoir operations.

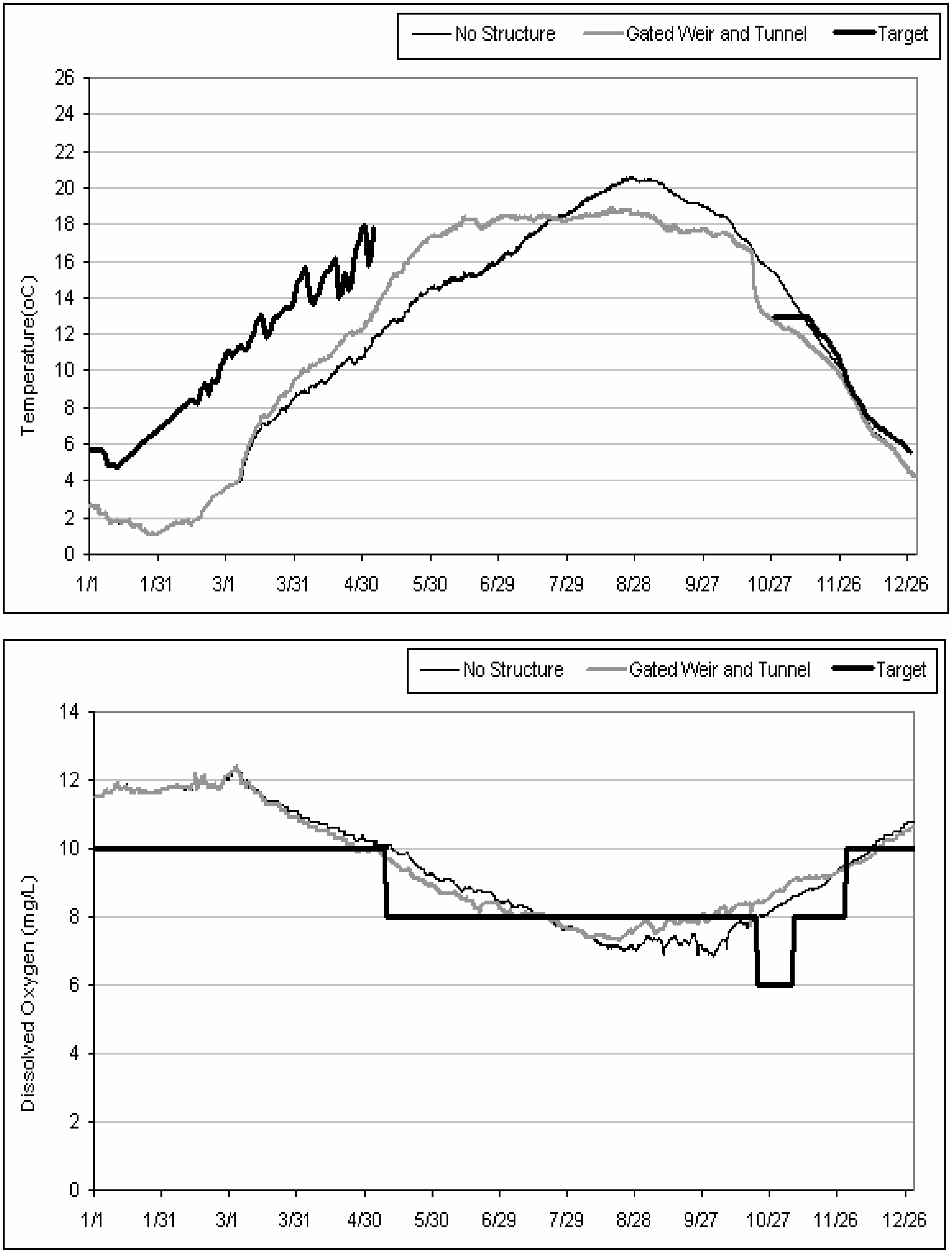


Figure 32. Low Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the TMDL conditions model setup and proposed reservoir operations.

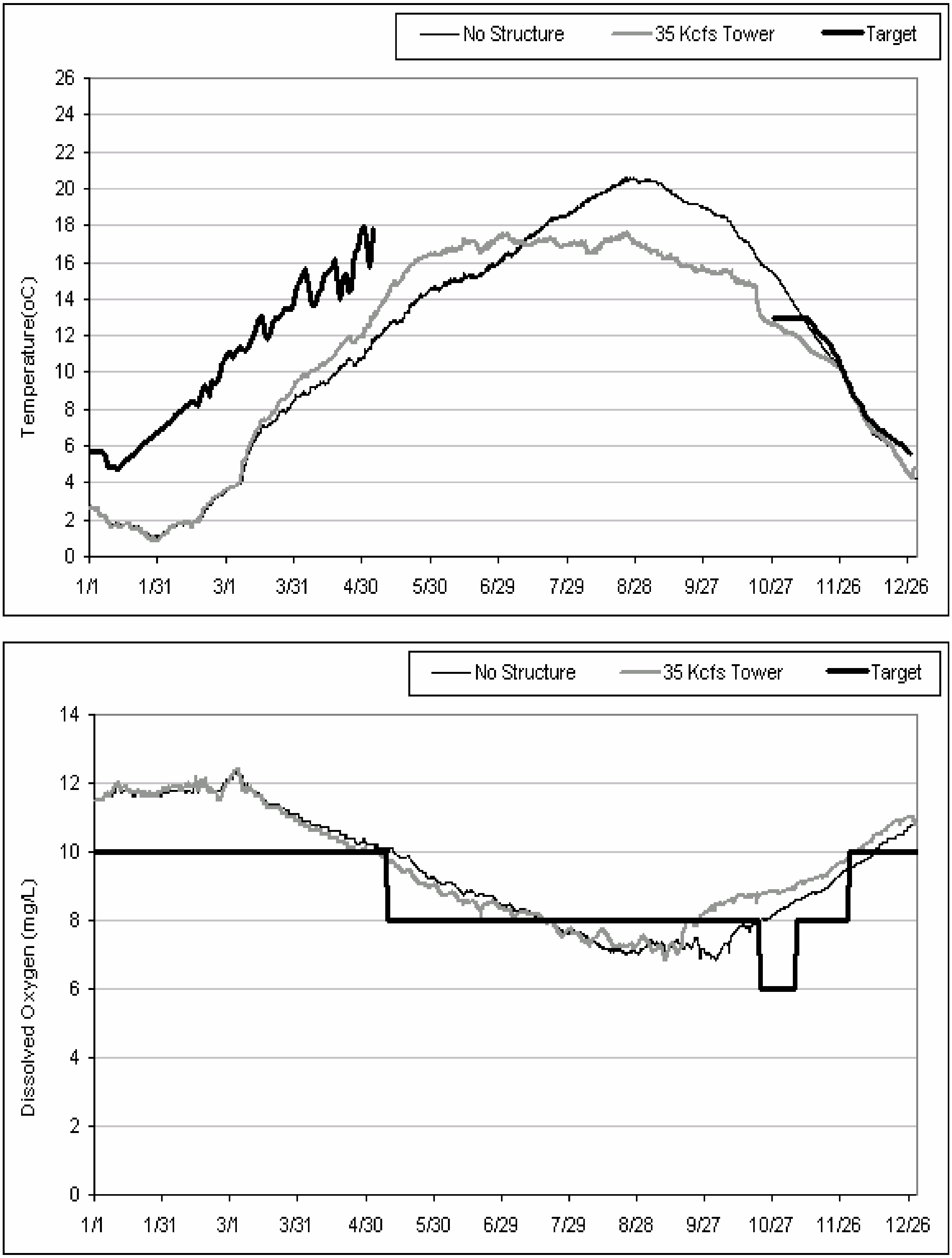
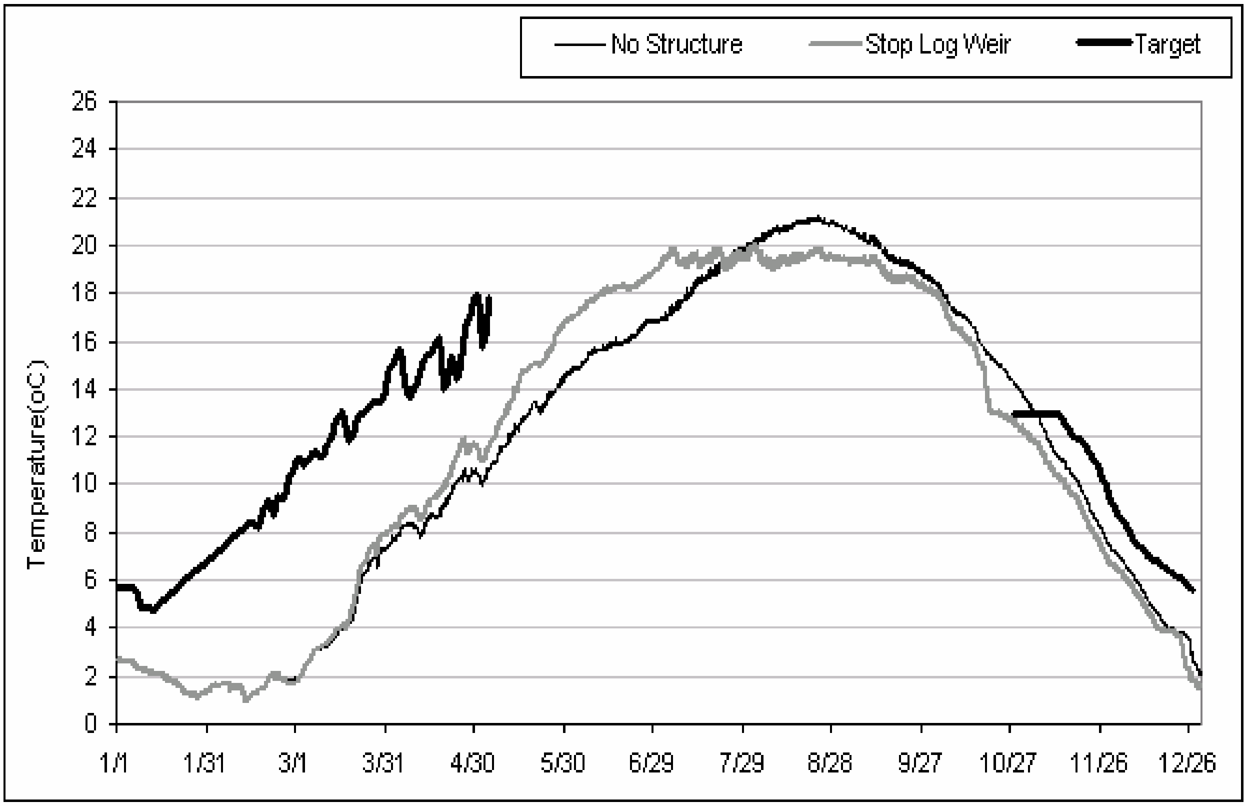


Figure 33. Low Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the TMDL conditions model setup and proposed reservoir operations.



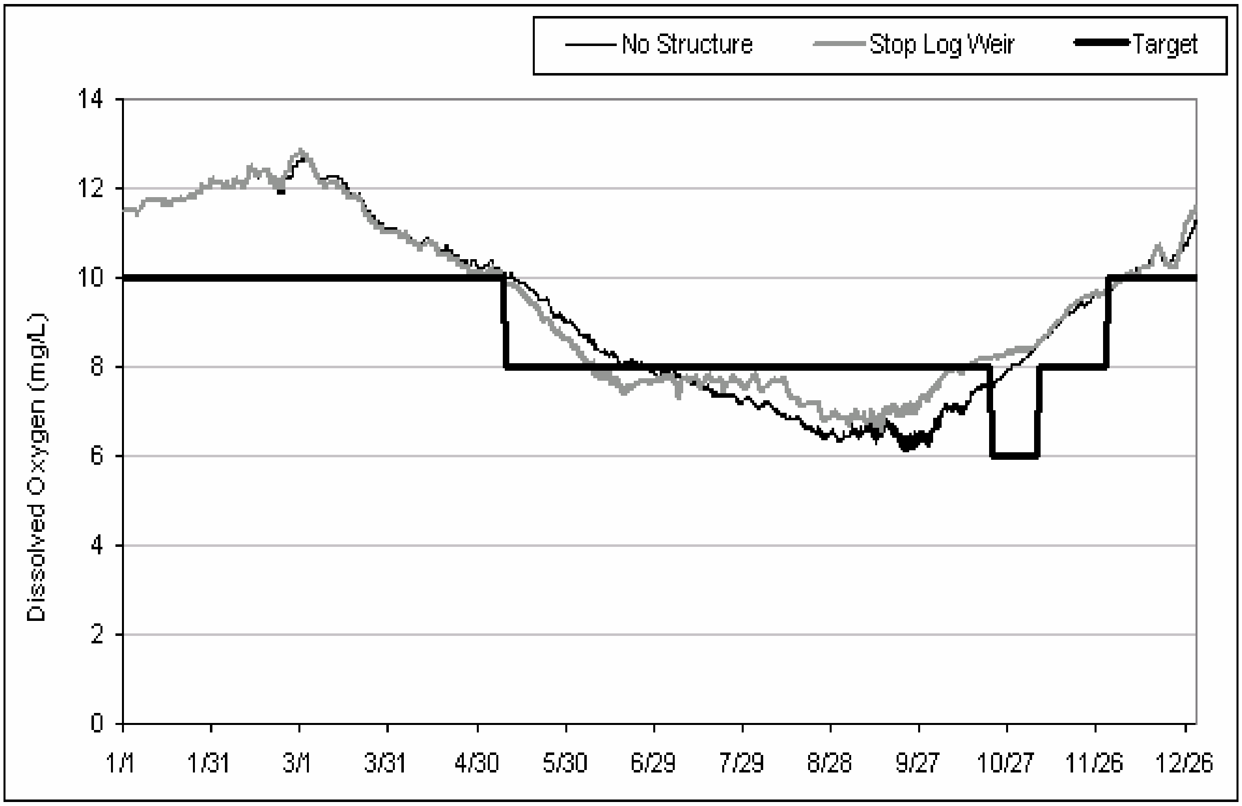
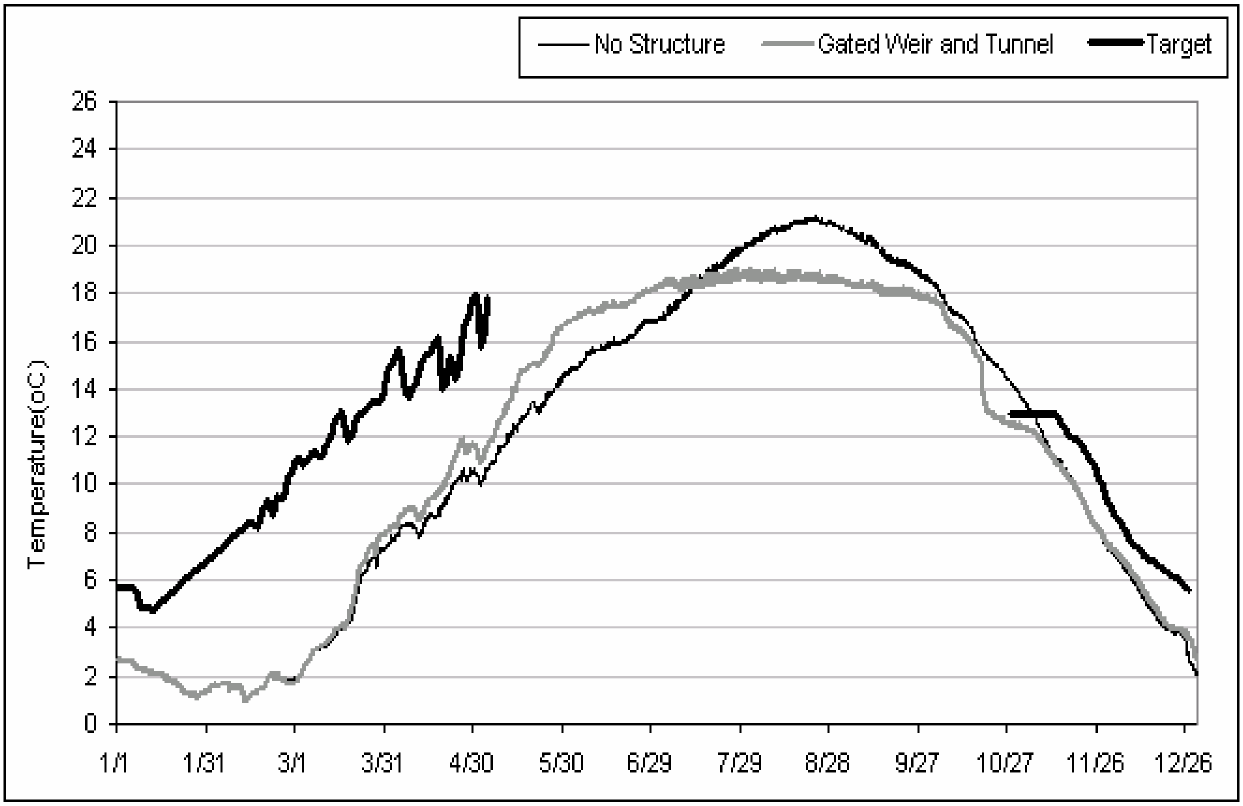


Figure 34. Medium-Low Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the TMDL conditions model setup and proposed reservoir operations.



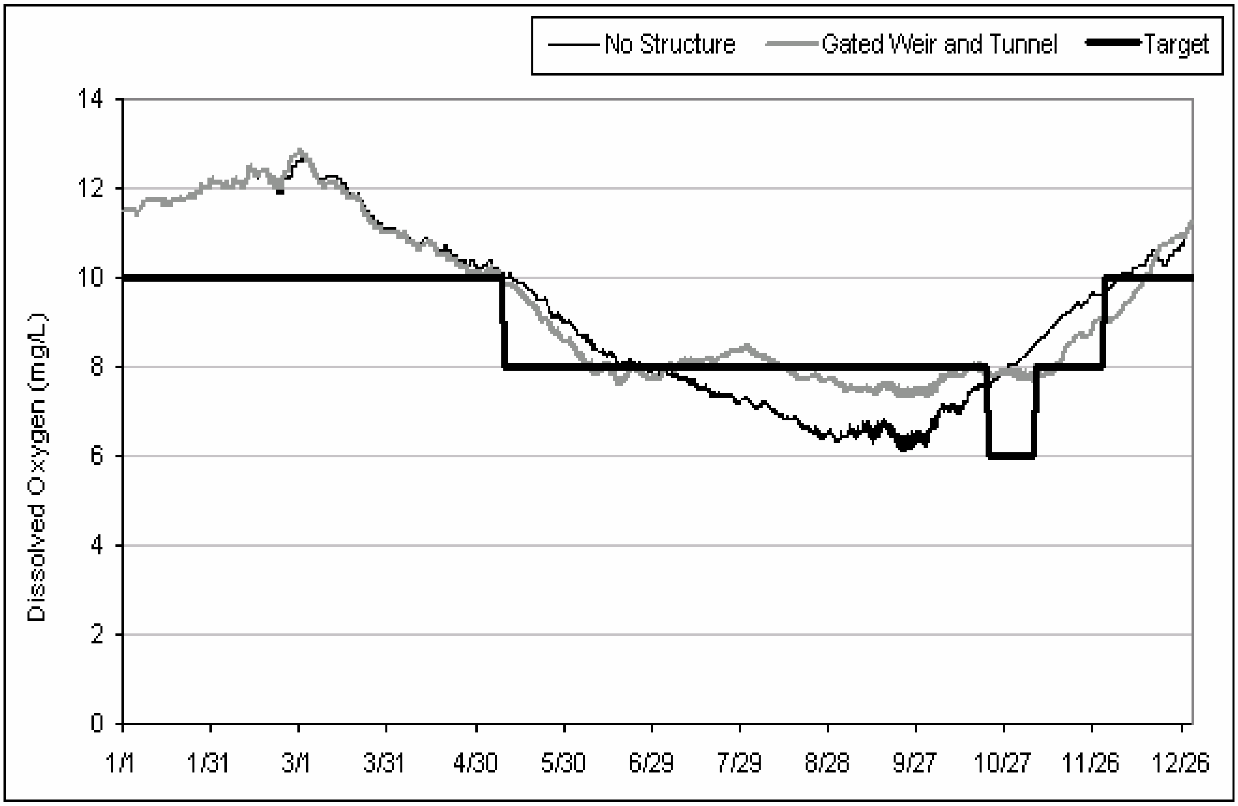


Figure 35. Medium-Low Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the TMDL conditions model setup and proposed reservoir operations.

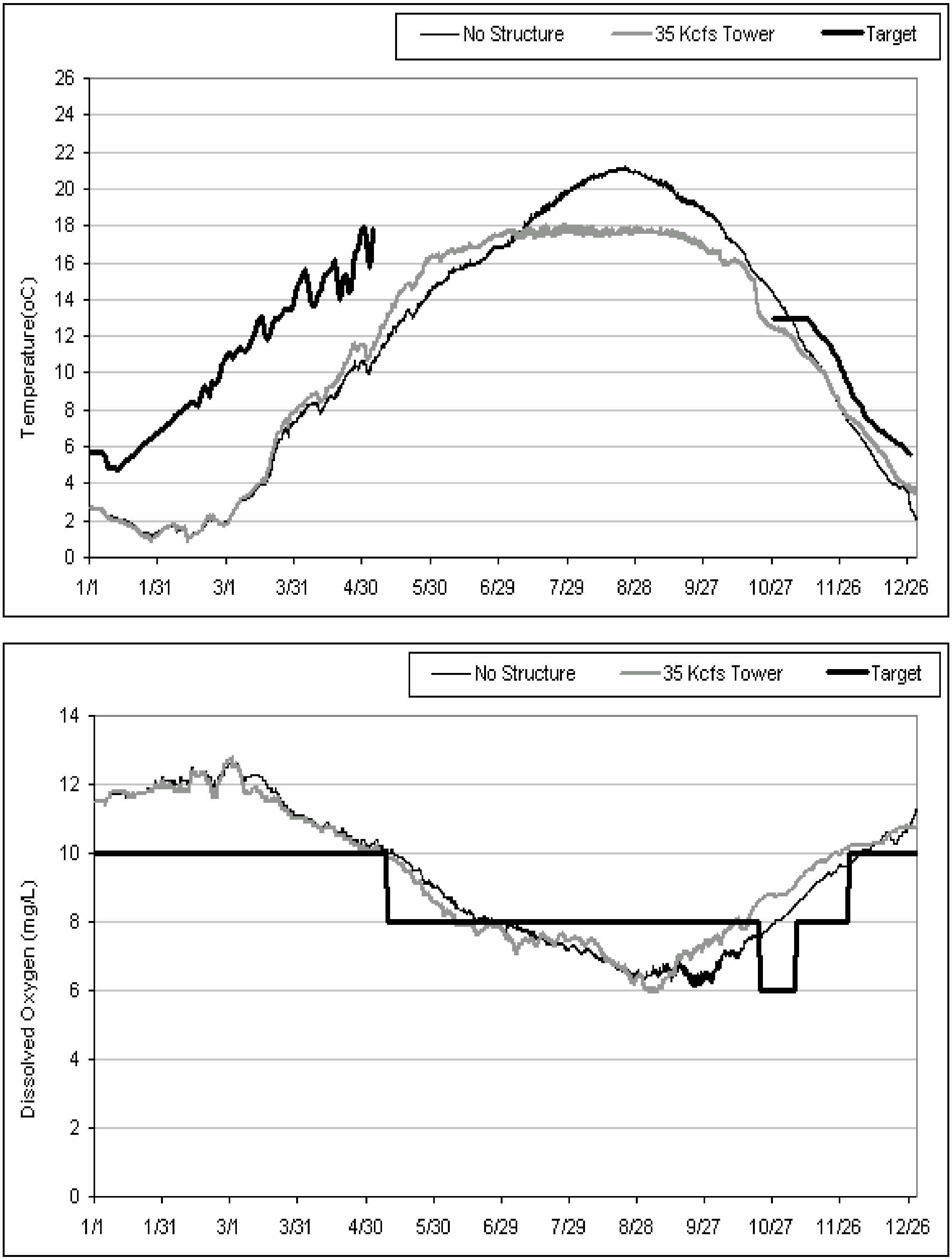


Figure 36. Medium-Low Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the TMDL conditions model setup and proposed reservoir operations.

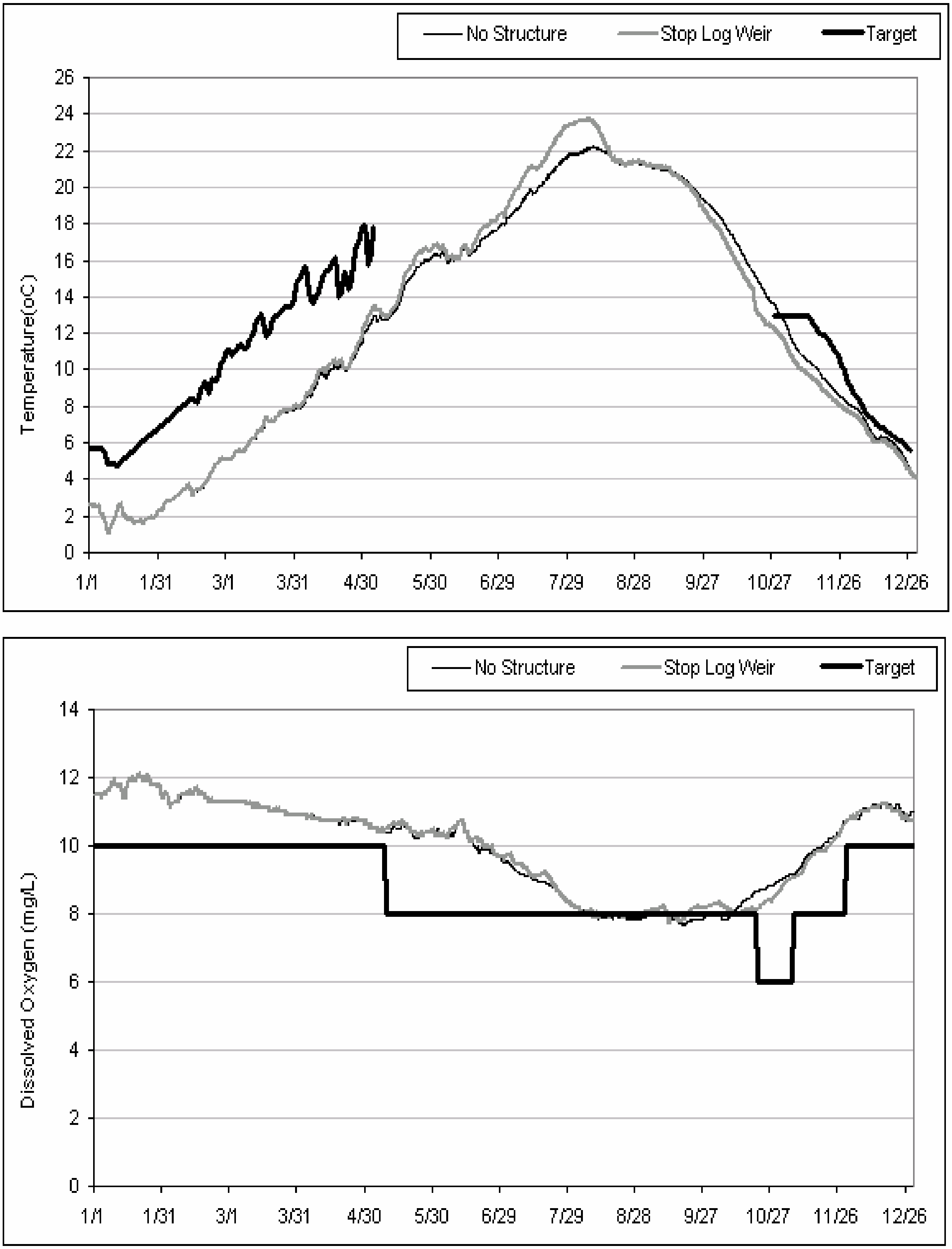


Figure 37. Medium Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the TMDL conditions model setup and proposed reservoir operations.

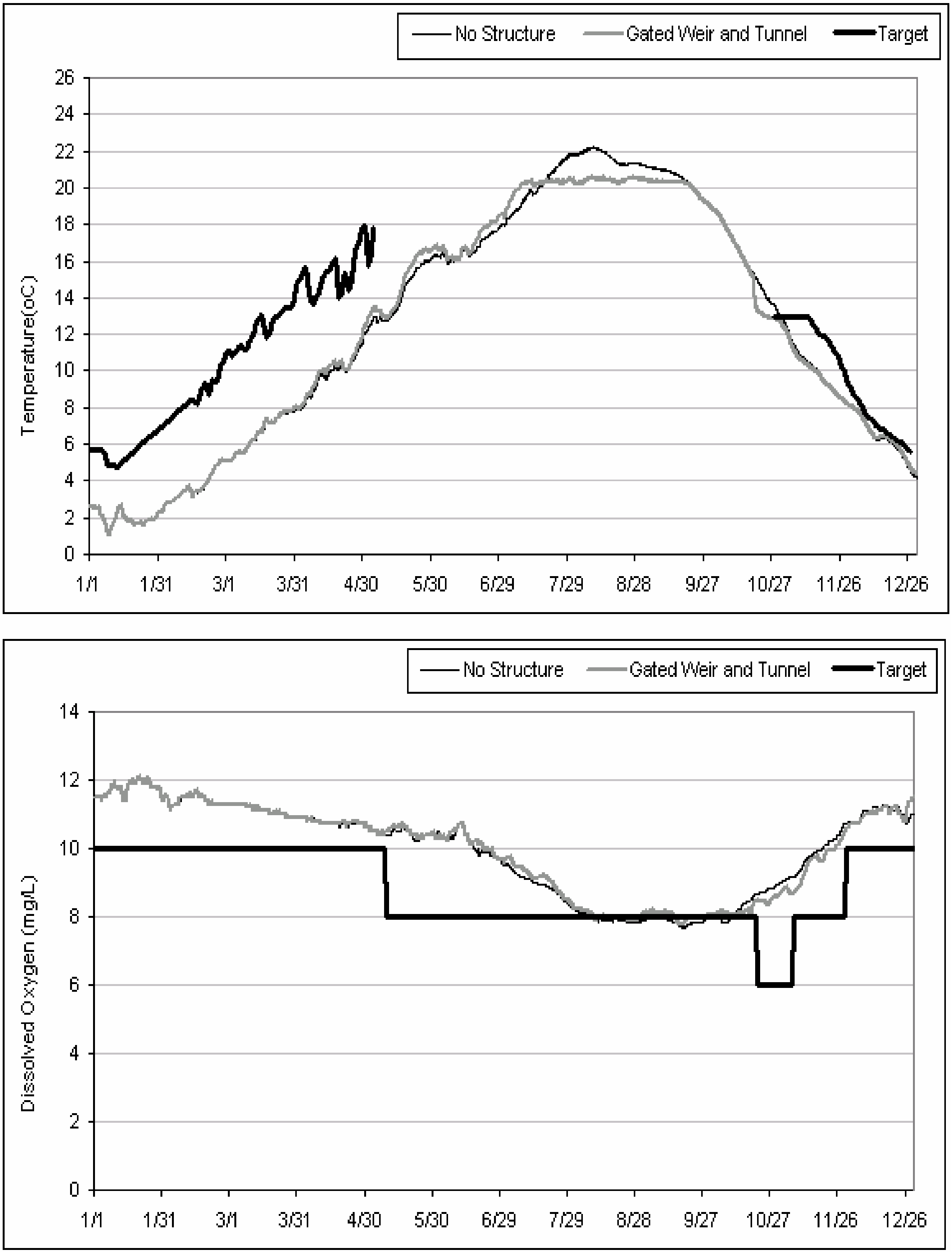
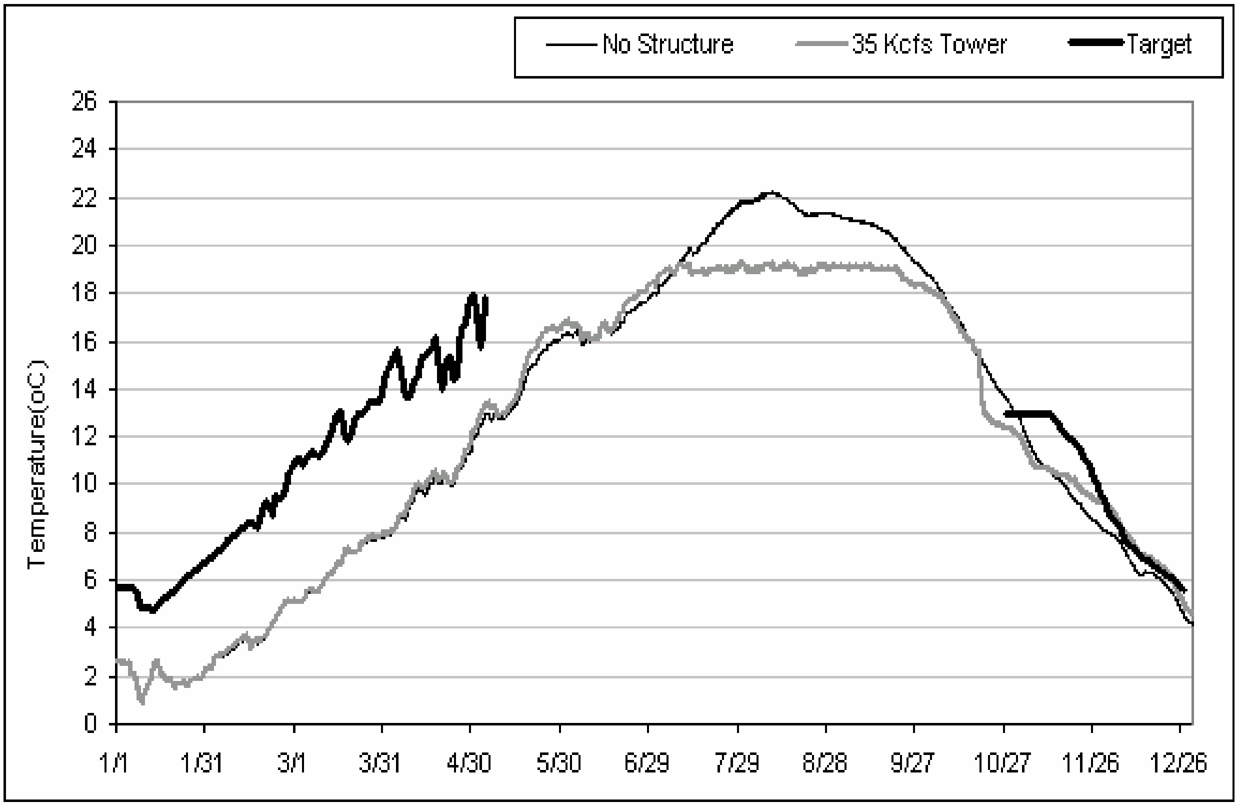


Figure 38. Medium Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the TMDL conditions model setup and proposed reservoir operations.



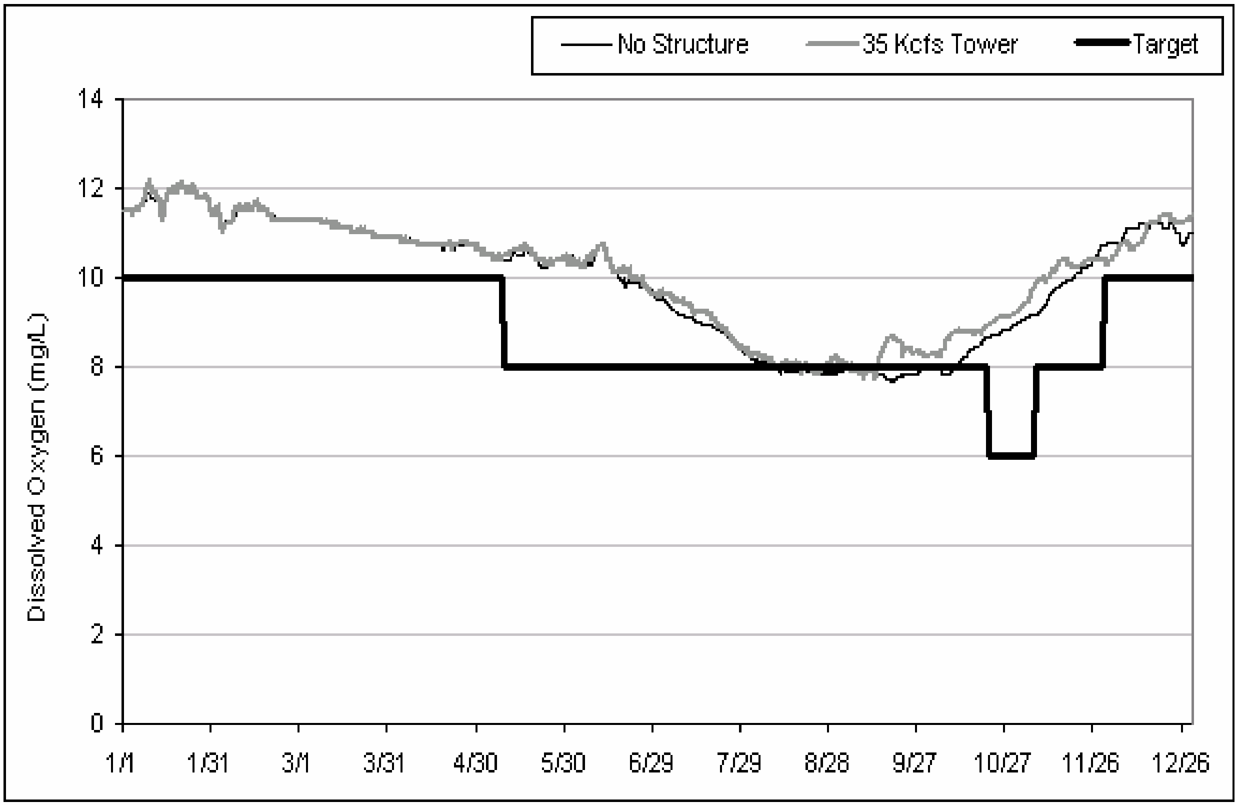


Figure 39. Medium Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the TMDL conditions model setup and proposed reservoir operations.

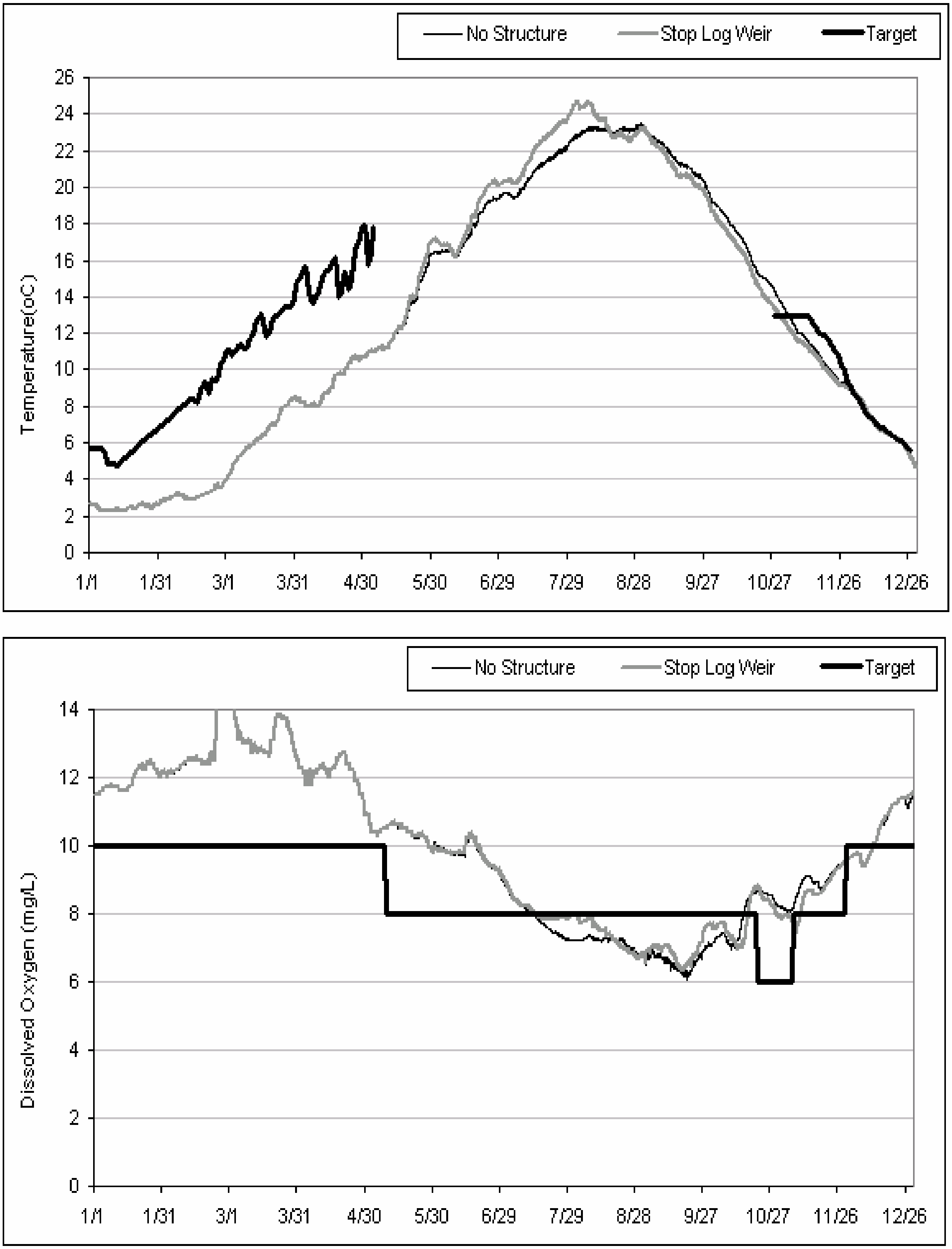
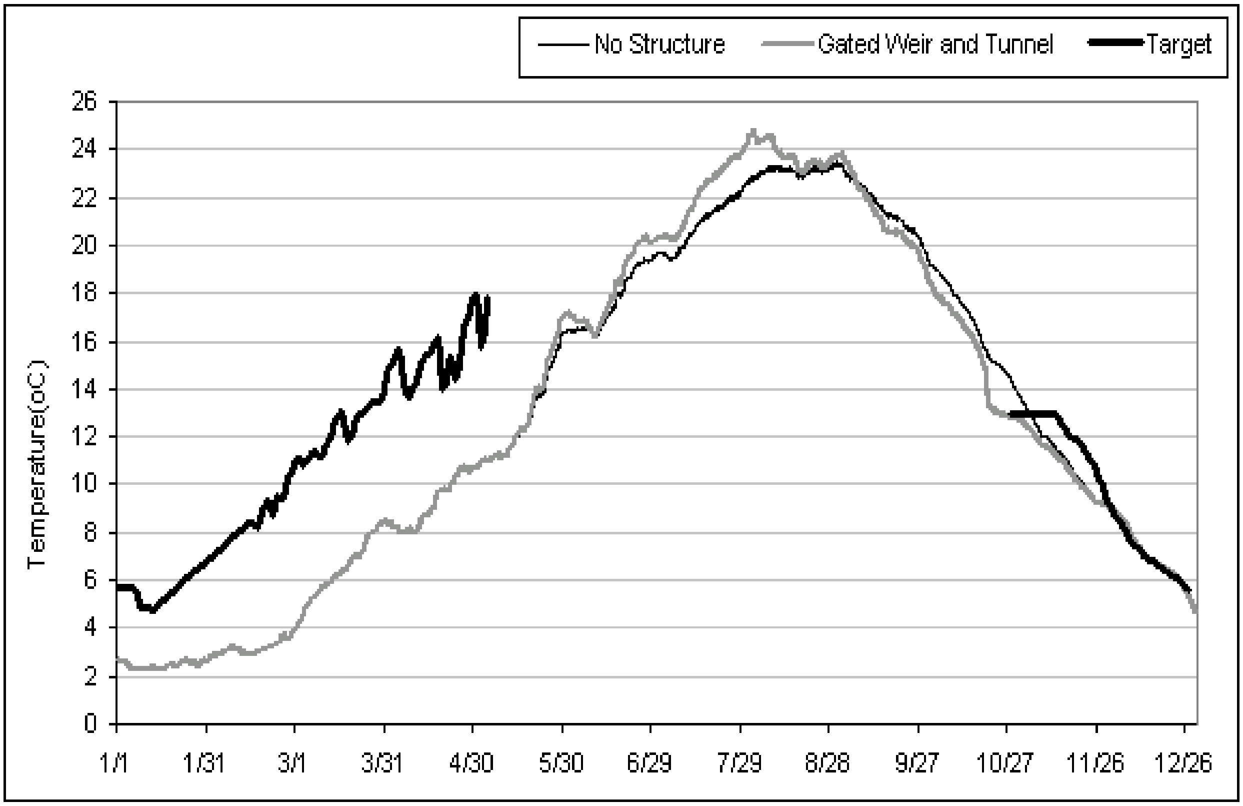


Figure 40. Medium-High Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the TMDL conditions model setup and proposed reservoir operations.



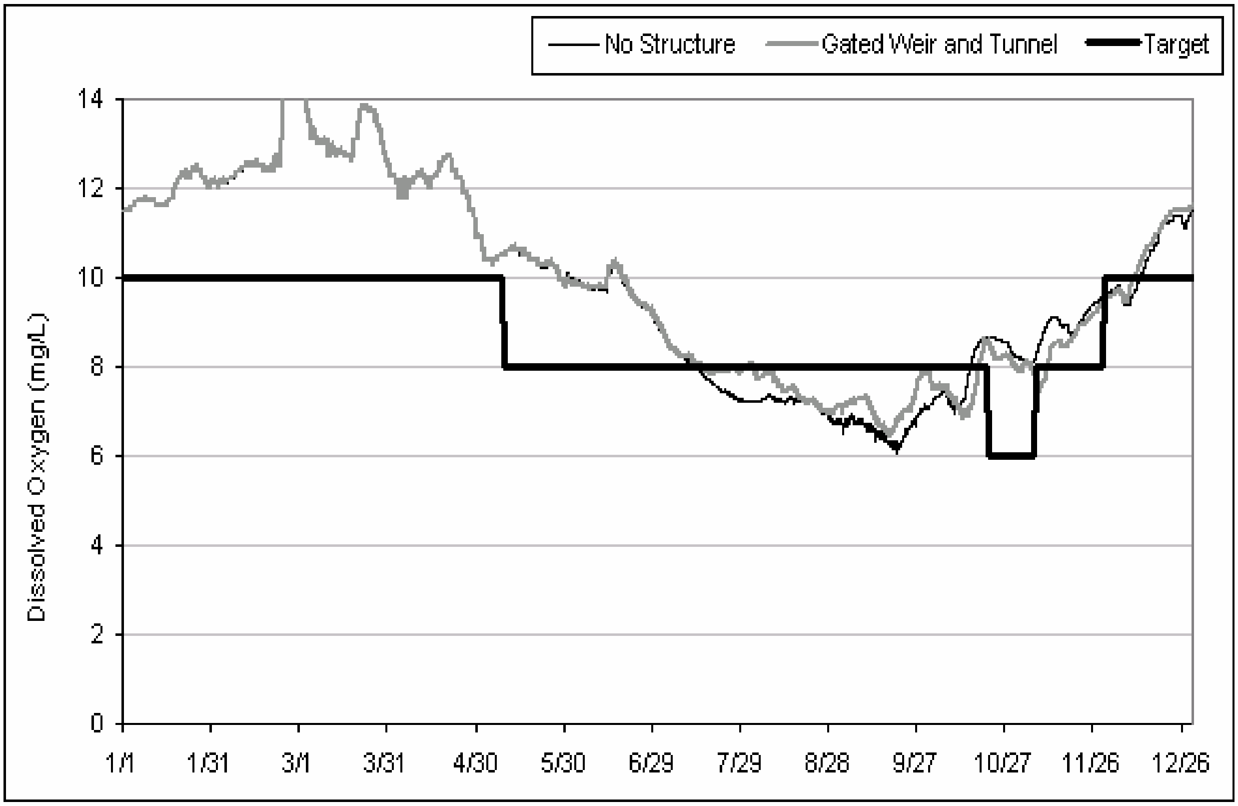
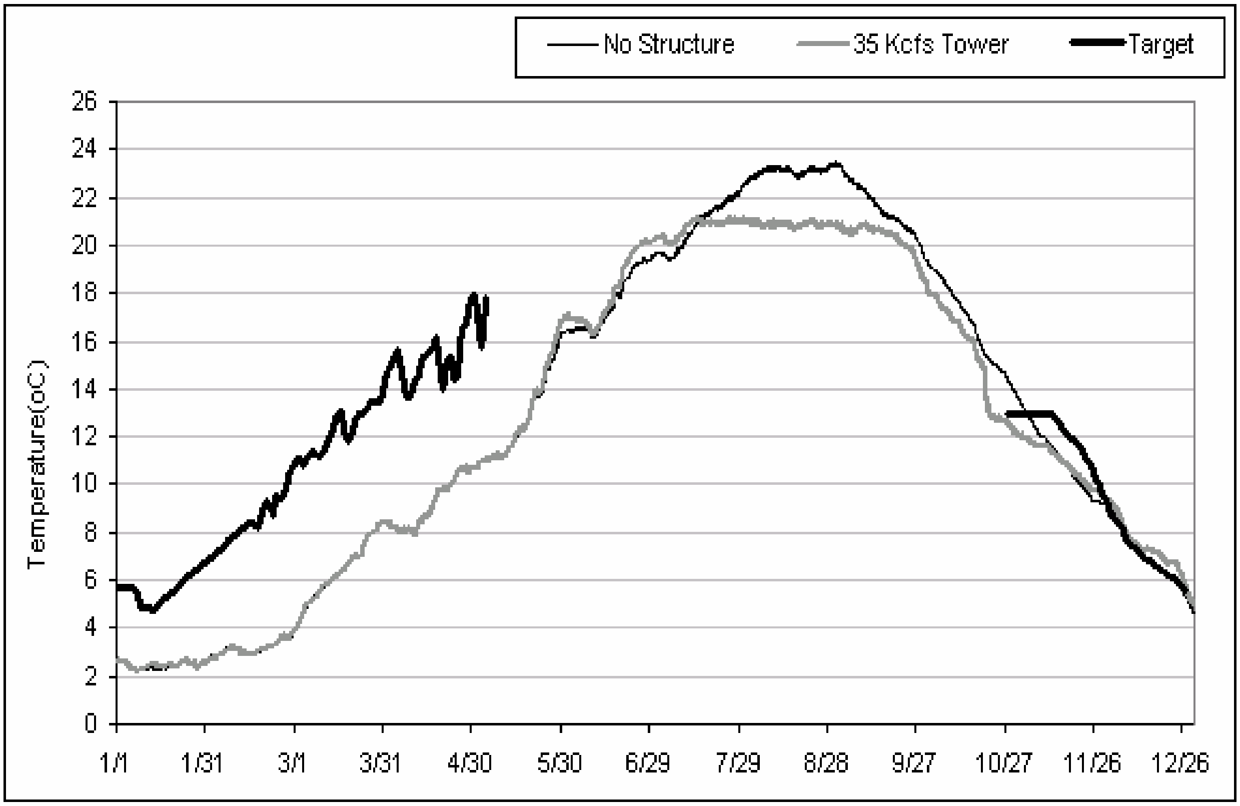


Figure 41. Medium-High Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the TMDL conditions model setup and proposed reservoir operations.



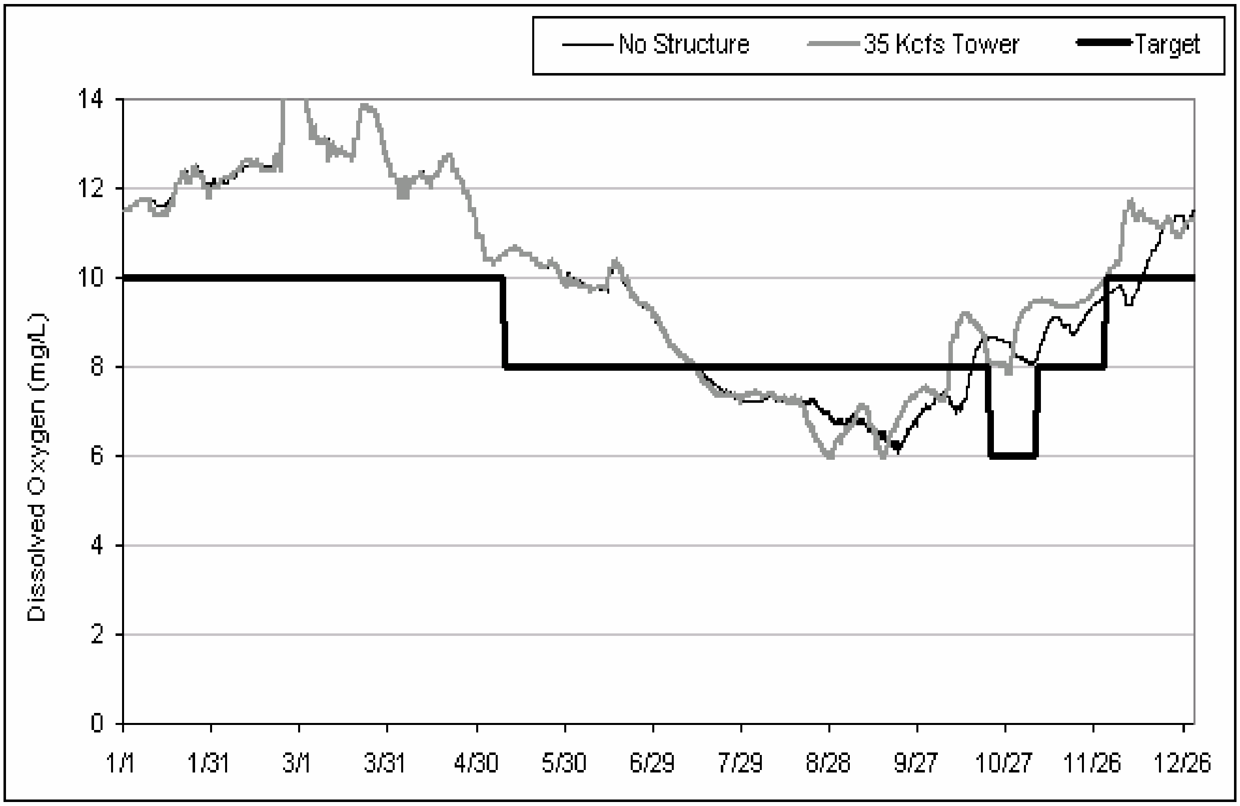
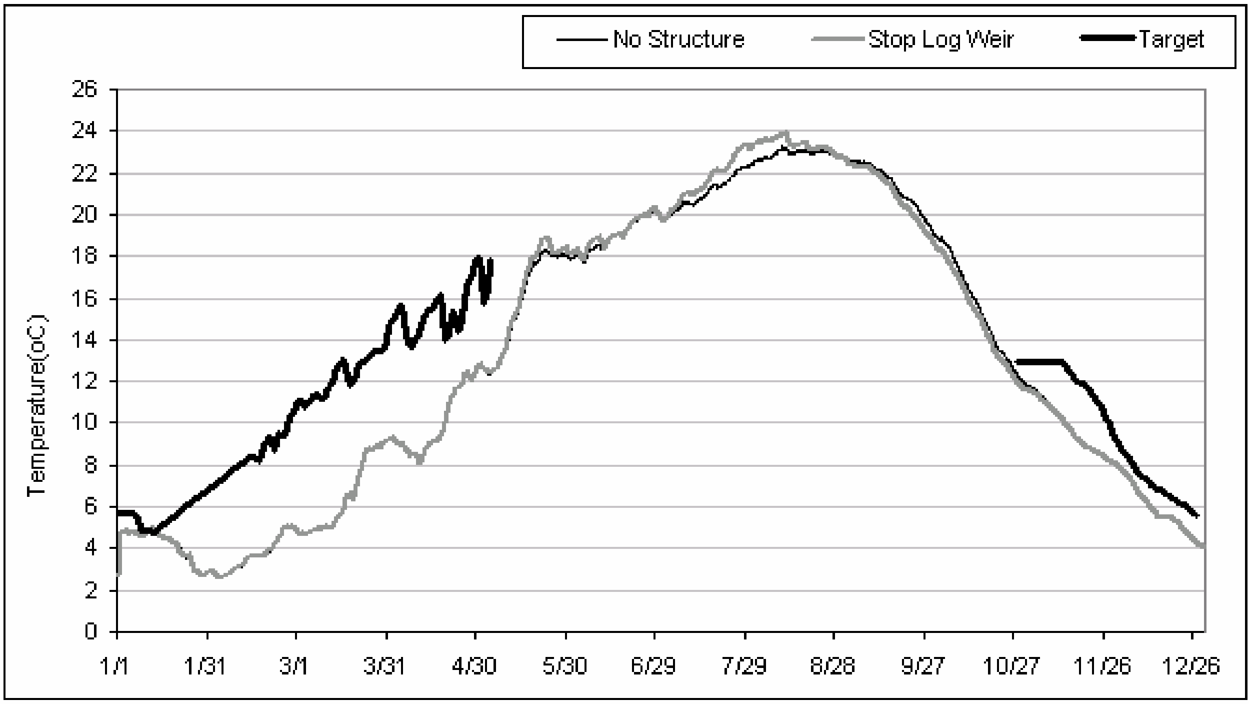


Figure 42. Medium-High Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the TMDL conditions model setup and proposed reservoir operations.



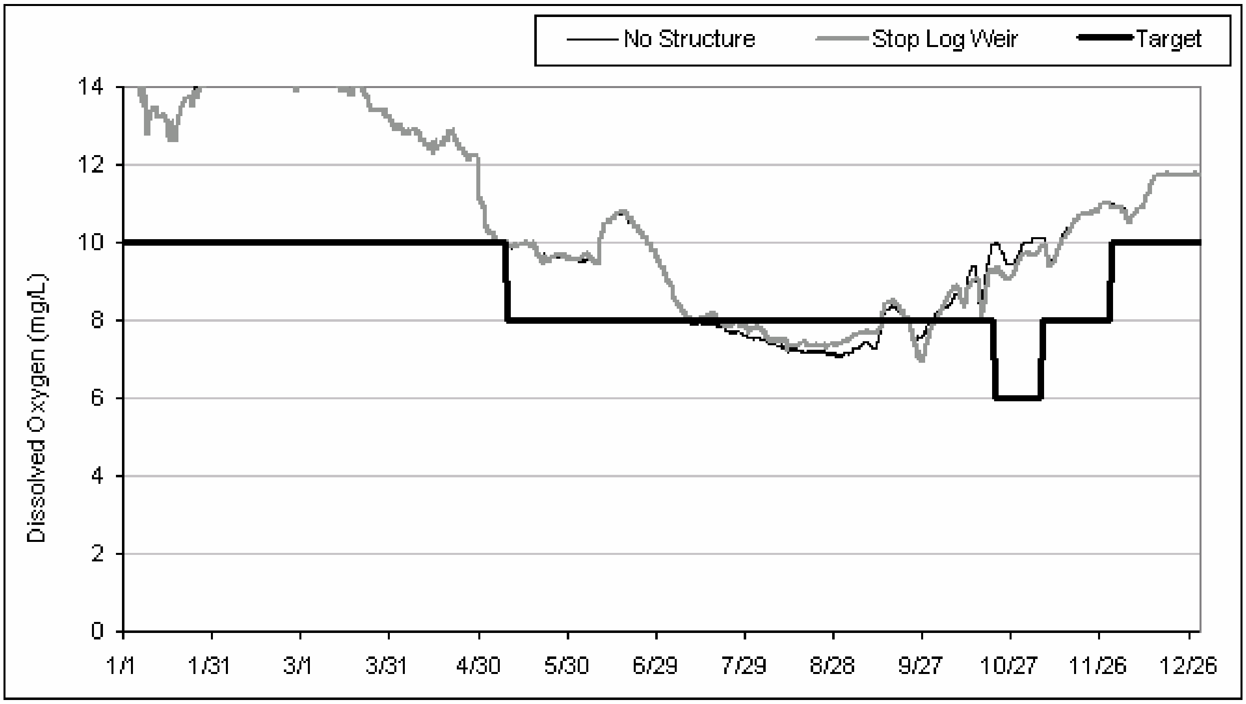


Figure 43. High Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the TMDL conditions model setup and proposed reservoir operations.

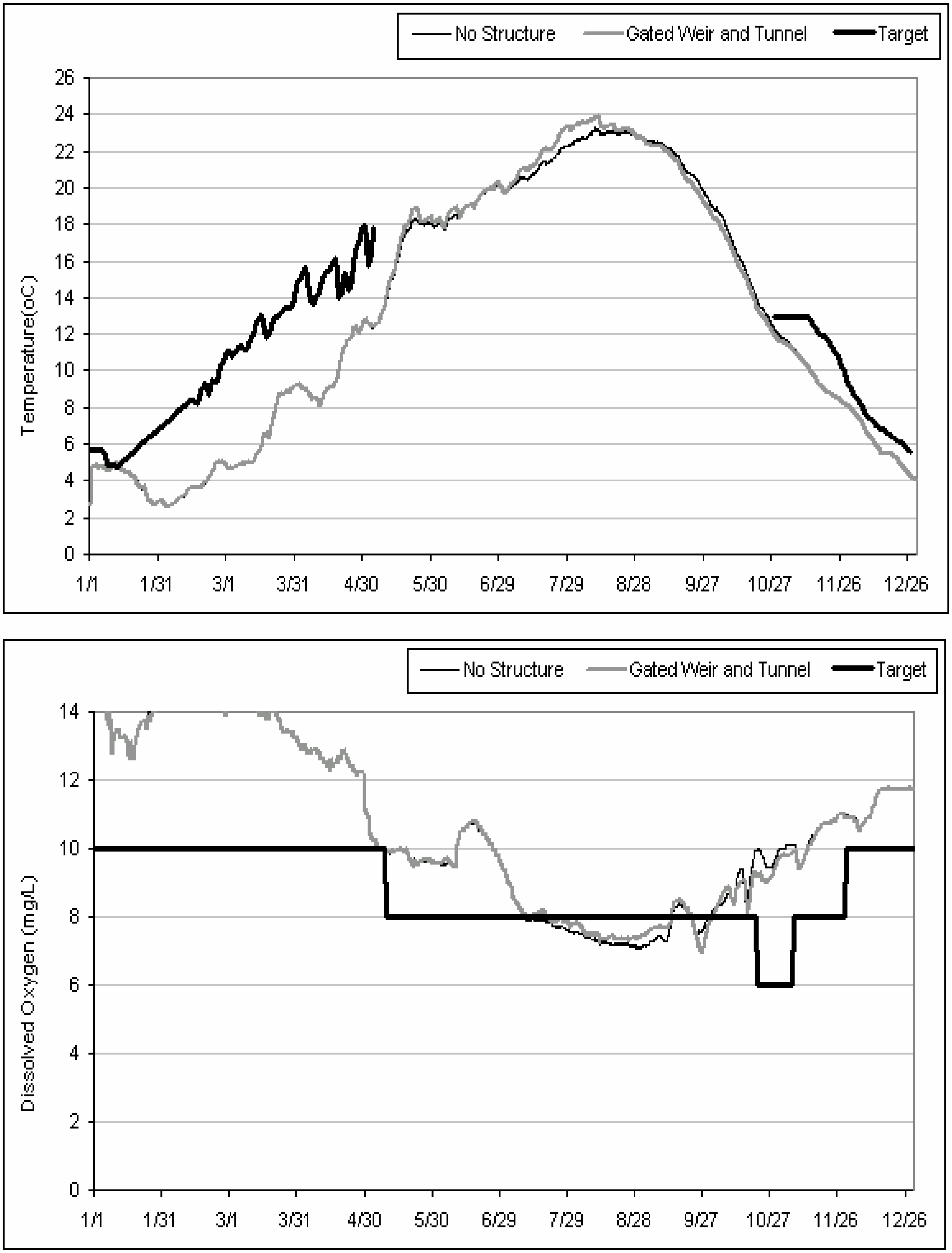


Figure 44. High Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the TMDL conditions model setup and proposed reservoir operations.

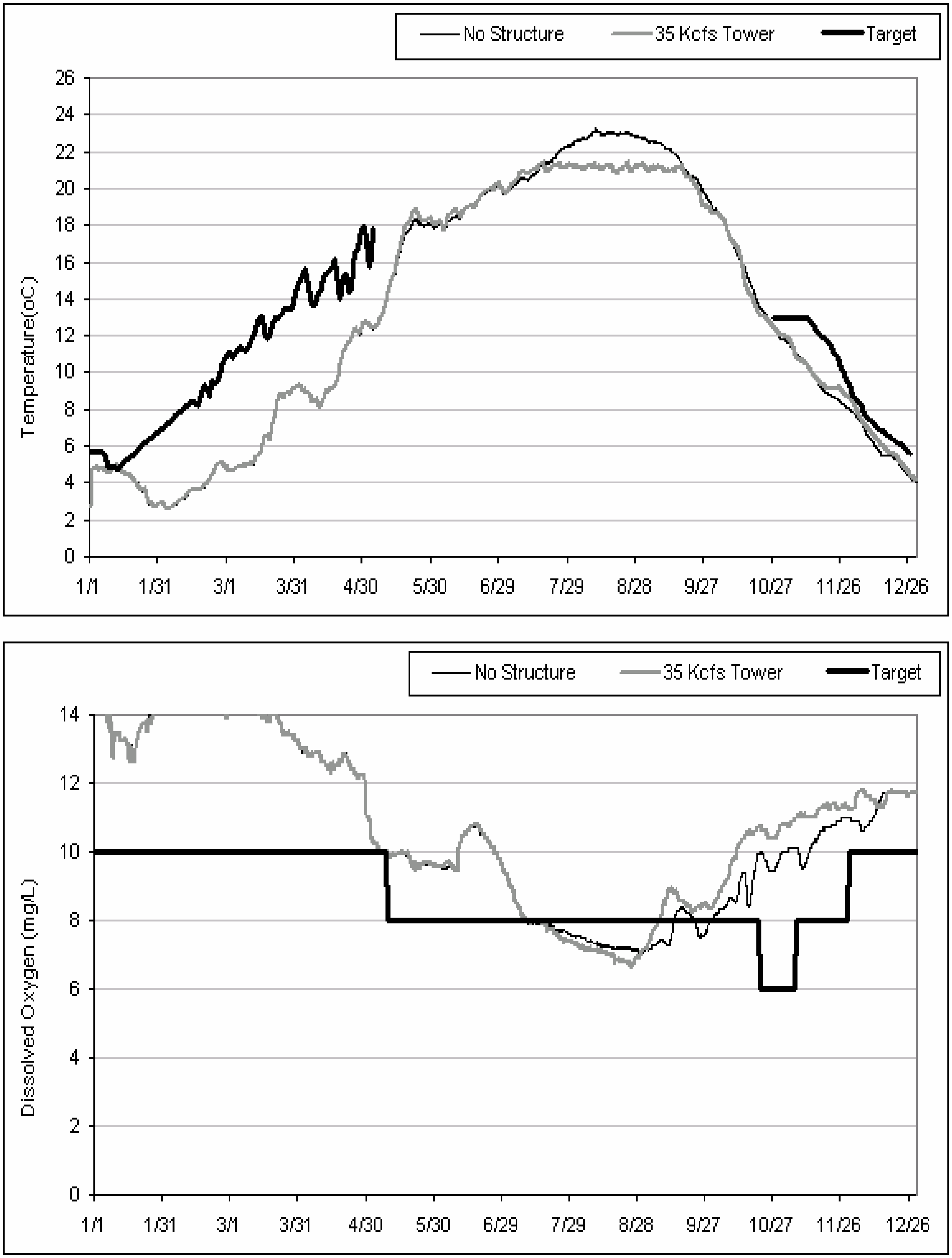
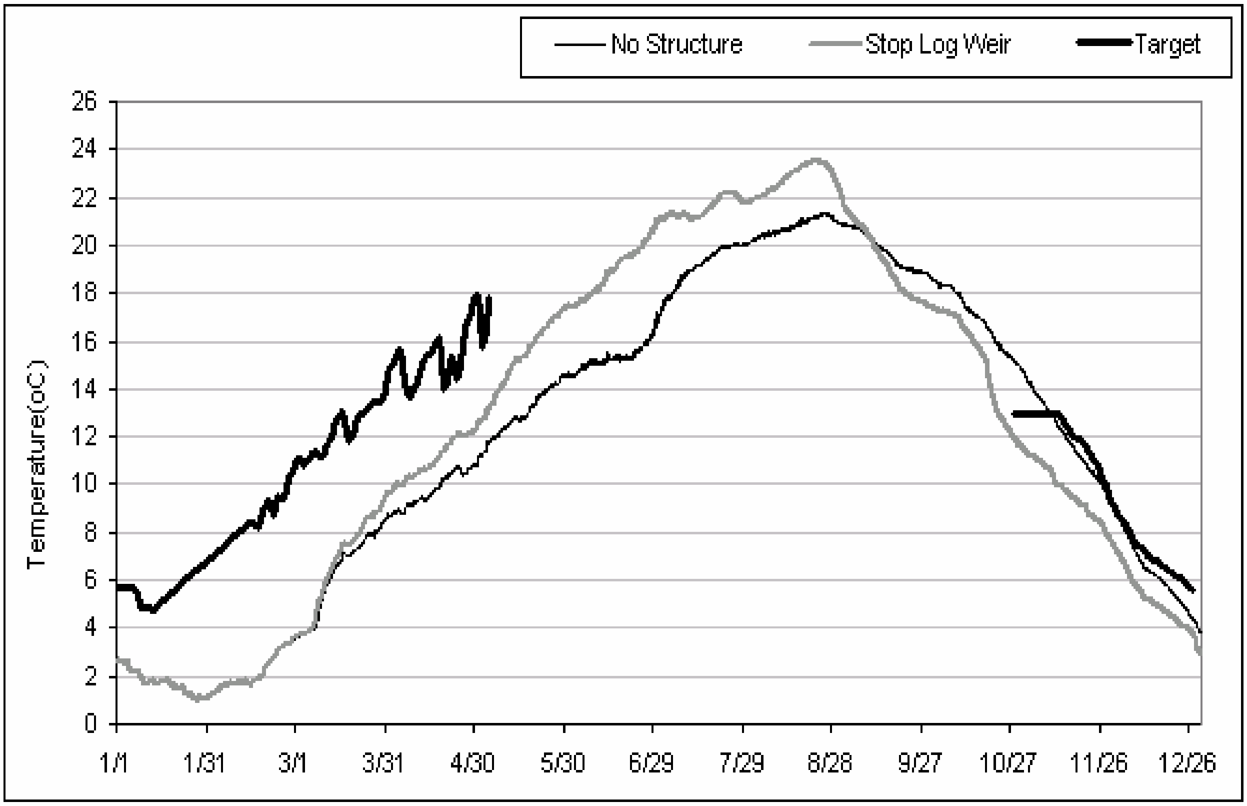


Figure 45. High Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the TMDL conditions model setup and proposed reservoir operations.



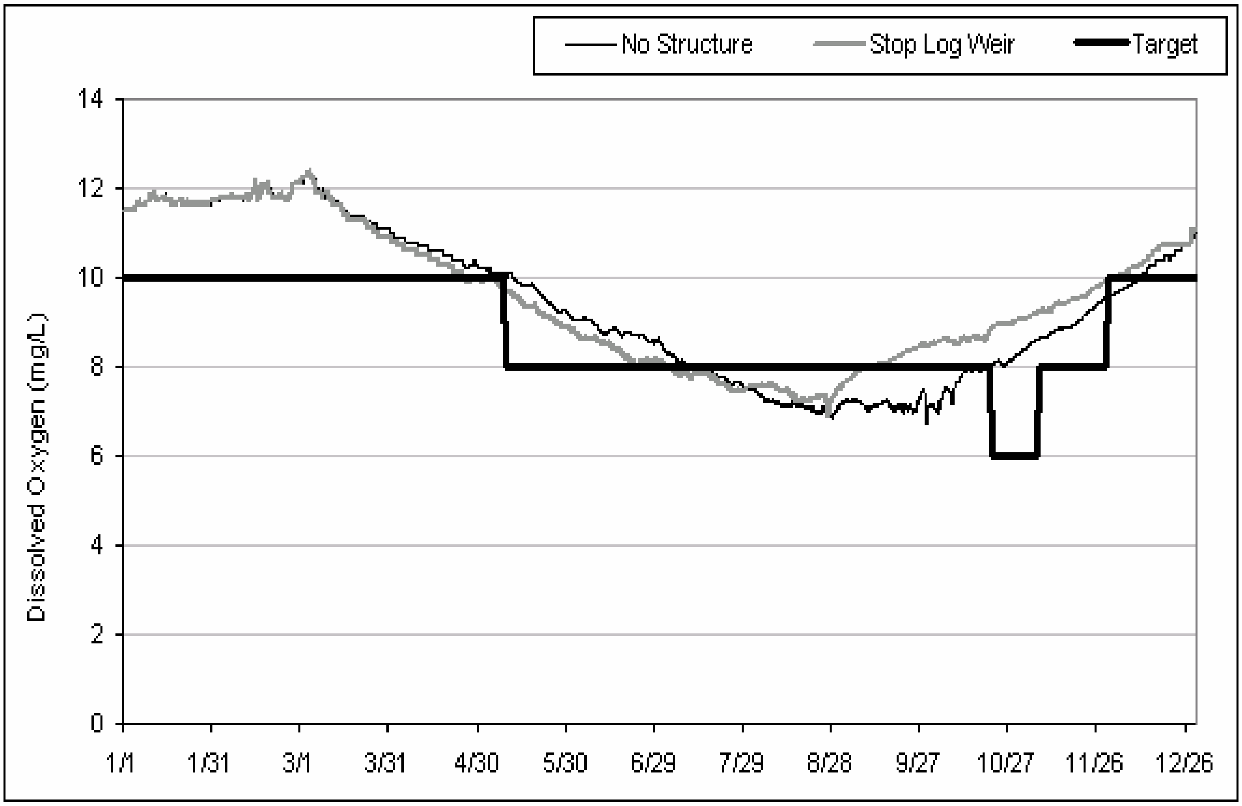
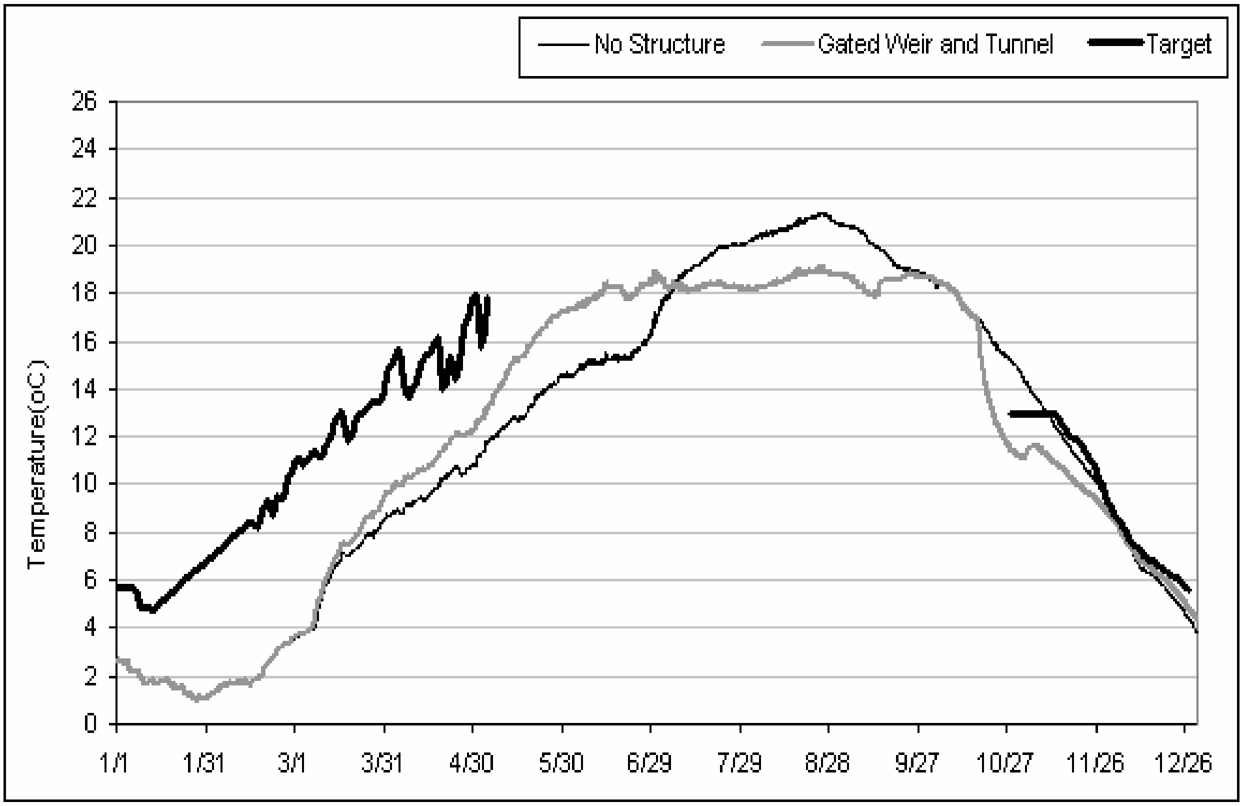


Figure 46. Low Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the TMDL conditions model setup and OP-2 reservoir operations.



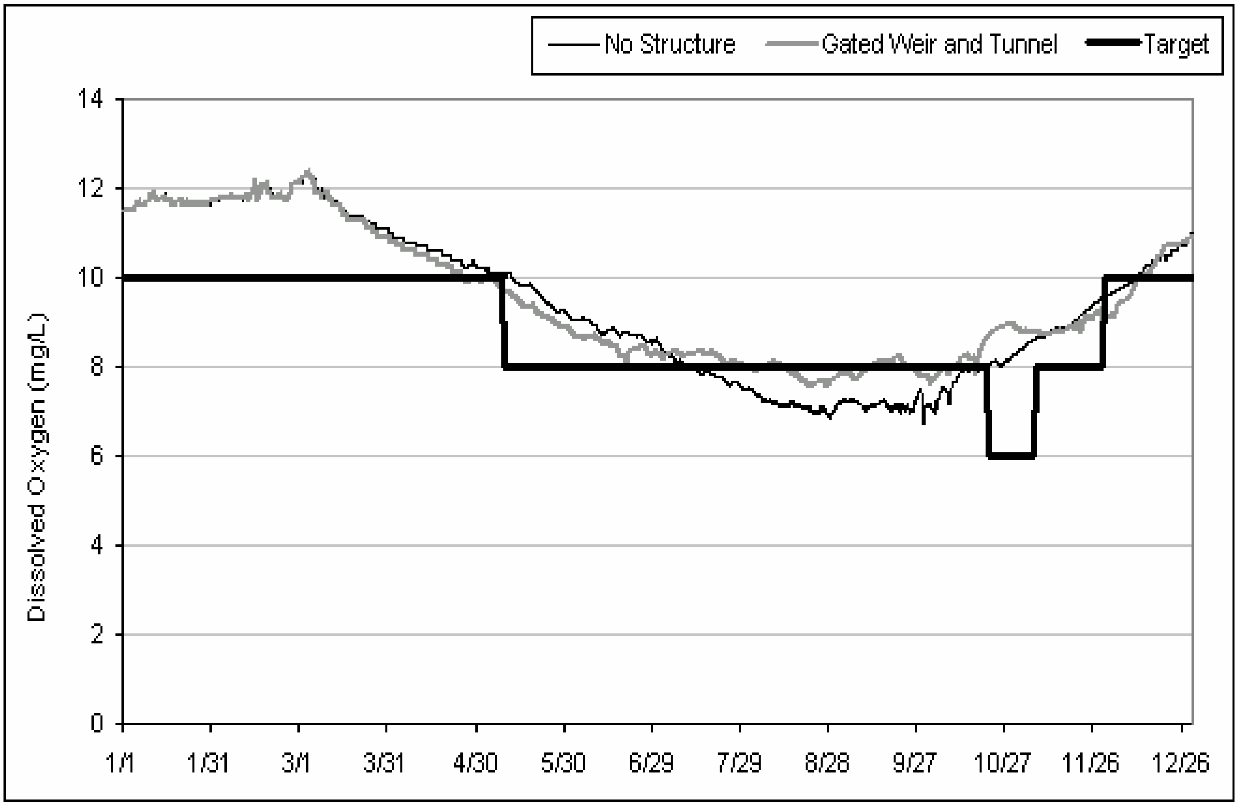
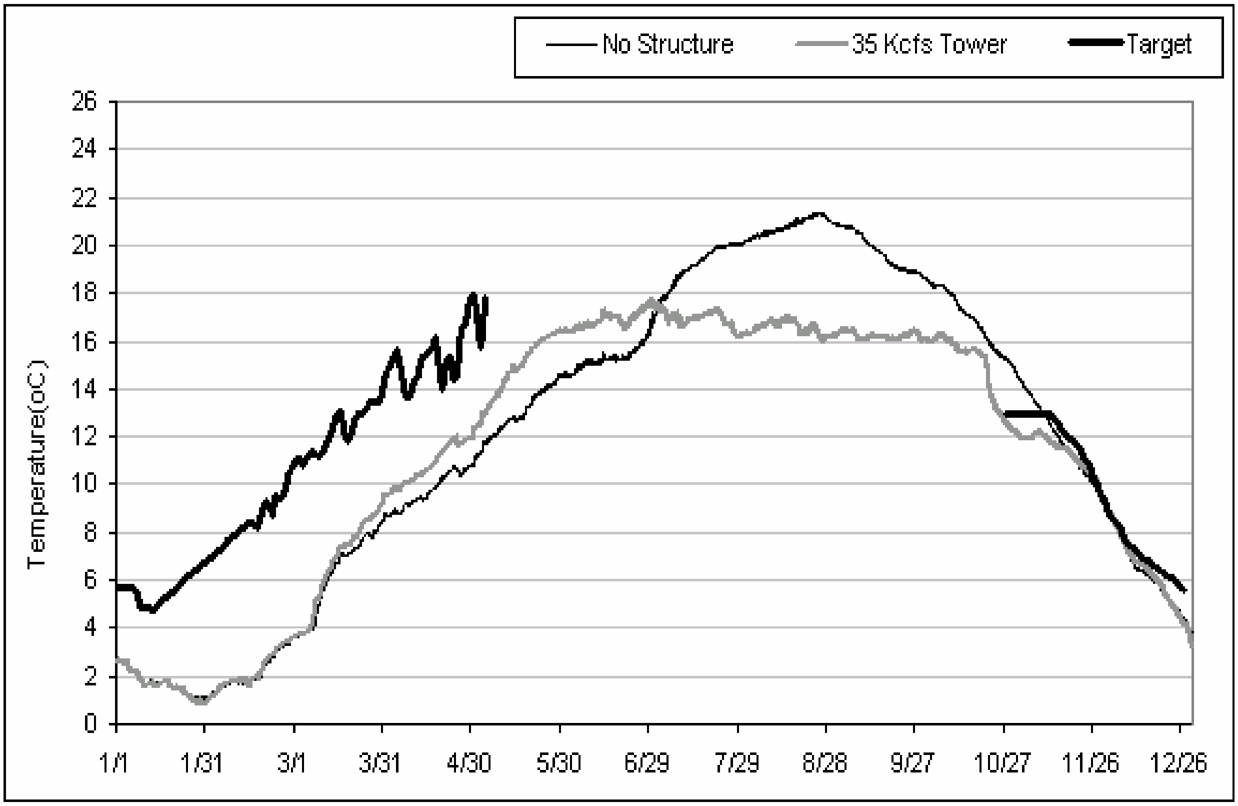


Figure 47. Low Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the TMDL conditions model setup and OP-2 reservoir operations.



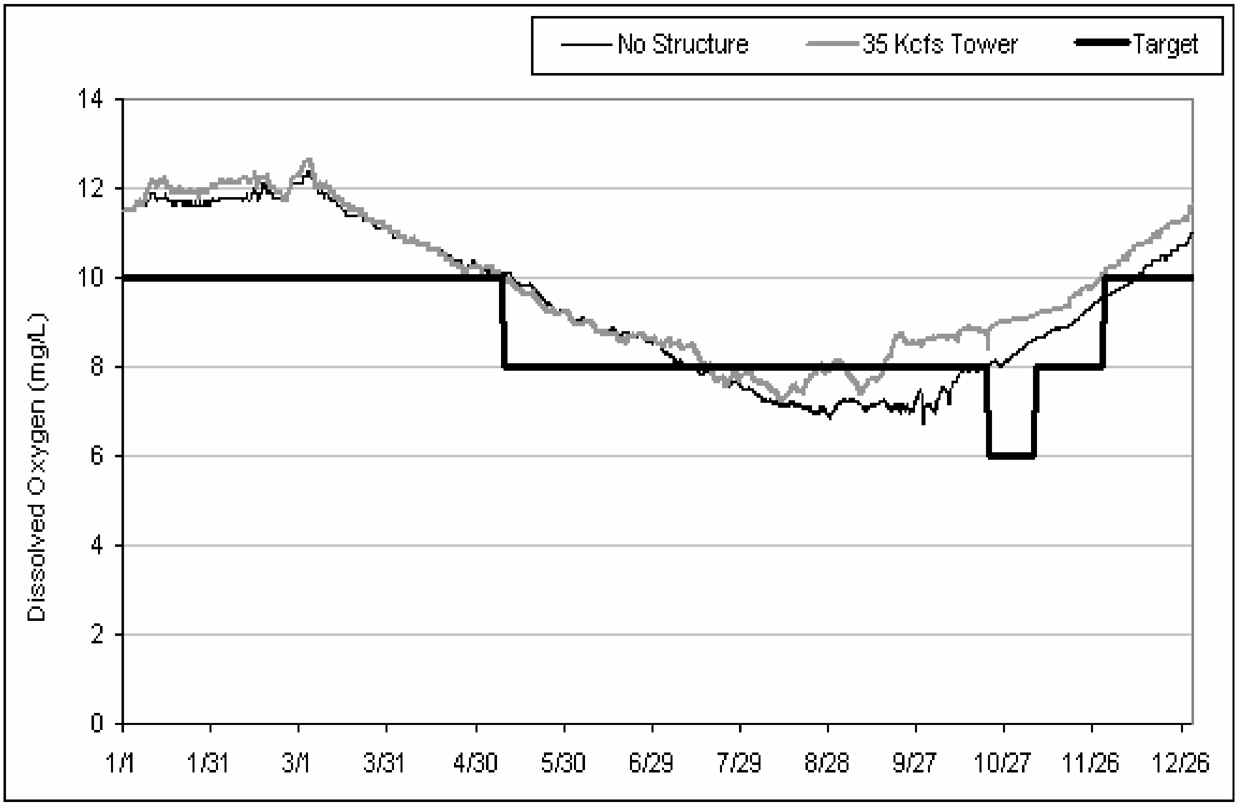
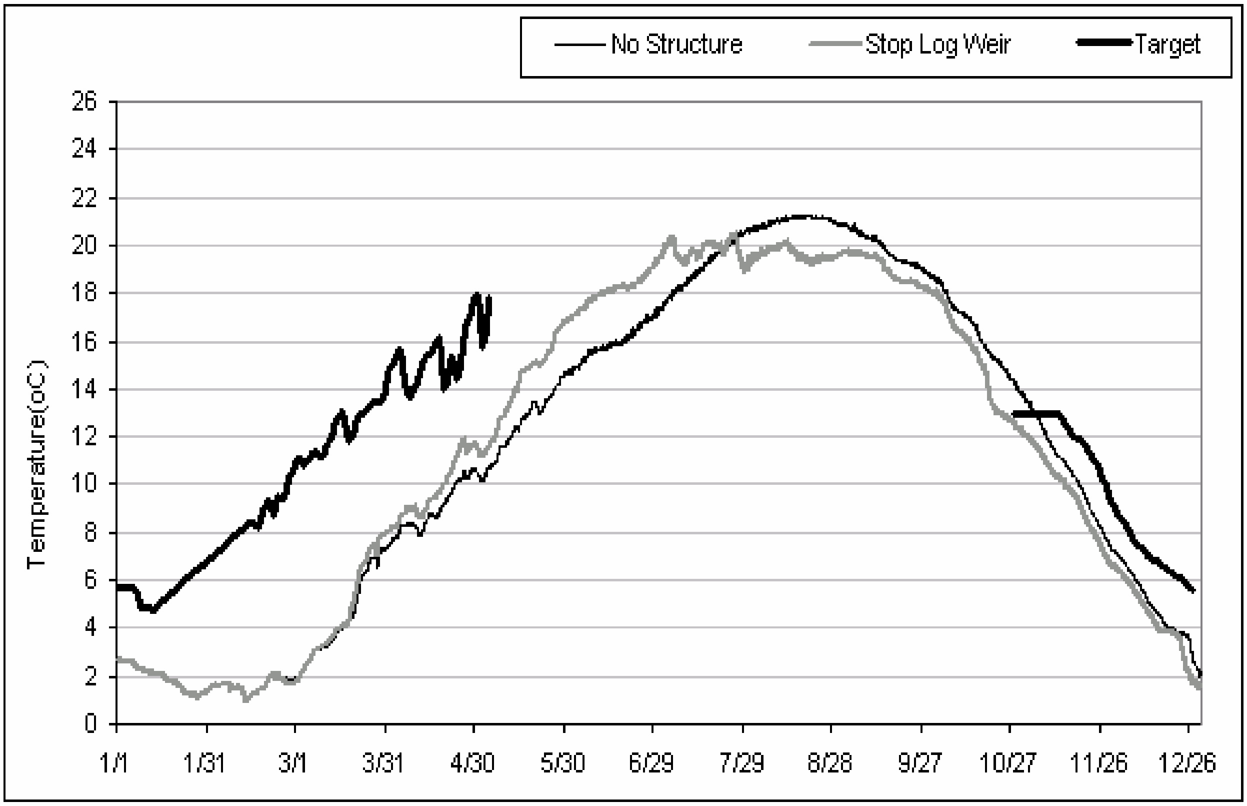


Figure 48. Low Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the TMDL conditions model setup and OP-2 reservoir operations.



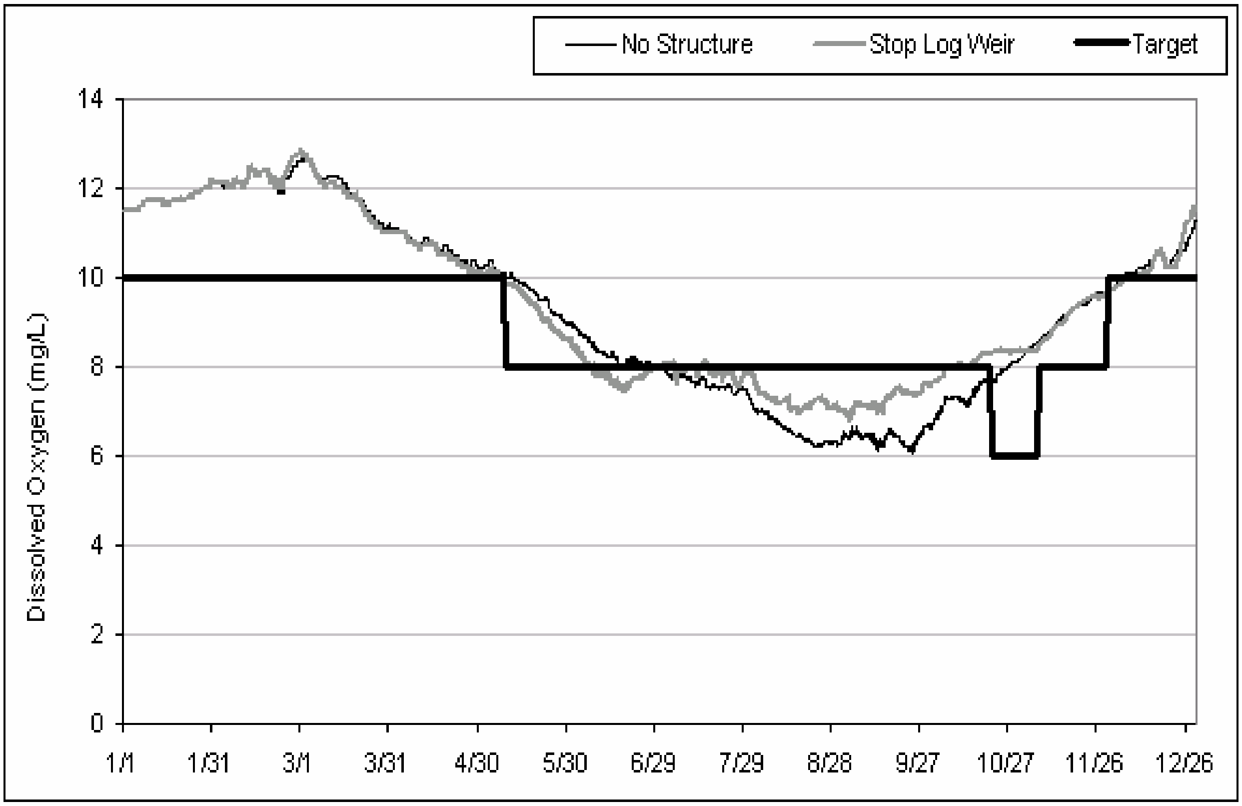
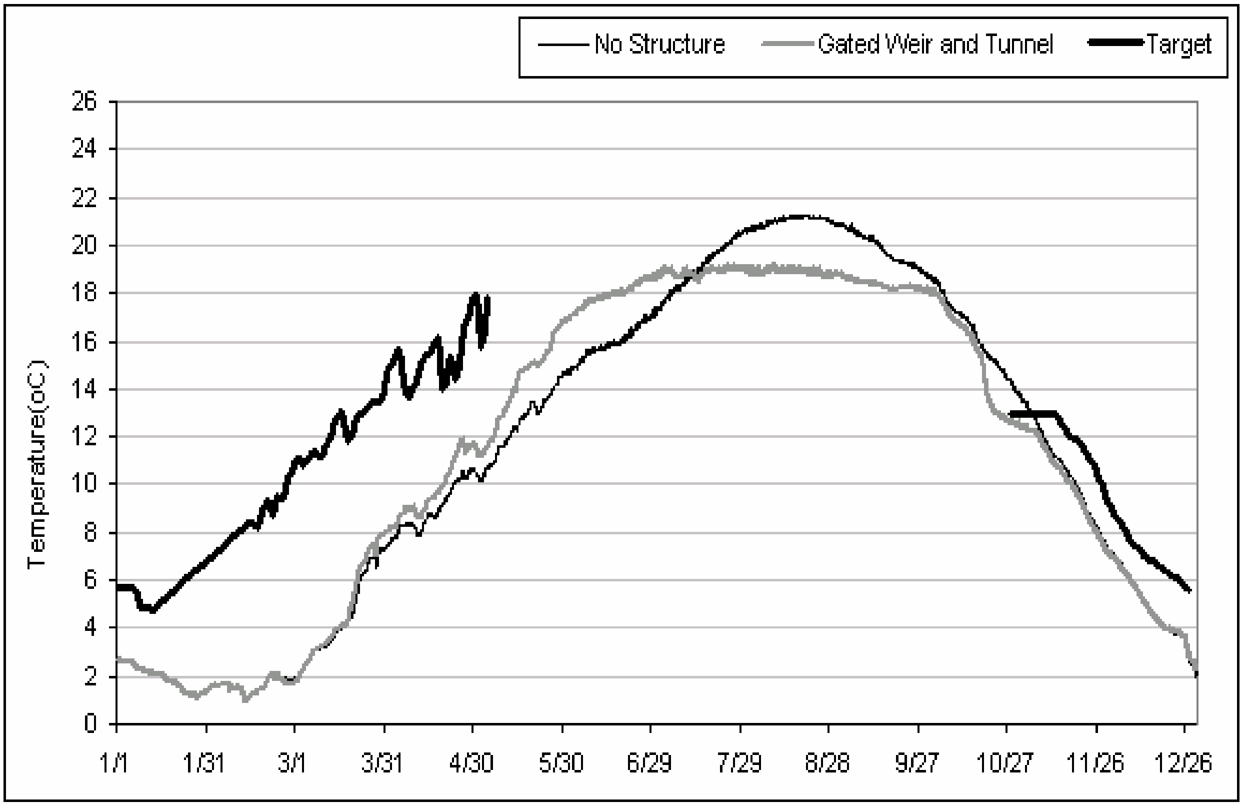


Figure 49. Medium-Low Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the TMDL conditions model setup and OP-2 reservoir operations.



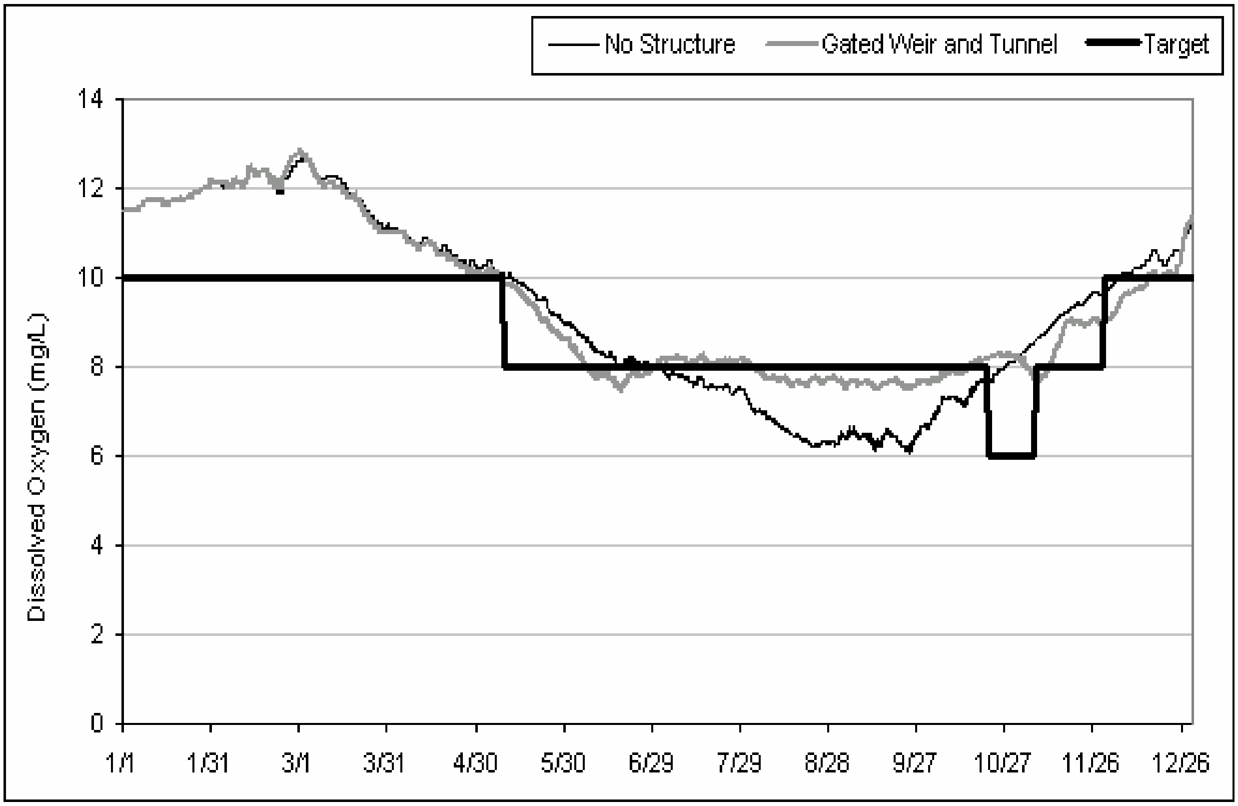
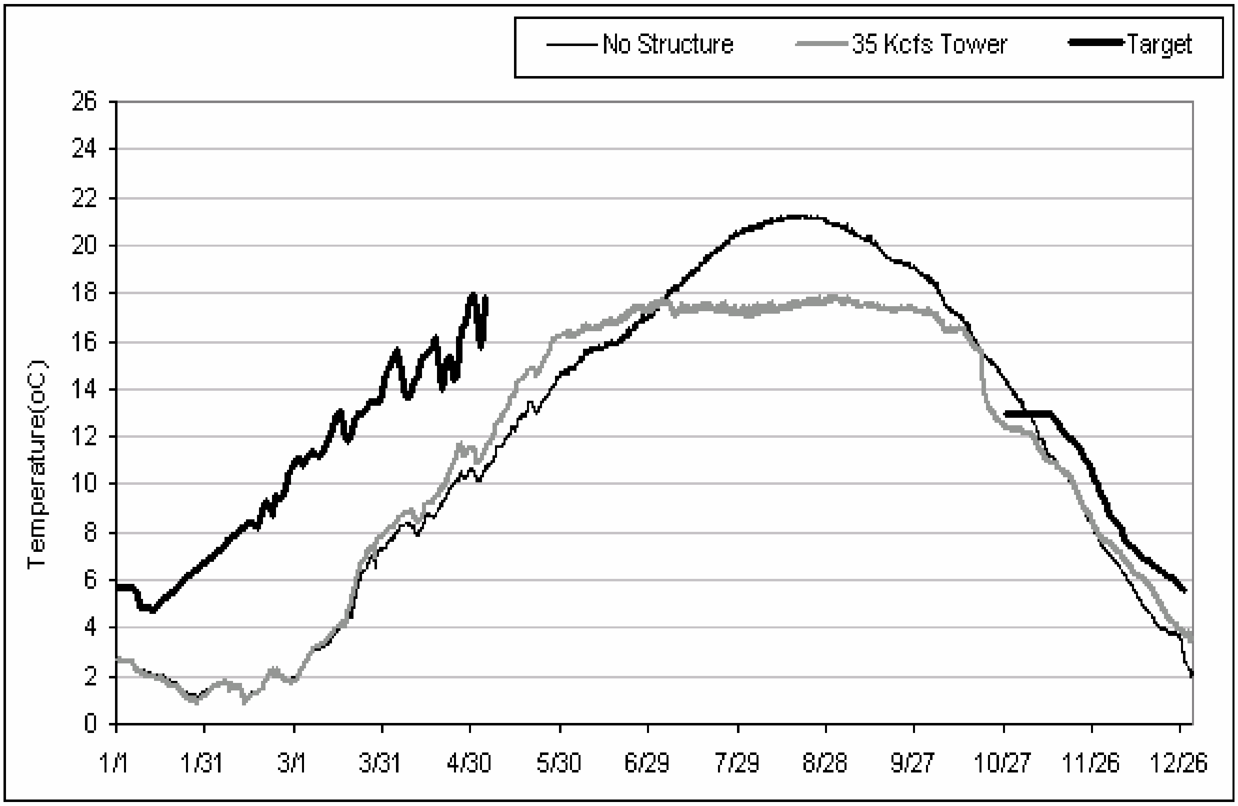


Figure 50. Medium-Low Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the TMDL conditions model setup and OP-2 reservoir operations.



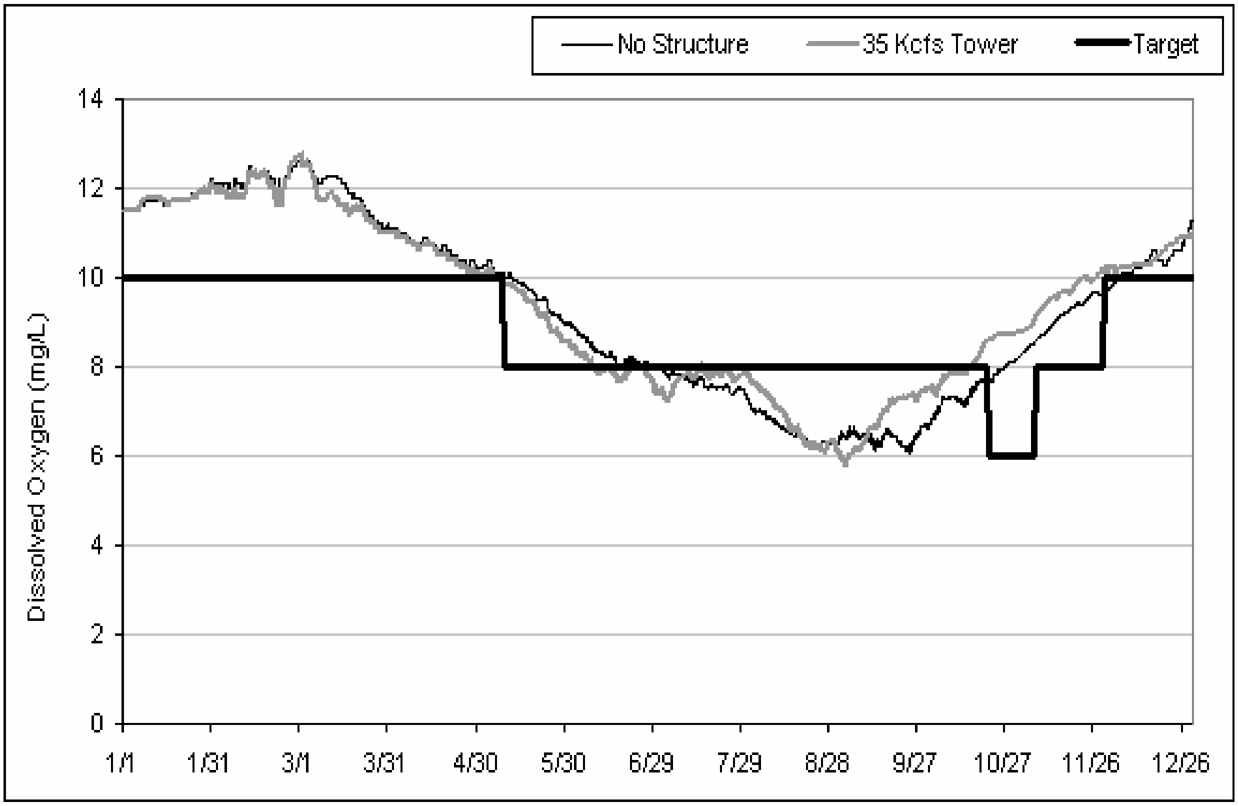
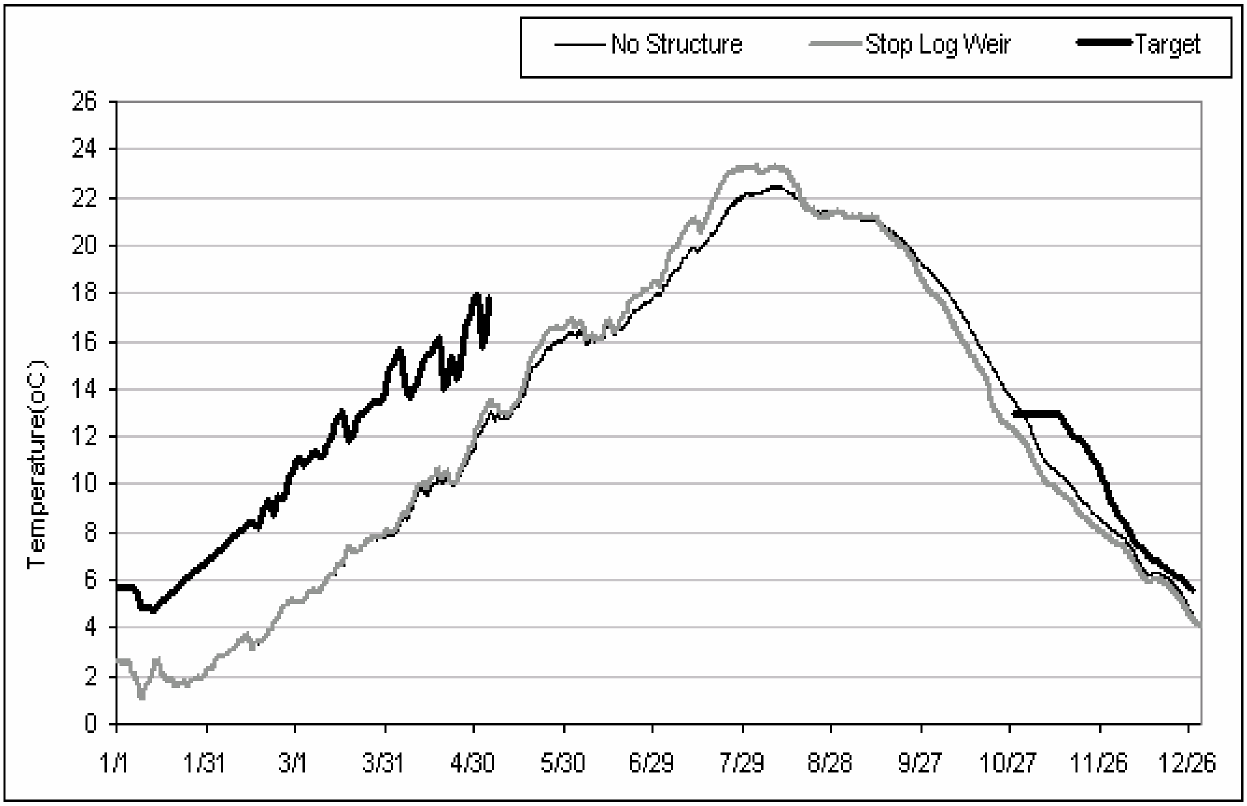


Figure 51. Medium-Low Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the TMDL conditions model setup and OP-2 reservoir operations.



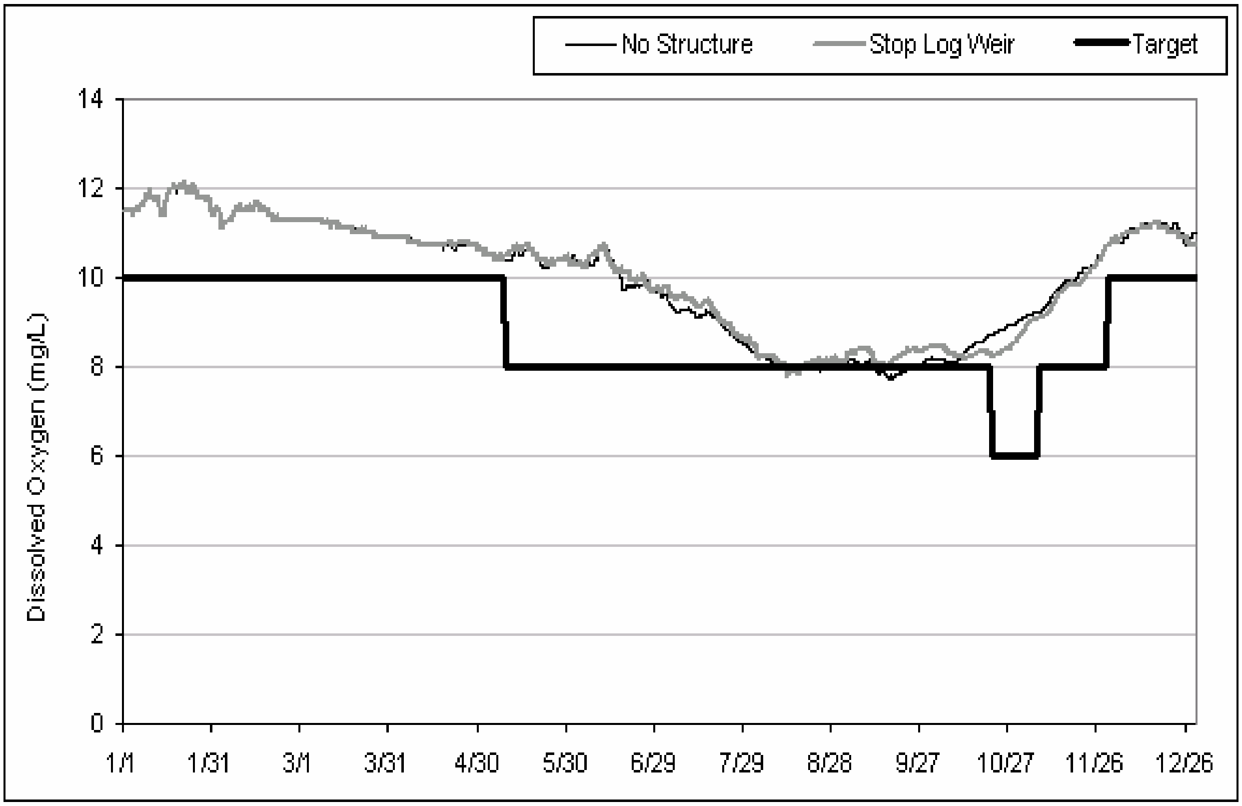
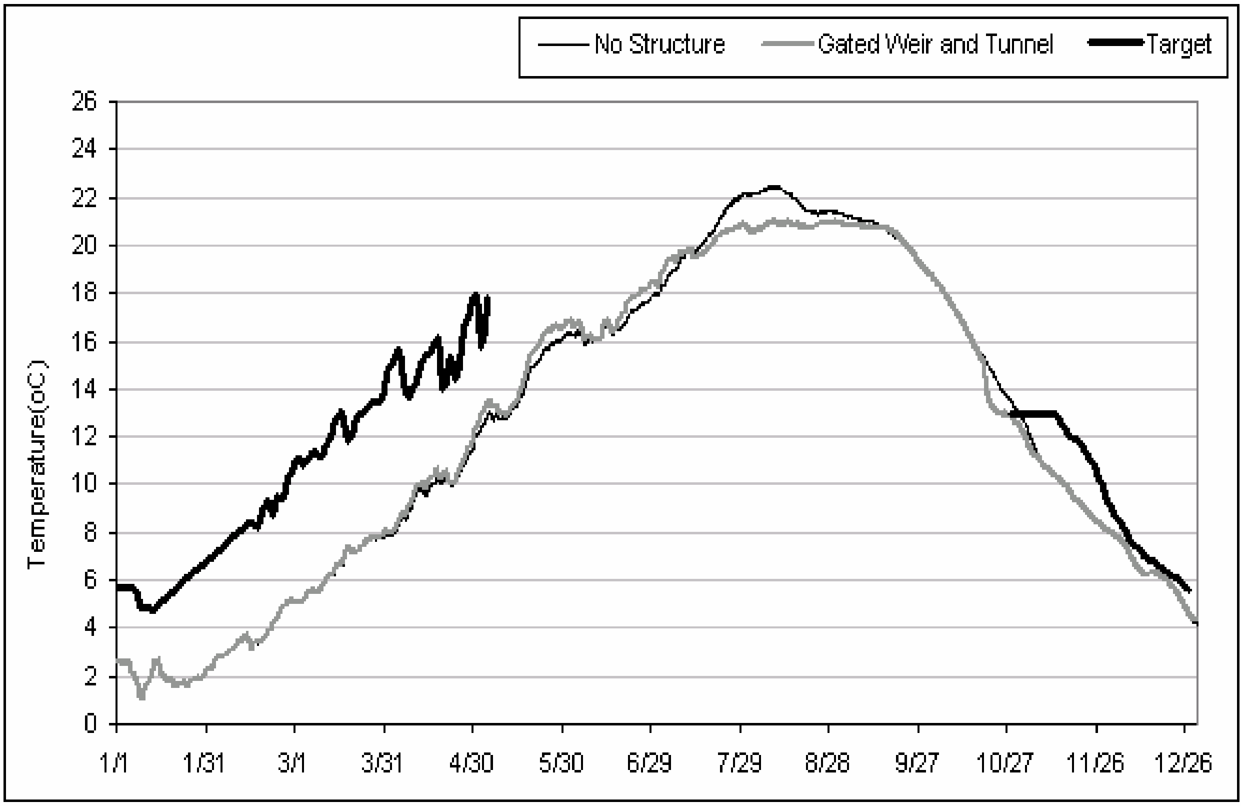


Figure 52. Medium Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the TMDL conditions model setup and OP-2 reservoir operations.



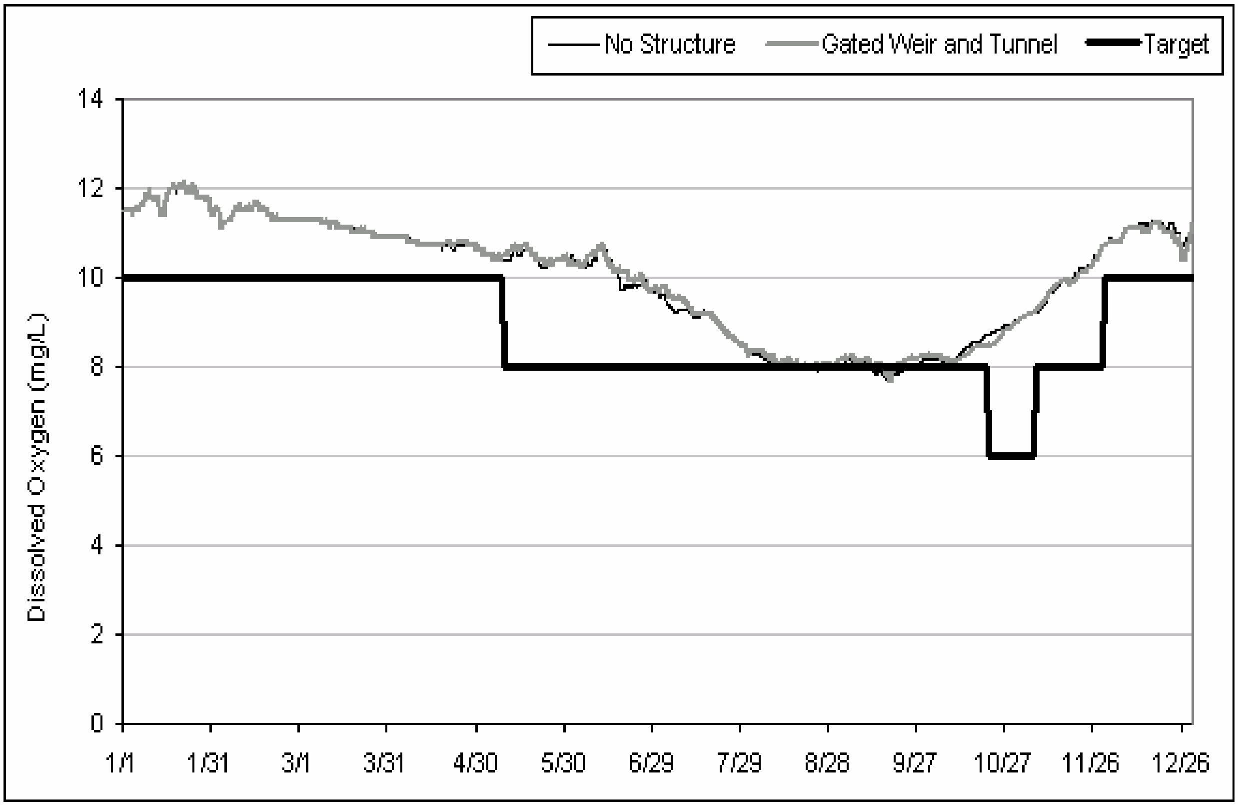


Figure 53. Medium Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the TMDL conditions model setup and OP-2 reservoir operations.

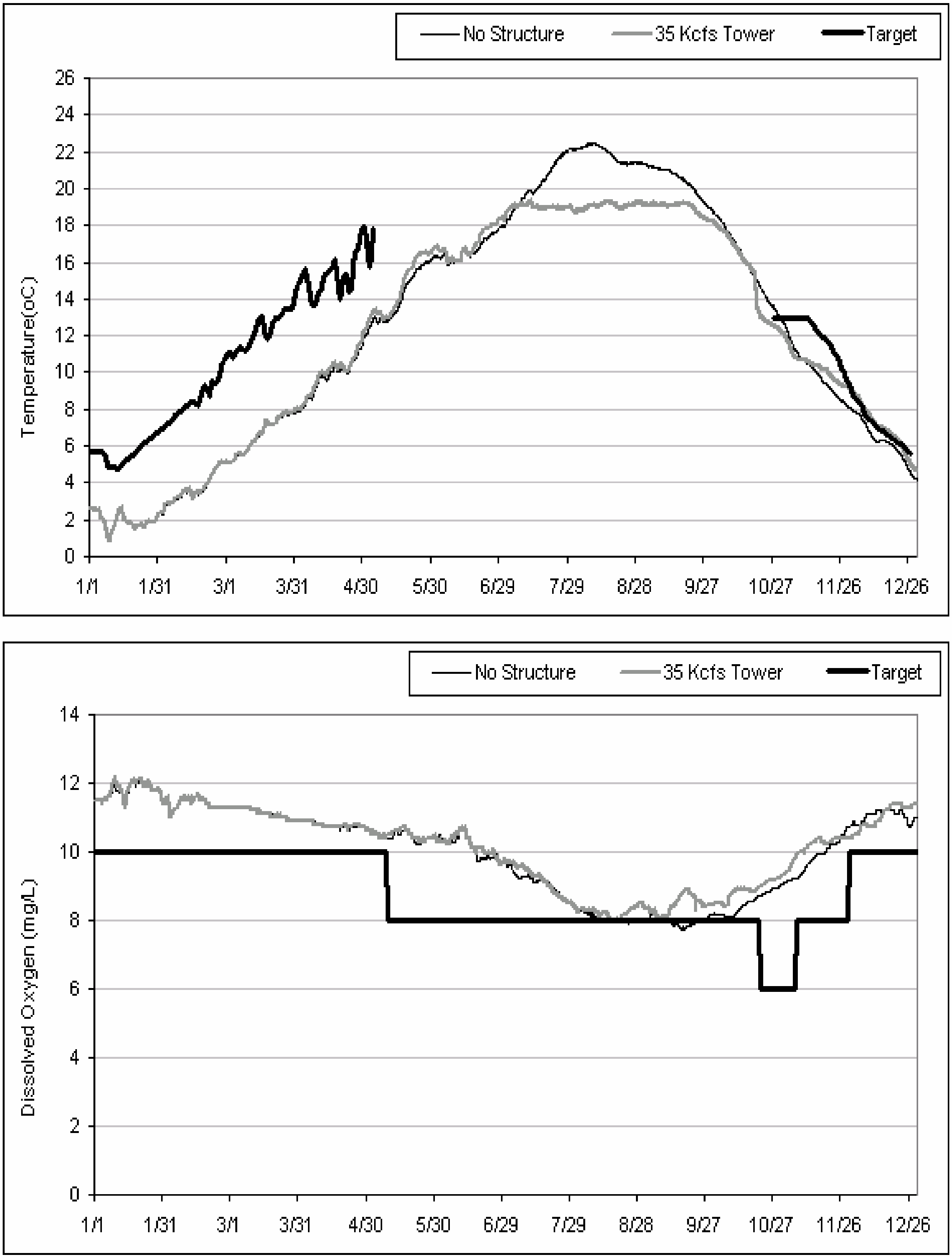
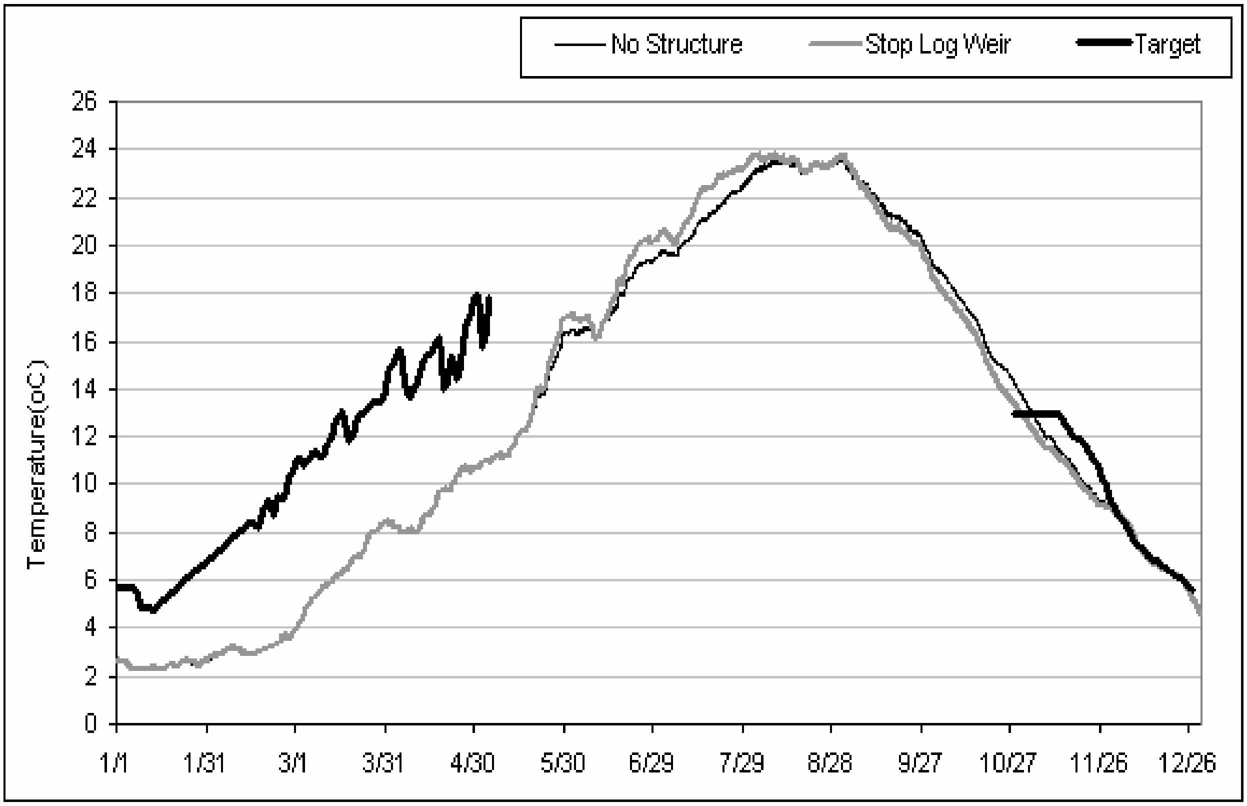


Figure 54. Medium Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the TMDL conditions model setup and OP-2 reservoir operations.



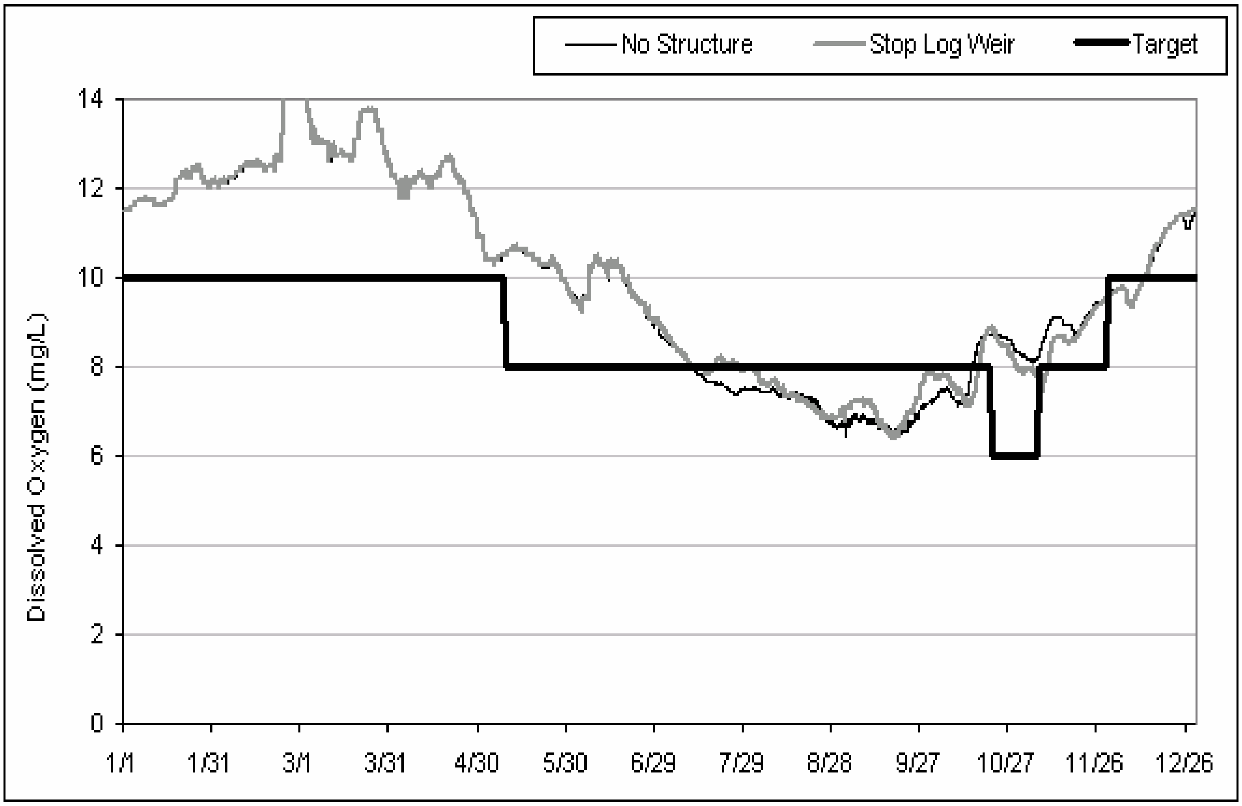


Figure 55. Medium-High Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the TMDL conditions model setup and OP-2 reservoir operations.

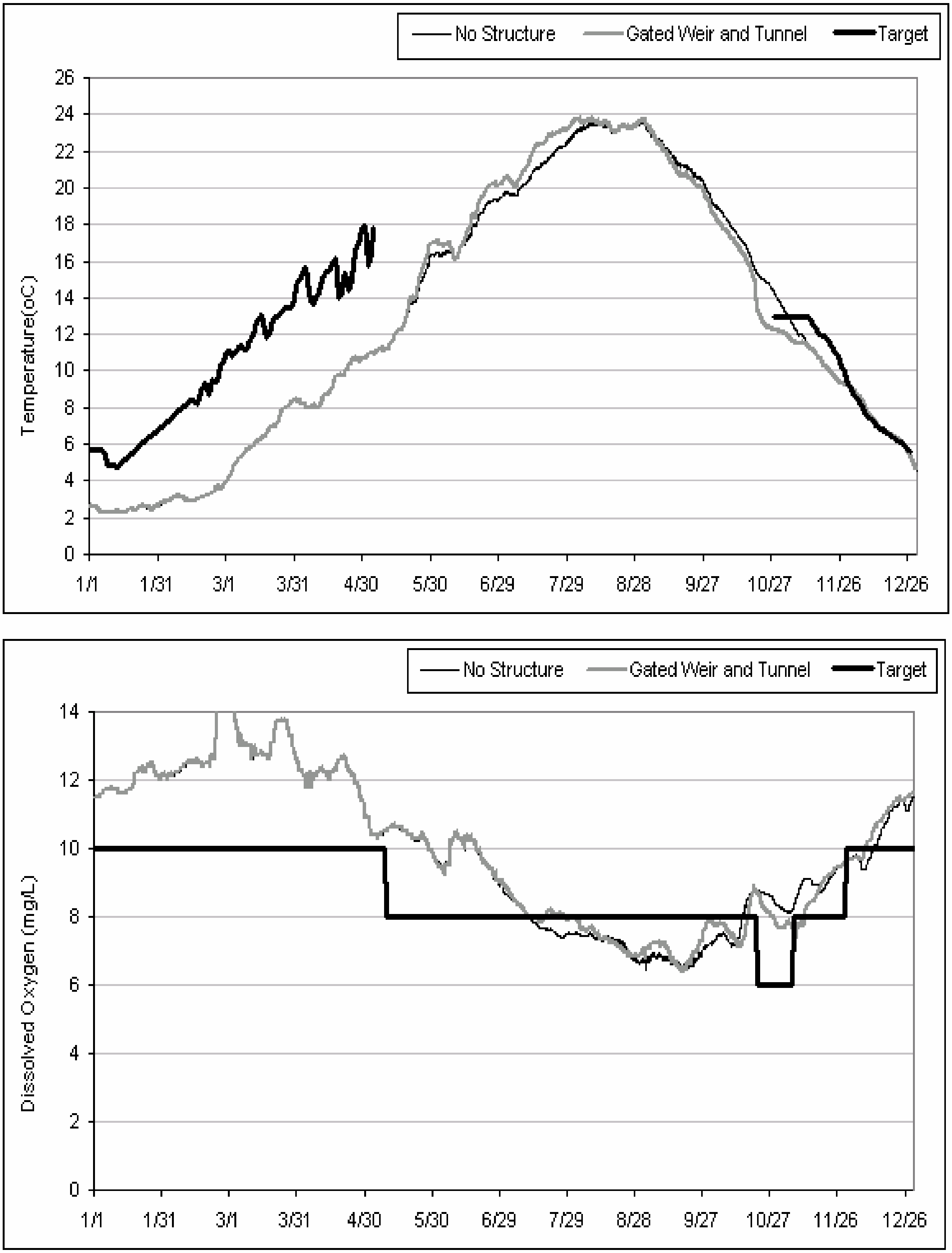
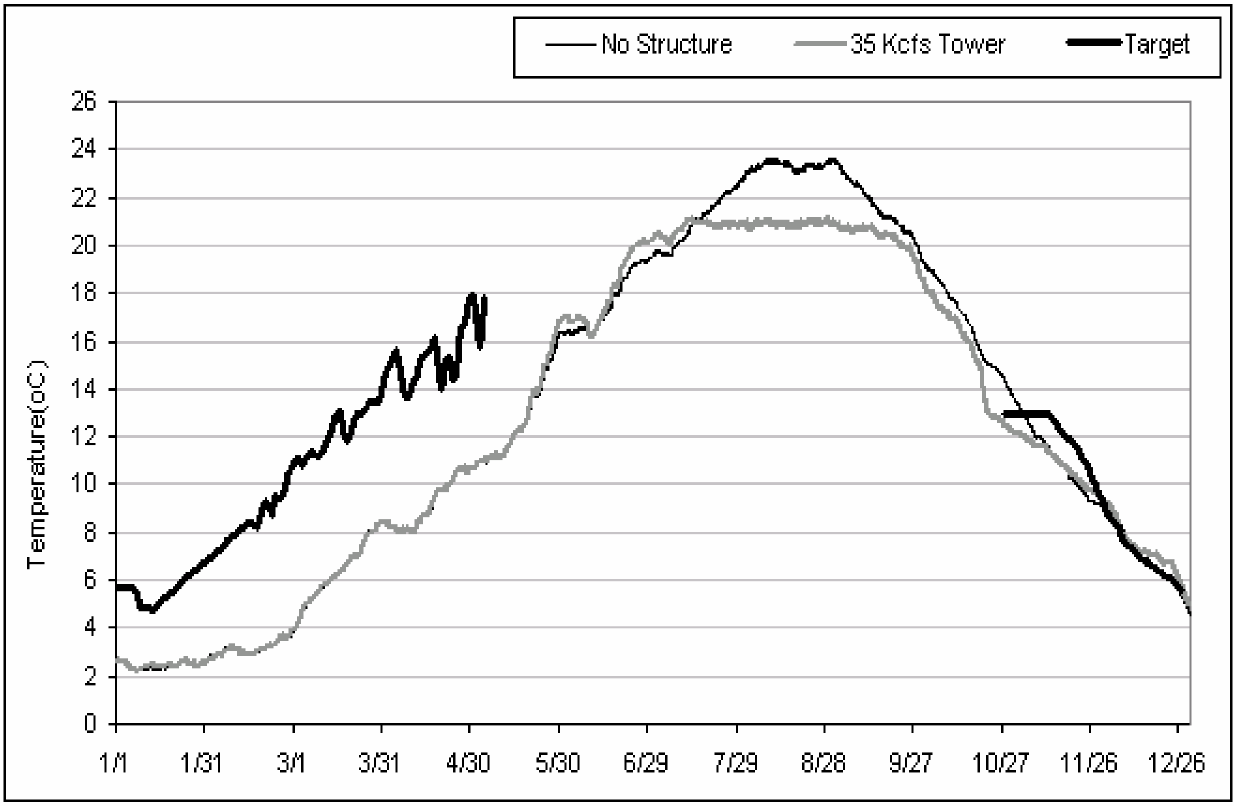


Figure 56. Medium-High Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the TMDL conditions model setup and OP-2 reservoir operations.



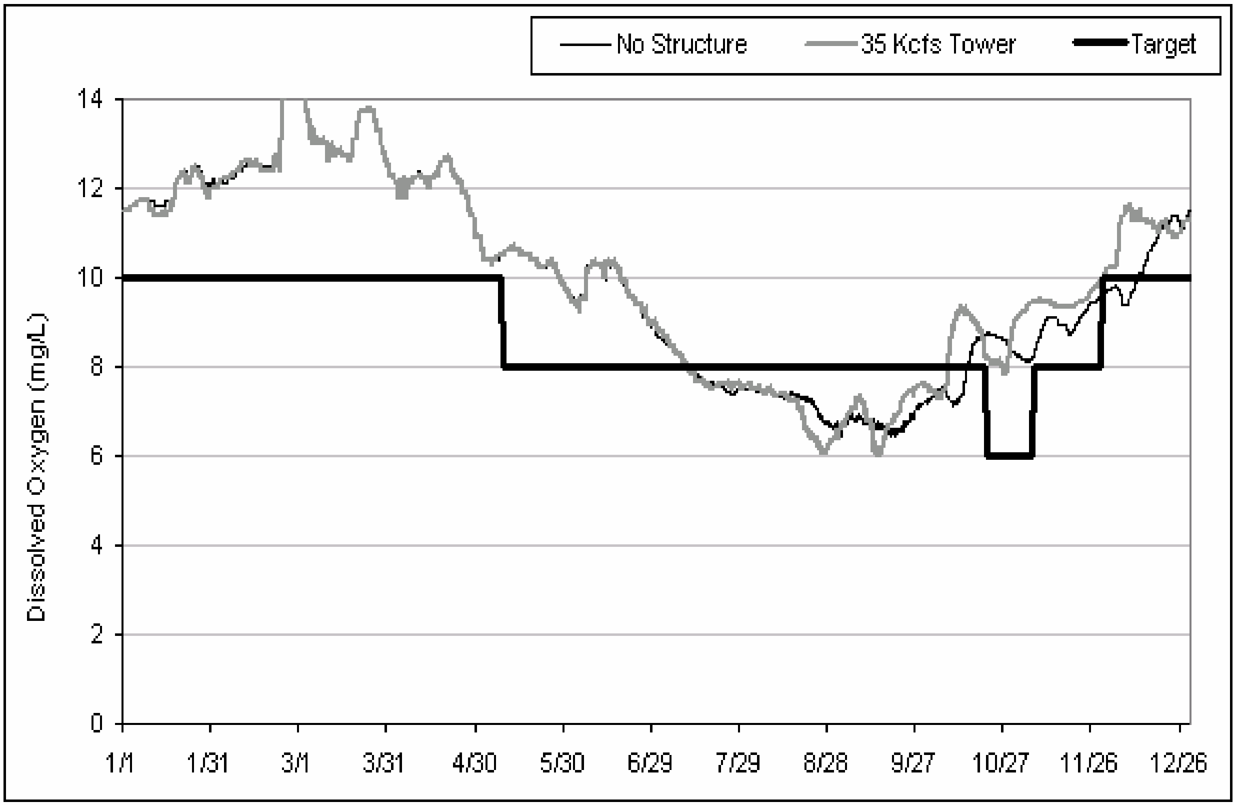
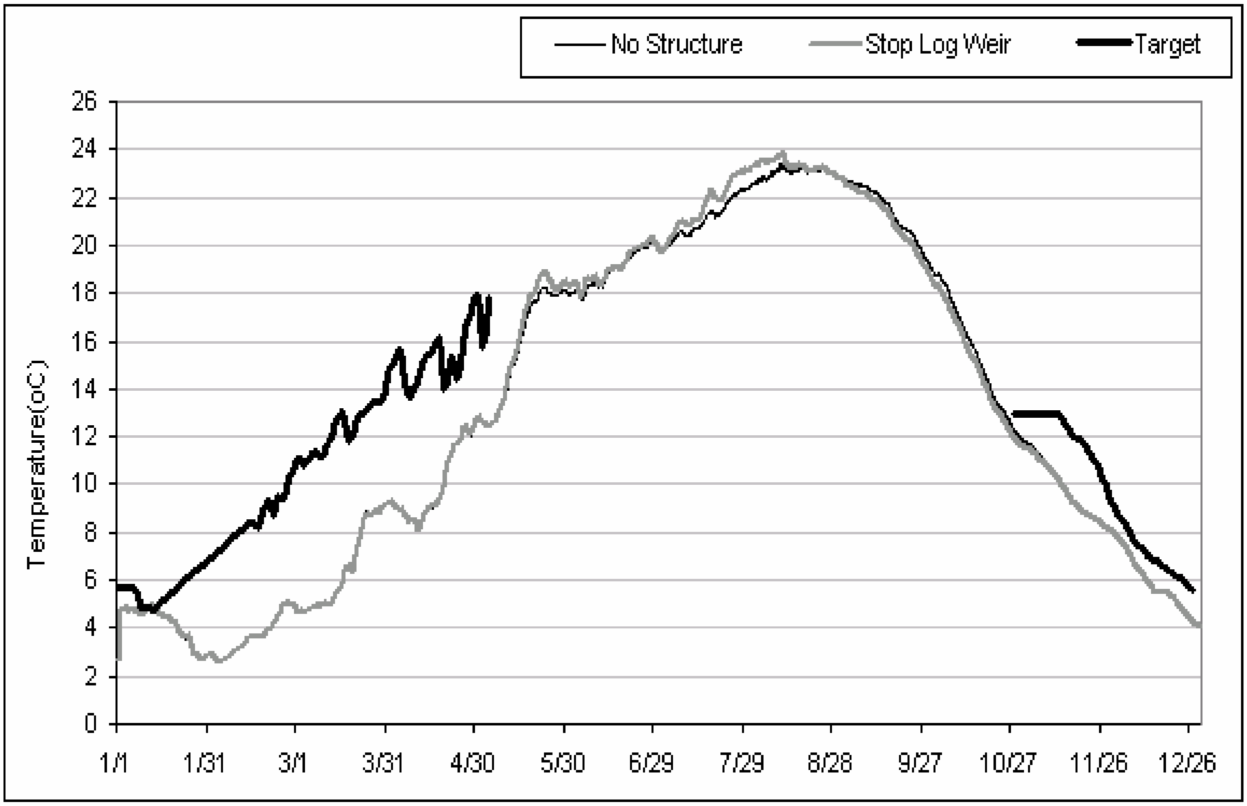


Figure 57. Medium-High Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the TMDL conditions model setup and OP-2 reservoir operations.



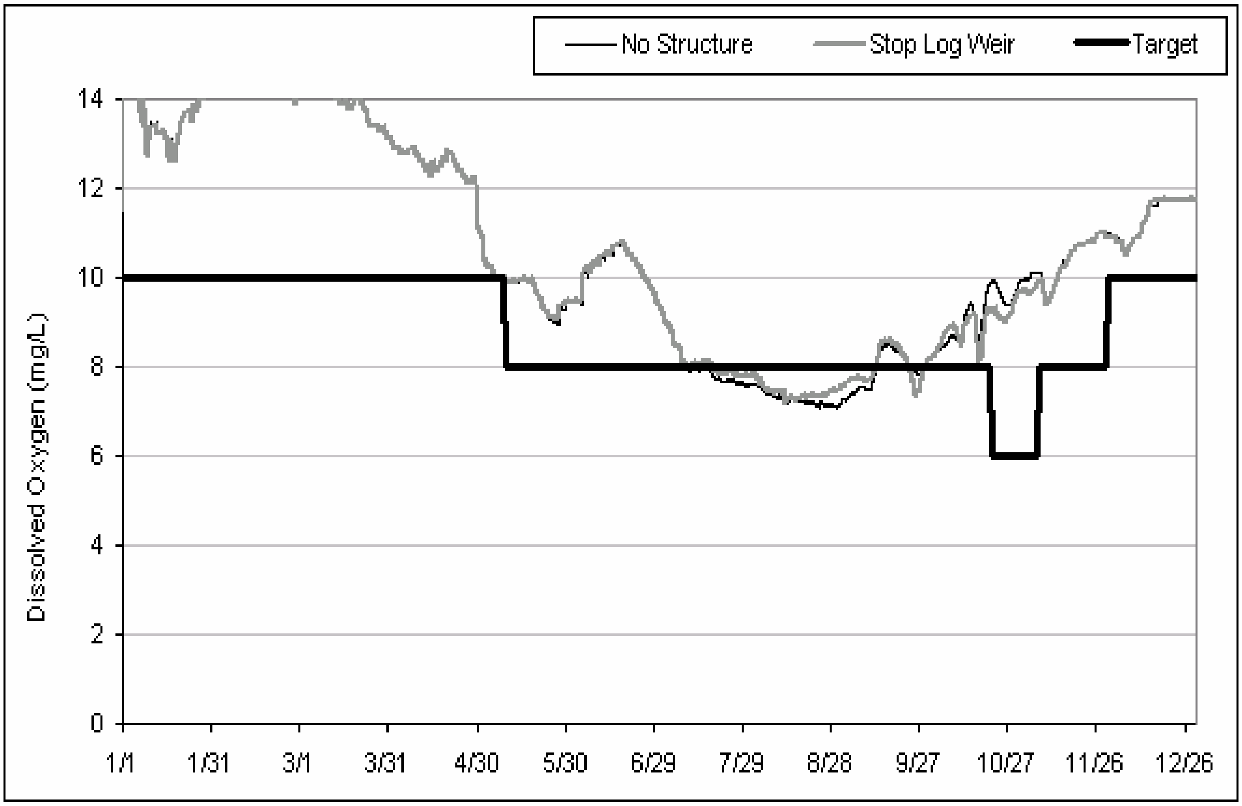


Figure 58. High Water Year hourly Hells Canyon outflows for the StopL and Base (No Structure) using the TMDL conditions model setup and OP-2 reservoir operations.

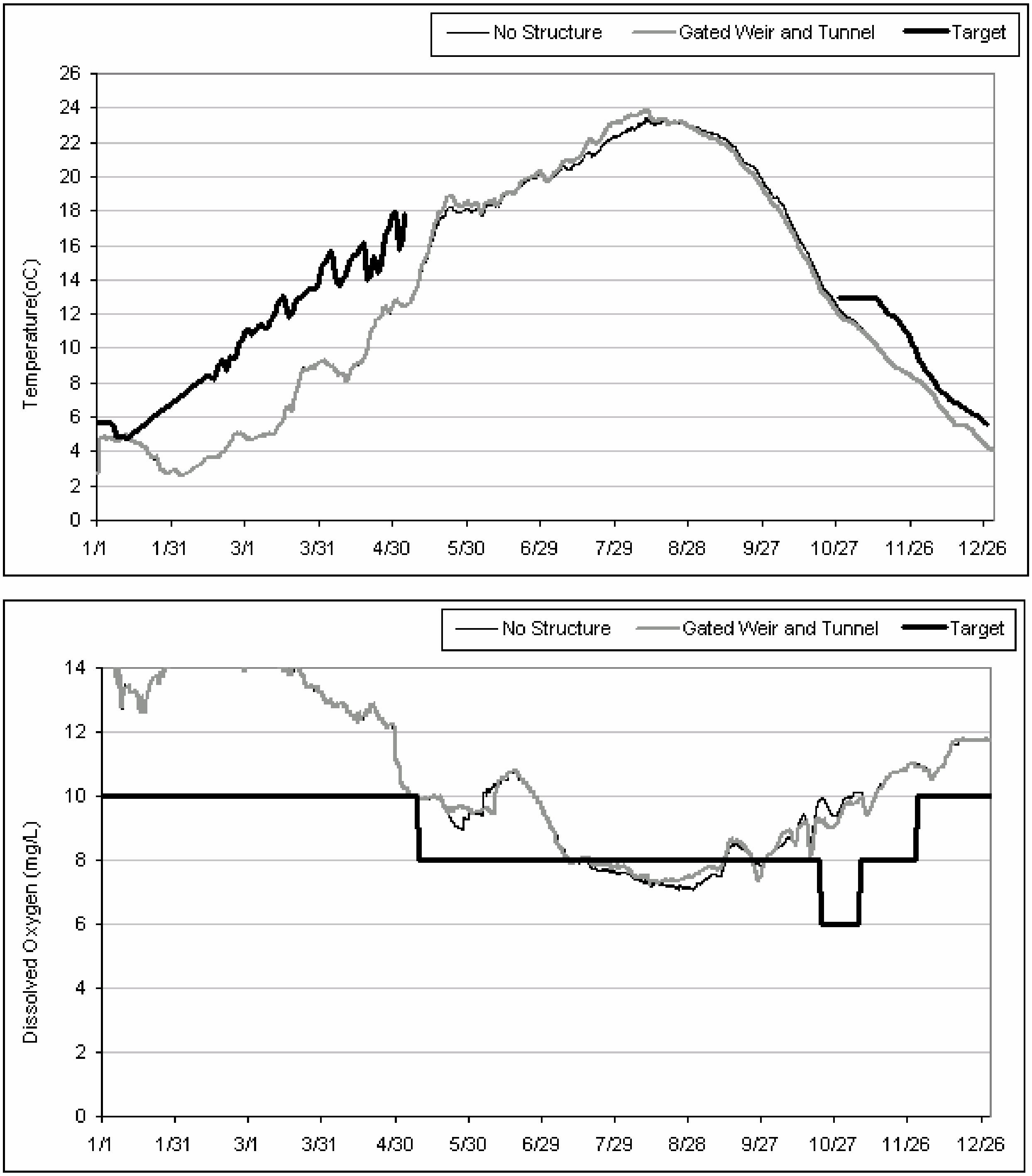


Figure 59. High Water Year hourly Hells Canyon outflows for the Gattun and Base (No Structure) using the TMDL conditions model setup and OP-2 reservoir operations.

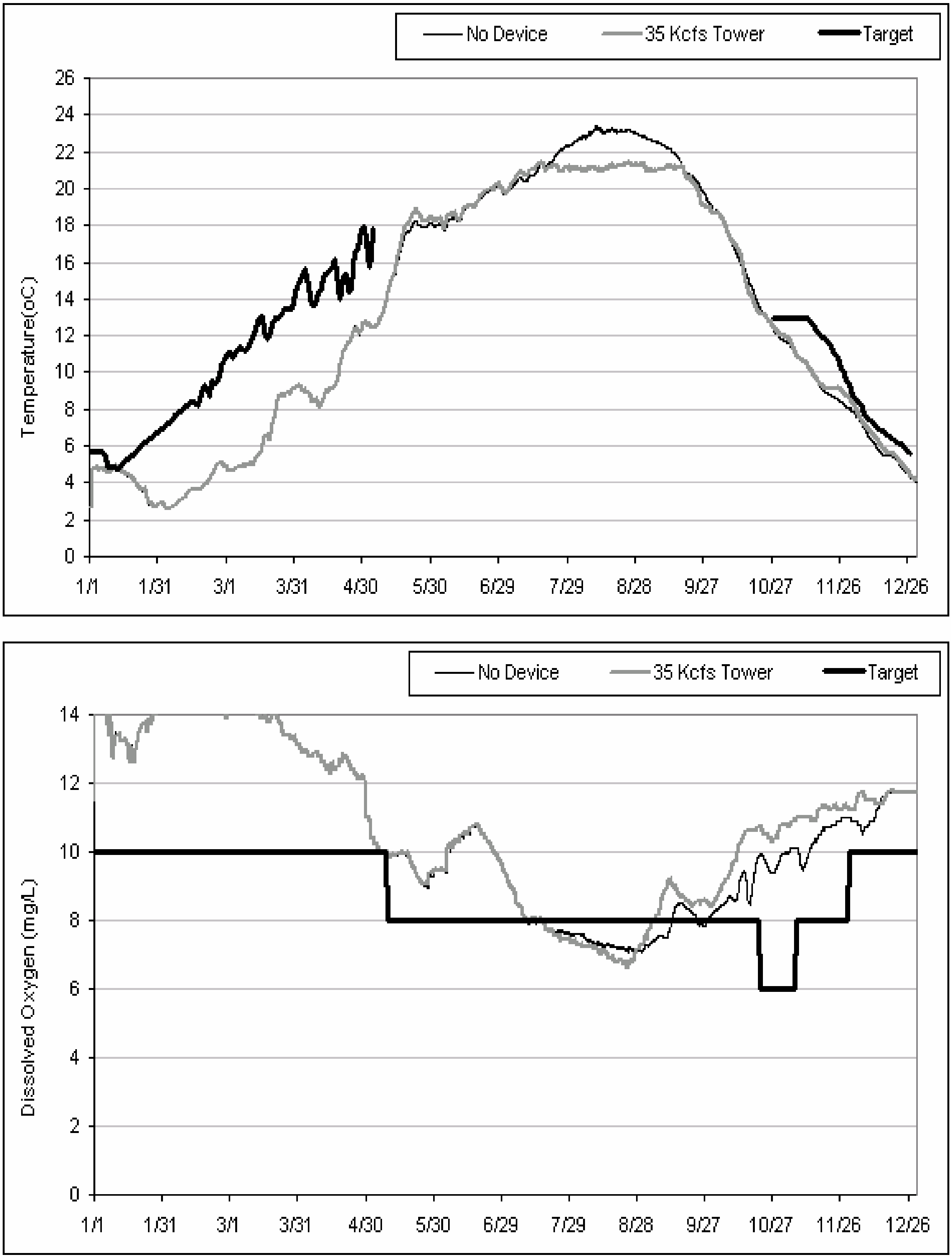


Figure 60. High Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the TMDL conditions model setup and OP-2 reservoir operations.

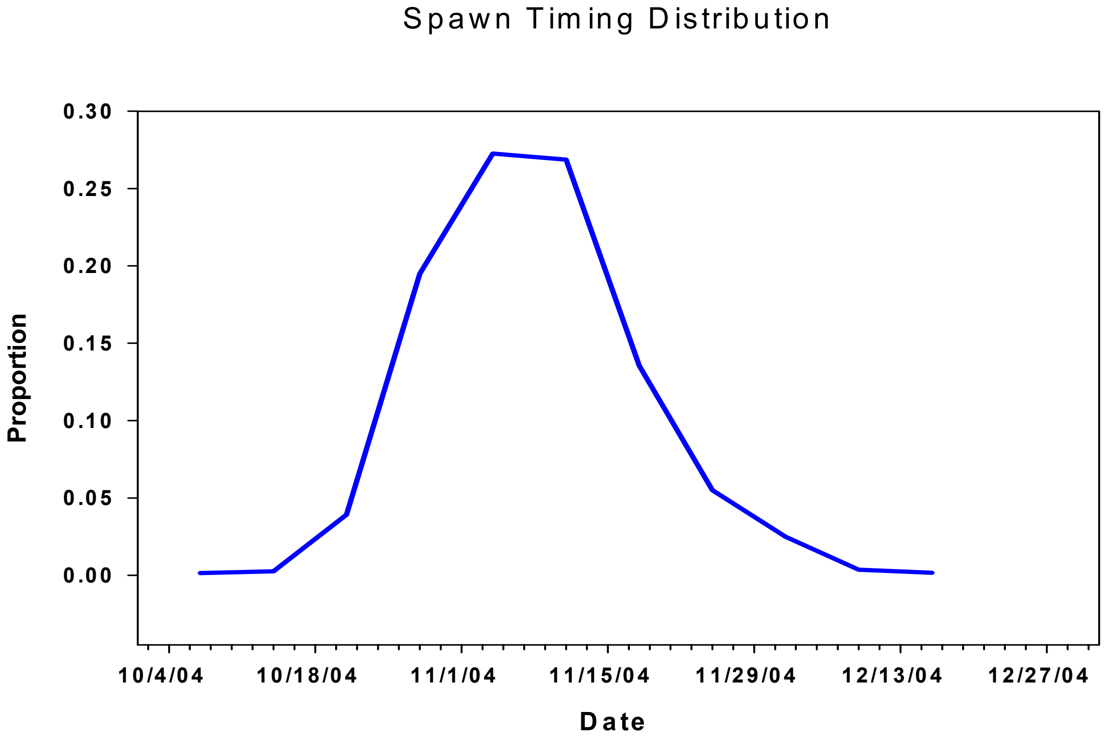


Figure 61. Cumulative daily spawning distribution using redd construction dates between 1993 and 2003 (IPC unpublished information).

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Appendix A. Copy of June 29, 2005 filing sent by IPC to FERC.

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Appendix A is a separate file (122 KB).

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Appendix B. Temperature and Dissolved Oxygen Isopleths for current conditions.

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Appendix B is a separate file (2.65 MB).

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Appendix C. Temperature and Dissolved Oxygen Isopleths for TMDL conditions.

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Appendix C is a separate file (4.25 MB).

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Appendix D. Oregon Department of Environmental Quality Comment Letter and IPC Response.

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Appendix D is a separate file (115 KB).

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Exhibit 7.1-15

October 5, 2005, Idaho Power Company's (IPC) response to the Federal Energy Regulatory Commission's (FERC) comments on AIR WQ 2(c) draft response

IDAHO POWER
An IDACORP Company

IDAHO POWER COMPANY
P.O. BOX 70
BOISE, IDAHO 83707

Craig A. Jones **(208) 388-2934**
Hells Canyon Relicensing Project Manager **fax (208) 388-6902**
Hydro Relicensing Department **e-mail cjones@idahopower.com**

October 5, 2005

Magalie R. Salas, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Room 1A East
Washington, D.C. 20426

Re: Hells Canyon Project No. 1971-079, Responses to FERC Comments on AIR WQ-2(c) Draft Response

Dear Secretary:

By letter dated September 13, 2005 the Federal Energy Regulatory Commission (FERC) provided Idaho Power Company (IPC) comments on its draft response to AIR WQ-2(c) and requested that IPC provide additional analyses and information in the final response. On September 26, 2005 IPC and FERC staff held a meeting via conference call to clarify FERC staff's comments and the information requested.

During the conference call, IPC discussed with FERC staff the timing of providing the additional analysis and information. As a result of that discussion, IPC is hereby requesting that it be allowed to provide the additional analysis and information by October 21, 2005. The filing by IPC will be responsive to FERC's letter dated September 13, 2005 as clarified by the conference call held on September 26, 2005. Because the information filed in WQ-2(c), along with parts (a) and (b), substantially responds to the original additional information request, the additional time should not unduly delay the relicensing process of the Hells Canyon Project.

As a result of the conference call, IPC understands that FERC staff is interested in identifying what benefits may exist if a temperature control structure (TCS) is operated for the singular purpose of enhancing fall Chinook emergence, growth and out migration with the goal of improving survival through the Federal Columbia River Power System.

FERC staff would also like to see the corresponding dissolved oxygen effects of the TCS operation. Accordingly, IPC will provide this analysis, along with the requested dissolved oxygen information.

Please contact me if there are any questions regarding this filing. A copy of this letter has been sent to the Service List.

Sincerely,

Craig A. Jones

CAJ/da
cc: Service List
Jim Tucker, IPC
Dave Meyers, IPC
Jim Vasile, DWT
Rick Glick, DWT
Alan Mitchnick, FERC

Judy Ellis	Adams County Commissioner
Sara Eddie	Advocates for the West
Connie Kelleher	American Rivers
County Judge	Baker, County of
Chairman	Blaine, County of
Regional Hydro Policy Specialist	Bureau of Indian Affairs
Mel Berg	Bureau of Land Management
Jim Clark	Bureau of Land Management
Eric Hoffman	Bureau of Land Management
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Response to FERC Comments on WQ-2(c)

Final Report

Hells Canyon Project
FERC No. P-1971-079

October 2005

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1 INTRODUCTION

By letter dated September 13, 2005 the Federal Energy Regulatory Commission (FERC) provided Idaho Power Company (IPC) comments on its draft response to AIR WQ-2(c) and requested that IPC provide additional analyses and information in the final response. On September 26, 2005 IPC and FERC staff held a meeting via conference call to clarify FERC staff's comments and the information requested. From the correspondences, IPC understands that FERC staff is interested in identifying what benefits may exist if a temperature control structure (TCS) is operated for the singular purpose of enhancing fall Chinook emergence, growth and out migration with the goal of improving survival through the Federal Columbia River Power System (FCRPS). The request directed IPC to conduct the analysis using fall temperature targets that differed from those which IPC identified and consulted with resources agencies as required in WQ-2(a). The September 26 request directed IPC to disregard existing Oregon and Idaho salmonid spawning temperature standards. FERC staff also requested IPC present information to assess additional oxygen requirements that may be needed to meet targets with operation of a TCS.

In earlier analyses completed for AIR WQ-2(b) and WQ-2(c), IPC simulated five different TCS structures for five different water years under both proposed and AIR OP-2 operations. The analyses showed that all of the structures were more effective in influencing temperatures in the lower water years than in the higher water years, where almost no effects occurred. Concurrent with the AIR process, IPC engaged in discussions and evaluation of TCS structures as part of a Hells Canyon settlement process to determine the effects of a TCS at Brownlee Dam on outmigrating fall chinook survival through Lower Granite Reservoir. To complete the survival analysis, it was necessary to estimate effects of a TCS on the temperatures downstream in Lower Granite Reservoir. But because IPC's existing model does not extend to Lower Granite Reservoir, IPC contracted with the U.S. Army Corps of Engineers (Corps) to complete the required modeling. The Corps model was run using the baseline (no TCS), Stop Log weir, and Gated Weir and Tunnel for the low and medium years, the results are included in Appendix A. These specific scenarios were selected because they provided a good range of the expected temperatures affects possible with a TCS. The temperature outputs from the Corps modeling were input into an existing fall Chinook survival model (created by the U.S. Fish and Wildlife Service (USFWS)) to estimate survival to Lower Granite Reservoir with and without operation of a TCS. The survival model was used in collaboration with NOAA fisheries. The resulting survival output from the model for baseline and TCS's scenarios were compared to determine the overall survival benefit

The following conclusions were drawn from the survival analyses. Firstly, water temperatures cannot be warmed sufficiently in the spring to provide a significant benefit to incubating fall Chinook salmon, e.g. the change in emergence timing is relatively modest. Secondly, a TCS has minimal effectiveness for influencing water temperatures downstream in Lower Granite Reservoir because: (a) the Snake River water discharged from Brownlee becomes diluted by major tributaries before it reaches Lower Granite Reservoir, thus diluting temperature influences from the TCS and (b) the water temperature discharged from Brownlee by a TCS tends to equilibrate by the time it travels through Lower Granite Reservoir. It was therefore concluded that the TCS cannot significantly enhance fall Chinook incubation conditions or significantly improve survival through Lower Granite Reservoir.

In the previous AIR WQ-2(c) submittal, based on the Corps modeling effort and the survival analysis undertaken by IPC and NOAA Fisheries, IPC concluded that the preferred alternative is to not install a TCS at Brownlee. IPC's position has not changed with this response. After investigating further TCS operations as requested by FERC, IPC has concluded a TCS does not have the ability to significantly enhance fall Chinook incubation conditions and cannot significantly improve survival through Lower Granite Reservoir. In this response, IPC offers further analysis for this conclusion and responds to FERC's inquiries relative to the effectiveness of TCS alternatives to meet the fall chinook survival goals described by FERC.

Although IPC maintains that the preferred alternative is not to construct a TCS, IPC has provided in this report the amount, timing and associated costs of DO augmentation with a structure as requested by FERC. IPC's estimates assume the appropriate watershed improvements to inflowing water quality defined and required in the Snake River Hells Canyon TMDL. This approach is consistent with both the approved TMDL, and ongoing 401 certification discussions with the Idaho Department of Environmental Quality (IDEQ) and Oregon Department of Environmental Quality (ODEQ). A primary focus of these discussions is defining IPC's responsibility for DO downstream of Hells Canyon Dam. In 2003, IDEQ and ODEQ jointly developed the *Snake River–Hells Canyon Total Maximum Daily Load* (TMDL) (ODEQ and IDEQ 2003) for the Snake River between river miles (RM) 409 and 188. IPC, as well as other stakeholders with property interests adjacent to and upstream from the river segment, participated in the TMDL development process. The TMDL contains load allocations for the Hells Canyon Complex (HCC) for various water quality parameters, including DO, but recognizes that DO concentrations in Brownlee Reservoir and the Snake River are closely linked to and influenced by inflowing nutrient concentrations. Consequently, the TMDL, in implementing a watershed approach, assigned total phosphorus load allocations to pollutant sources for the Snake River upstream of the HCC (RM 409–335) and a DO load allocation for Brownlee Reservoir (RM 335–285). However, the TMDL was primarily focused on conditions in and upstream from Brownlee Reservoir but did not specifically address DO conditions in the Snake River downstream of Hells Canyon Dam. As part of the 401 process, work is ongoing by IPC, ODEQ and IDEQ to determine an appropriate DO allocation for the HCC at Hells Canyon Dam. It is expected that IPC's responsibility for DO downstream of the HCC, and measures to address that responsibility, ultimately will be determined in the 401 process.

2 RESPONSE

2.1 Temperature Goals

IPC understands that FERC staff is interested in identifying what benefits may exist if a temperature control structure (TCS) is operated for the singular purpose of enhancing fall Chinook emergence, growth, and out migration with the goal of improving survival through the Federal Columbia River Power System. After corresponding with FERC, it was determined that optimal temperature goals for enhancing Fall Chinook incubation and growth desired by FERC include the following:

1. For spring warming, to warm the outflow temperatures as much as possible in the early spring (January 1st thru May 15th) for the purpose of enhancing Fall Chinook incubation timing.
2. For early summer cooling, once the outflow warms to 15°C, maintain the outflow temperature at 15°C as long as possible using all of the stored cool water. 15°C was determined to be the optimal temperature for Fall Chinook growth and rearing (Groves and Chandler 2001).
3. In the fall, (October 23rd thru December 31st), the outflow temperatures should remain the same as existing conditions (the temperatures without a structure). Based on results from WQ-2(c) that fall cooling reduces Fall Chinook by slowing incubation, and correspondence with FERC staff, fall cooling (as originally requested by FERC in AIR WQ-2), has not been included in this analysis. It should be noted that this request disregards the Oregon and Idaho State water quality standards, and any model runs and analysis for scenarios that do not lower fall temperatures will not result in conditions that meet existing State water quality standards.

2.2 CE-QUAL-W2 Modeling

In AIR WQ-2(b) and WQ-2(c), FERC requested simulating a wide range of conditions including various TCS alternatives, water years, and reservoir operations. Based on the conclusions drawn from this modeling, IPC has limited this analysis in an attempt to meet the October 21 deadline for this information request. In this analysis, one TCS (the Stop Log weir), in the low water year, under proposed operations was modeled. Based on the conclusions drawn from WQ-2(b) and (c), IPC believes a qualitative analysis for the other structures, years, and flow augmentation reservoir operations for the other scenarios is appropriate. Also, the Hells Canyon outflow model results were not re-run through the Corps model to quantify the effects in Lower Granite Reservoir. Based on results from the previous modeling efforts, IPC can reliably estimate effects in Lower Granite without spending extra time to re-run the Corps model. Further detail of the modeling performed in this analysis is given below.

For this analysis, the Stop Log weir was the only structure simulated in the CE-QUAL-W2 model. The Stop Log weir was selected because, overall, it should give a reasonable representation of the general effectiveness of all of the structures in obtaining the goals given above. The Stop Log weir is a reasonable representation because all of the structures would perform almost identically in the spring and fall. The difference in the effectiveness between the structures is the length of time that the 15°C outflows could be extended into the summer. The deep water withdrawal options (the Gated Weir and Tunnel and 35 Kcfs Tower) would extend the time period that 15°C could be provided slightly longer into the summer because more cooling water is available. However, this would be expected to only provide marginal benefits for survival through Lower Granite Reservoir because in earlier modeling it was noted that a TCS can only provides minimal temperature influence on the temperatures in Lower Granite Reservoir.

In the model, the weir was located in the upstream most segment of the intake channel (a location similar to the conceptual design). For spring warming, to provide the warmest water possible, the weir elevations were chosen to be as high as possible assuming no more than 2.5 feet of headloss, which is within the allowable range provided for in the conceptual designs. Later in the year, to cool the outflows to the 15°C target, all of the stoplogs were sequentially removed from the top of the weir to moderate the release of cool water. All of the stored cool water was used to meet the 15°C target and none was saved for use later in the year. The removal of stoplogs was automatically controlled by adding customized coding to CE-QUAL-W2 that compared the modeled outflow temperature to the desired optimized temperature and then stoplogs were removed accordingly.

The low water year was selected for this analysis to concentrate on the year where the structure has the greatest ability to affect temperatures. In WQ-2(b), it was found that all of the structures were more effective in the lower water years. In fact, in the medium, medium-high, and high water years almost no spring warming occurred and only minimal summer cooling. Therefore, the modeling effort was streamlined to focus on the low year where the structures have potential to influence temperatures.

Proposed reservoir operations were used for this analysis and the flow augmentation scenario was not modeled. In AIR OP-1(e) and AIR WQ-2(b), it was found that there was almost no difference in the outflow temperatures and DO between the two scenarios during the spring and fall. Therefore, in this analysis, it is expected that both reservoir operations would yield similar results in the spring and fall. In the summer, relative to Hells Canyon outflows, the difference between the two operations was when the augmentation water was drafted from Brownlee, the outflow temperatures were generally somewhat warmer than with proposed operations. It follows that, in this analysis, if a structure were used to try and maintain a 15°C outflow temperature, it could not be maintained for as long with the flow augmentation scenario as with proposed operations.

2.3 Evaluation of Temperature Results

2.3.1 CE-QUAL-W2 Modeled Temperatures

The Hells Canyon hourly outflow temperatures using the Stop Log weir for the low water year are shown in Figure 1. A qualitative analysis of the temperature effectiveness for the Stop Log weir, Gated weir, Gated Weir and Tunnel, and 35 kcfs Tower for all five representative water years is given in Table 1. As stated in WQ-2(b), the most significant factor influencing the effectiveness of the various structures was the hydrologic conditions in a given year. All of the structures will have greater effectiveness in the low water years than in high water years. For spring warming, regardless of the structure selected, warming is only likely to occur in the lower water years after the month of March. The modeling in this analysis shows that the Stop Log weir was able to maintain cooler temperatures (relative to the no structure option) through the early and mid summer, and that the fall temperatures were about the same as without the structure.

2.3.2 Qualitative Evaluation of Temperatures through Lower Granite Reservoir using the New Operations

In the Corps modeling of the TCS operations presented in AIR WQ-2(b), it was determined that a TCS has only minimal effectiveness for influencing water temperatures downstream in Lower Granite Reservoir because: (a) the Snake River water discharged from Brownlee becomes highly diluted by major tributaries before it reaches Lower Granite Reservoir, thus diluting temperature influences from the TCS; and (b) the water temperature discharged from Brownlee by a TCS tends to equilibrate by the time it reaches Lower Granite Reservoir. More detail of the earlier modeling is provided in Appendix A. The CE-QUAL-W2 modeling results provided in this analysis were not run through the Corps model of Lower Granite Reservoir because of time constraints and because the Brownlee outflow temperatures with the new operations of the TCS would likely not significantly influence temperatures in Lower Granite Reservoir.

2.3.3 Fall Chinook Survival Analysis

The current analysis included the goal of warming the outflow temperatures as much as possible in the early spring (January 1st thru May 15th) for the purpose of promoting earlier fall Chinook salmon emergence. This resulted in an estimated two day earlier emergence relative to the base condition for the low water year. This is based on a median spawn date of November 4th and a thermal unit accumulation of 1,066 units. In the higher water years, because a TCS is less effective for warming temperatures in the spring, a TCS will likely not be effective for providing earlier emergence.

In addition to earlier emergence, another goal was to maximize growth conditions for rearing juvenile fall chinook salmon. In a review of temperature requirements for different life stages of fall chinook salmon, Groves and Chandler (2001) determined the optimal temperature range for rearing fall chinook salmon was between 10ºC and 15ºC. To analyze potential growth benefits, we used growth rate equations developed for Snake River fall chinook salmon by Connor and Burge (2003). Growth rate equations involve the calculation of a temperature index, which is the mean temperature from March 20 to June 20. For the low water year, under baseline conditions with no TCS, the temperature index was 11.7ºC, and with the TCS was 12.6ºC. These result in daily growth rates of 1.09 mm/day as compared to 1.16 mm/day, respectively. Over a 45-day rearing period, this would equate to a 3.15 mm growth advantage with the TCS. It is important to note that under existing conditions, Snake River fall chinook salmon exhibit very rapid growth as compared to those of other stocks of ocean-type chinook salmon, even exceeding many of those associated with productive brackish and saltwater habitats along the Pacific coast of North America (Connor and Burge 2003). In the higher water years, because a TCS is likely less effective for providing optimal temperatures into the summer, a TCS will also be likely be less effective for maximizing fall chinook growth conditions.

Lastly, a third goal was to determine what survival advantage could be obtained by operating a TCS as described above for migration survival through the FCRPS, principally Lower Granite Reservoir, as a result of the change in emergence timing and potential growth advantage. Emergence timing may influence fall chinook salmon survival relative to the timing of when smolts arrive at Lower Granite Reservoir. Connor et al. (2003) concluded earlier emerging smolts arrive at Lower Granite Reservoir earlier and generally experience better conditions (higher flows and lower temperatures) for survival through the reservoir. The USFWS developed a model for juvenile fall chinook salmon survival through Lower Granite Reservoir that is influenced by both flow conditions and water temperatures. In addition, Connor et al. (2002), determined that enhanced growth opportunities could also result in faster transformation of parr to smolt stages, potentially influencing earlier migration.

In previous analyses of TCS's filed in AIR WQ 2(c), operation of the TCS's in a low water year (1992) resulted in substantial increase in water temperatures in the Hells Canyon outflow during the early summer months because warmer water was being released to maximize storage of colder water to meet the fall salmonid spawning standard of 13ºC (Appendix A; Appended Figure 1). When these temperatures were routed through the free-flowing section of Hells Canyon and Lower Granite Reservoir, the corresponding temperature difference was significantly masked by the time it reached the Lower Granite tailwater (Appendix A; Appended Figure 5) such that it did not differ substantially from baseline. The evaluation of the 1995 (medium water year) resulted in less departure from baseline, even in the immediate outflow at Hells Canyon Dam (Appendix A; Appended Figure 2).

The analysis conducted with this information request resulted in cooler outflows in efforts to maintain temperatures near 15ºC, such that temperatures were cooler than baseline during the early summer months. These temperatures were not routed to the Tailrace at Lower Granite as was the original analyses filed with WQ2-(c). However, based on the minimal effect that the original TCS evaluation had on water temperature at the tailrace of Lower Granite in earlier analyses, it is not anticipated that the temperature difference observed with this additional analysis would deviate substantially from baseline. If temperature conditions at Lower Granite tailrace do not deviate substantially from baseline, then the anticipated survival deference of this operation with the two days accelerated emergence in the low water year is estimated to be 24.7% (percentage of fish that survive through Lower Granite Reservoir) under baseline conditions as compared to 25% under the TCS operation. Therefore, a TCS only increases survival by 0.3%, which is considered to be negligible. In the higher water years, it can also be concluded that any slightly earlier emergence provided by a TCS would also not result in any significant change in survival. It is likely that a much greater shift in emergence timing would be required before substantial differences would be realized in survival of outmigrating fall chinook salmon. Similarly, the anticipated differences in growth are not significant, and increased survival relative to earlier migration because of a growth advantage would not be expected with this operation.

2.4 Dissolved Oxygen

2.4.1 Simulation of Dissolved Oxygen

Of the two scenarios presented in WQ-2(b) and (c) (current conditions and TMDL conditions) simulations for this analysis were performed using inflowing conditions representative of upstream water quality improvements as required by the Snake River Hells Canyon TMDL (IDEQ and ODEQ 2003). As performed in previous WQ-2 AIR simulations, estimated TMDL improvements were modeled for all the representative years using calculations described in Myers et al. 2003. A total phosphorus (TP) concentration target of 70 µg/L has been established for the upstream reach of the Snake River as part of the TMDL (IDEQ and ODEQ 2003). Dissolved phosphorus and organic phosphorus were reduced in the Brownlee Reservoir model inflows to simulate how the reservoir would respond to the TP target. With inflow water quality improvements and the associated decrease in organic matter (OM) loading as contemplated by the TMDL, sediment oxygen demand (SOD) should also decrease over the long term. The proposed TP reduction and resulting SOD improvements were simulated to assess the reservoir's response to potential long-term water quality improvements in inflow.

To simulate the TP target, dissolved phosphorus and organic phosphorus (organic matter, including algae) were reduced from the baseline boundary conditions such that inflowing TP levels did not exceed 70 µg/L. As watershed management actions are implemented to meet the target, organic matter (OM) loads and sedimentation are expected to decrease. As loads decrease and existing OM decays through natural processes, SOD will decrease. Response to these long-term improvements were simulated by reducing SOD to 0.1 g O_2/m^2/day throughout the reservoir. This SOD is more typical of naturally occurring SOD levels (Cole and Wells 2002). For the Oxbow and Hells Canyon reservoirs, discharge from the upstream reservoir was used as the inflow boundary condition and SOD was reduced to Brownlee levels (0.1 g O_2/m^2/day).

2.4.2 Dissolved Oxygen Augmentation

The modeling shows that DO may drop below targets (identified in WQ-2(a)) even after water quality improvements from upstream TMDL implementation occur (Figure 1). The tons of additional oxygen needed for the DO concentrations in the Hells Canyon discharge to reach the targets given in WQ-1(a), once upstream TMDL improvement occur, was estimated at about 800 tons on an annual basis. Overall, the timing and amount of DO supplementation does vary throughout the year but the DO generally falls below targets during the late summer and early fall. Note that, this DO augmentation requirement is specific to the scenario analyzed and could change significantly for other TCS operations, reservoir operations, or water years. Also, because it was requested that DO be added at the Brownlee Powerhouse (as part of AIR WQ-2(c)), it is necessary to add additional DO beyond the 800 tons to account for processing in Oxbow and Hells Canyon reservoirs that cause some of the additional DO to be lost (roughly 40 percent). This additional DO requirement was included in the sizing and operational costs of potential aeration measures.

Forced air injection can provide the DO augmentation required at the lowest cost compared to using other methods such as liquid oxygen delivery and injection or on-site oxygen manufacturing and injection. Forced air applications use compressors or blowers to force atmospheric air into the draft tube, either through passages in the turbine or the draft tube wall. The blowers are designed to operate when the turbines are running. Oxygen in the air then dissolves into the water to increase the DO in the turbine discharges. Oxygen transfer is obtained in the turbulent flow of the draft tube and as the bubbles rise to the surface in the tailrace. As oxygen is dissolved into the water, nitrogen and other gases in the air are also dissolved, increasing the TDG concentrations. Because elevated TDG is undesirable, the quantity of air that can be added to the outflows is limited and TDG levels need to be considered when using blowers for augmentation.

To estimate the DO increase that blowers could provide, a new model was created to calculate the DO benefit from the blowers based on Brownlee powerhouse rates, powerhouse discharge water temperatures and DO levels, tail water elevations, blower air flow rates, and the known dynamics of gas transfer in water. The model also considered the increase in TDG levels relative to the state standard of 110 percent and did not allow the Brownlee powerhouse outflow TDG to exceed 110 percent. From the modeling, it was found that blowers can provide enough DO for the outflows to attain the targets without exceeding TDG limits. Also from the modeling, it was found that the most appropriate blower sizing to provide the estimated DO benefit was one blower for the Brownlee powerhouse units 1-4 using a 900 horsepower motor that has ability to add 6,500 cfm (cubic feet of air per minute), and two blowers for unit 5 with 1,000 horsepower motors having the ability to add 13,000 cfm of air. Further design details of this system are included in Appendix B. The capital construction costs of the blower system is estimated to be $2.2 million. The annual costs to operate the blowers is about $61,000, which includes allowances for lost turbine efficiency (efficiency is reduced in proportion to the volume of air introduced into the draft tube), electrical power demands needed to operate the blowers, and maintenance costs.

2.5 Other Considerations

In AIR response WQ-2(a), (b), and (c), IPC outlined some of the uncertainties associated with a TCS. Despite the advanced modeling capabilities developed by IPC using CE-QUAL-W2 there is considerable uncertainty regarding the changes in chemical and biological responses that would result from installing and operating a TCS. The TCS is expected to alter the current thermal patterns and characteristics of Brownlee Reservoir. Predicting with quantitative certainty, the effects the action will have on reservoir primary productivity, ‘near-field’ flow patterns, resuspension of contaminants currently immobilized in the reservoir sediments, and localized dissolved oxygen conditions is not practical. For example, elevating the level of the thermocline in Brownlee Reservoir could increase the risk that unusual meteorlogic conditions would cause episodic entrainment of anoxic hypolimnetic water throughout the water column. This could result in widespread fish mortality in expansive areas of the reservoir. Likewise, unanticipated anomalies in withdrawal patterns from Brownlee Reservoir could result in large scale hypoxia or anoxia downstream of Brownlee Dam. Even with provisions for oxygen supplementation, total avoidance of downstream oxygen deficiencies could not be assured.

2.6 Conclusions

Based on earlier AIR modeling results and analyses conducted in cooperation with agencies (including NOAA Fisheries) in the context of the SWG, IPC has concluded that the preferred alternative is to not install a TCS at the HCC. While the FERC has requested evaluation of a TCS using different operations, IPC has found that a TSC does not have the ability to significantly enhance fall Chinook incubation conditions, and cannot significantly improve survival through Lower Granite Reservoir.

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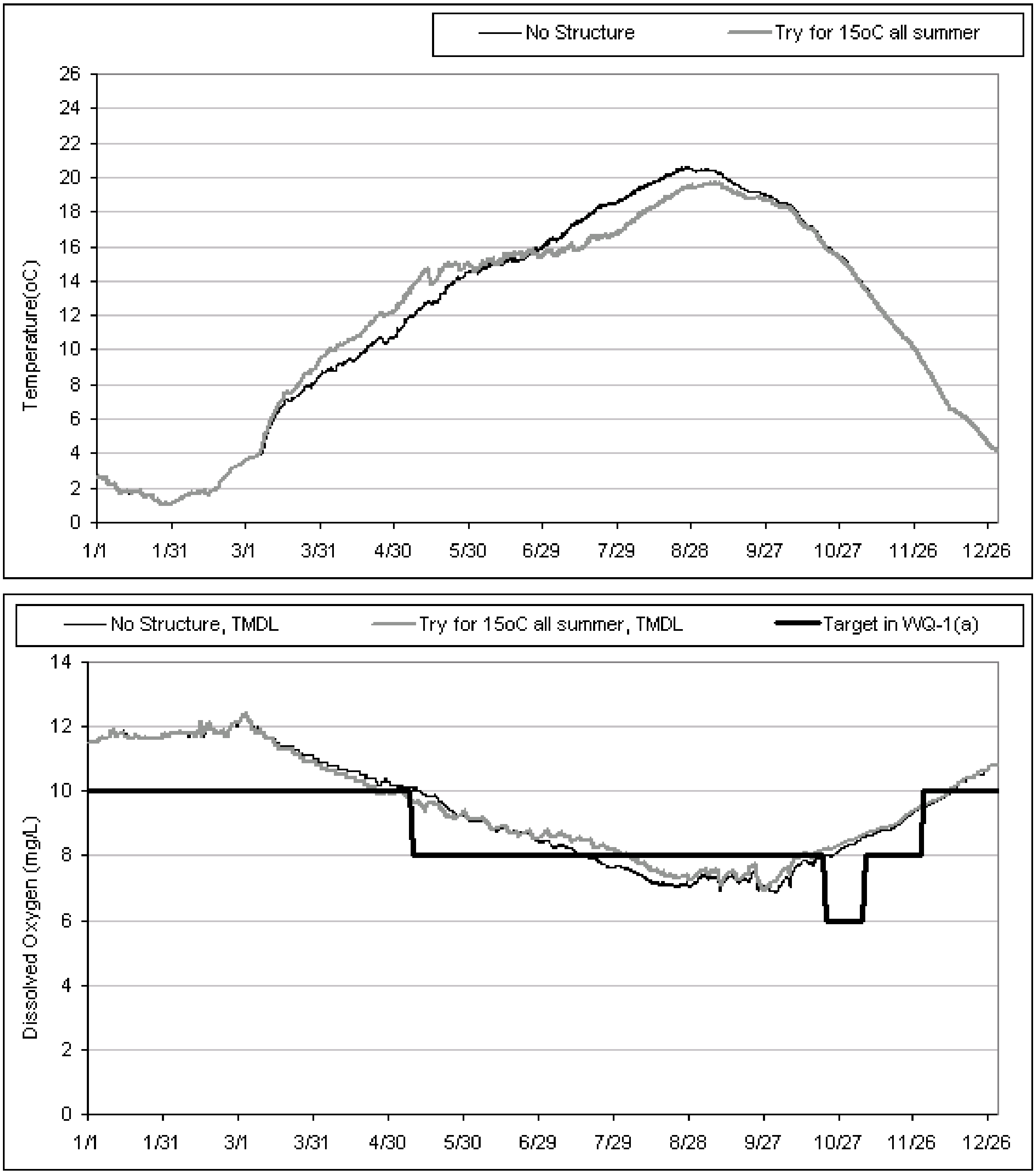
Table 1. Summary of the effectiveness of each of the structures to modify temperature for the various water years. Some of the conclusions are based on model results (modeled), and some are based on qualitative analysis (qualitative).

Structure	Low Year	Medium-Low Year	Medium Year	Medium-High Year	High Year
Spring Warming (all structures provide about the same benefits)					
Stop-Log Weir	Modeled. All structures provide for some warming (less than 1.5°C) only after March 14.	Modeled in WQ-2(b). All structures provide for some warming (less than 1.5°C) only after March 14.	Modeled in WQ-2(b). Minimal effectiveness for all structures.	Modeled in WQ-2(b). All structures are not effective.	Modeled in WQ-2(b). All structures are not effective.
Gated Weir					
Gated Weir and Tunnel					
35 kcfs Tower					
Early Summer, effectiveness of maintaining the 15°C Target					
Stop-Log Weir	Modeled/Qualitative. Can maintain a cooler Hells Canyon outflow temperature in the early summer.[1]	Qualitative. Can maintain a cooler Hells Canyon outflow temperature in the early summer.[1]	Qualitative. Can only maintain a cooler Hells Canyon outflow temperature for a short period.[1]	Qualitative. Can only maintain a cooler Hells Canyon outflow temperature for a very short period.[1]	Qualitative. Can only maintain a cooler Hells Canyon outflow temperature for a very short period.[1]
Gated Weir					
Gated Weir and Tunnel	Qualitative. Can maintain a cooler Hells Canyon outflow temperature in the early summer. Cooler temperatures than Stop-Log or Gated Weir.[1]	Qualitative. Can maintain a cooler Hells Canyon outflow temperature in the early summer. Cooler temperatures than Stop-Log or Gated Weir.[1]	Qualitative. Can maintain a cooler Hells Canyon outflow temperature in the early summer. Cooler temperatures than Stop Log or Gated Weir.[1]	Qualitative. Can maintain a cooler Hells Canyon outflow temperature in the early summer. Cooler temperatures than Stop-Log or Gated Weir.[1]	Qualitative. Can maintain a cooler Hells Canyon outflow temperature in the early summer. Cooler temperatures than Stop-Log or Gated Weir.[1]
35 kcfs Tower					
Fall, Same as Existing					
Stop-Log Weir	Modeled/Qualitative. All structures should be able to provide the same as existing temperatures without a structure in the fall for all water years.				
Gated Weir					
Gated Weir and Tunnel					
35 kcfs Tower					

[1] The temperature effects in Lower Granite Reservoir resulting from operation of a TCS at Brownlee would be minimal and likely would not significantly influence fall chinook survival.

Figure 1. Hells Canyon hourly outflow temperature and dissolved oxygen using the Stop Log weir for the low water year. The DO targets are based on those provided in WQ-2(a)



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Responses to FERC Additional Information Request WQ-2(c)

Detailed Evaluation of Alternative Temperature Control Structures

Appendix A

Copy of June 29, 2005 Filing Sent by Idaho Power Company to FERC

Hells Canyon Project
FERC No. P-1971-079

September 2005

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June 29, 2005

Magalie R. Salas, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Room 1A East
Washington, D.C. 20426

Re: Hells Canyon Project No. 1971-079, Responses to Requests for Additional Information
(June 7, 2005 dated letter from J. Mark Robinson, Director OEP)

Dear Secretary:

Enclosed for filing with the Federal Energy Regulatory Commission (FERC) are one (1) original and eight (8) copies of a response to additional information requested by Mark Robinson, Director OEP related to additional information request (AIR) WQ-2(c).

In a letter dated June 7, 2005 responding to Idaho Power Company's request for an extension of time to file AIR WQ-2(c), Mr. Robinson requested that Idaho Power Company provide the results of the Corps of Engineers' modeling results by June 30, 2005. The purpose of the modeling was to determine the influence of various temperature control structures at Brownlee Dam on water temperatures in the lower Snake River between the Anatone gage and the Lower Granite Reservoir tailwater. The modeling has been completed, and the results are provided herein as requested

Finally, by copy of this letter, the Service List is hereby notified that this information will be available for viewing at ipchydro.org. In addition, copies of this filing may by requested by contacting Dee Aulbach by phone at (208) 388-6109 or e-mail at daulbach@idahopower.com.

Please contact me if there are any questions regarding this filing.

Sincerely,

Craig A. Jones

CAJ/da

Cc:
- Service List
- Allan Mitchnick, FERC
- Dave Meyers, IPC
- Nathan Gardiner, IPC
- Jim Tucker, IPC
- Jim Vasile, Davis Wright Tremaine

Temperature Control Structure Modeled Influence on Lower Granite Reservoir

Modeling Purpose

The purpose of the Corps modeling was to evaluate potential changes in water temperature between the Anatone guage and the Lower Granite reservoir tailwater resulting from two different temperature control structures (TCS) – a stoplog weir (StopL) and a gated weir with tunnel (Gattun) – at Brownlee Dam.

Modeling Approach and Results

The modeling approach decided upon by members of the Hells Canyon Settlement Working Group was to model both low water year and medium water year conditions based on water years 1992 and 1995, respectively. The Hells Canyon Complex CE-QUAL W2 model (Zimmerman et al. 2002)[1] was used to simulate base conditions (no TCS), StopL conditions, and Gattun conditions, assuming proposed operations of the Hells Canyon Complex as presented in the Hells Canyon Complex Final License Application and in AIR WQ-2(b). The two weir structures were modeled such that cold water was optimized to meet the fall chinook salmon spawning criteria of 13 degrees C on October 23. Graphical displays of the Hells Canyon Complex CE-QUAL W2 model results for the 1992 and 1995 water years are provided in Appended Figures 1 and 2.

The Hells Canyon CE-QUAL W2 output provided boundary conditions to MIKE11, a one-dimensional, variable flow and temperature model developed for the free-flowing reach of the Snake River between the Hells Canyon Complex and Lower Granite Reservoir (Rungø 2003)[2]. The MIKE11 model was used to simulate both flow and temperature at the Anatone Gage (River Mile 167.7), approximately 20 miles upstream of the Lower Granite reservoir, and serves as the boundary location for the Corps CE-QUAL-W2 model developed for Lower Granite Reservoir. Graphical displays of the Hells Canyon Complex MIKE11 model results for the 1992 and 1995 water years, which served as boundary conditions to the Corps model, are provided in Appended Figures 3 and 4.

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[1] Zimmerman, S., S. E. Parkinson, R. Myers, S. K. Parkinson, J. Harrison, and M. Kasch. 2002. Hells Canyon Complex reservoir water quality modeling. In: S. K. Parkinson, editor. Chapter 4. Project hydrology and hydraulic models applied to the Hells Canyon Reach of the Snake River. Technical appendices for new license application: Hells Canyon Hydroelectric Project. Idaho Power, Boise, ID. Technical Report E.1-4.

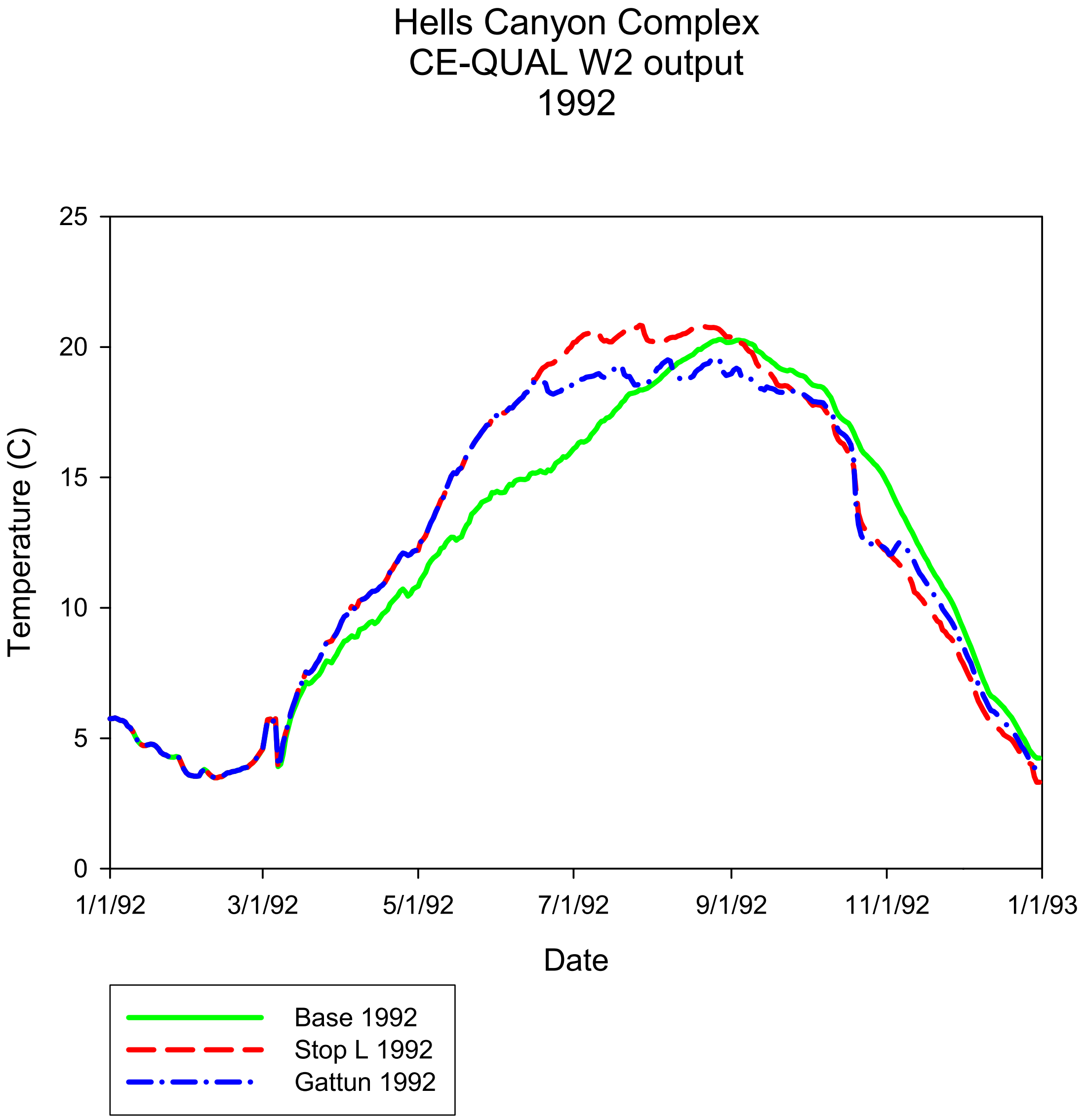
[2] Rungø, M. 2001. Hells Canyon MIKE 11 hydrodynamic model. In: S. K. Parkinson, editor. Chapter 5. Project hydrology and hydraulic models applied to the Hells Canyon Reach of the Snake River. Technical appendices for new license application: Hells Canyon Hydroelectric Project. Idaho Power Company, Boise, ID. Technical Report E.1 4.

Operations of Dworshak Reservoir, located on the North Fork of the Clearwater River, has the potential to strongly influence temperature conditions in the Lower Granite Reservoir and tailwater. The Clearwater river is tributary to the Snake River and enters the Snake River within Lower Granite Reservoir. Operations of Dworshak Reservoir in 1992 and 1995 water years differed than present day operations. Presently, operations at Dworshak begin to draft the reservoir in early July to provide flow augmentation and cooler water temperatures intended to benefit outmigrating juvenile fall chinook salmon in Lower Granite Reservoir. These operations at Dworshak Reservoir presently extend into early September. It was assumed in this modeling effort that Dworshak Reservoir would be operated as it is presently, thereby modifying conditions of the 1992 and 1995 water year boundary conditions for the Corps Lower Granite Reservoir CE-QUAL W2 Model. Graphical displays of the Corps CE-QUAL W2 model are provided in Appended Figures 5 and 6.

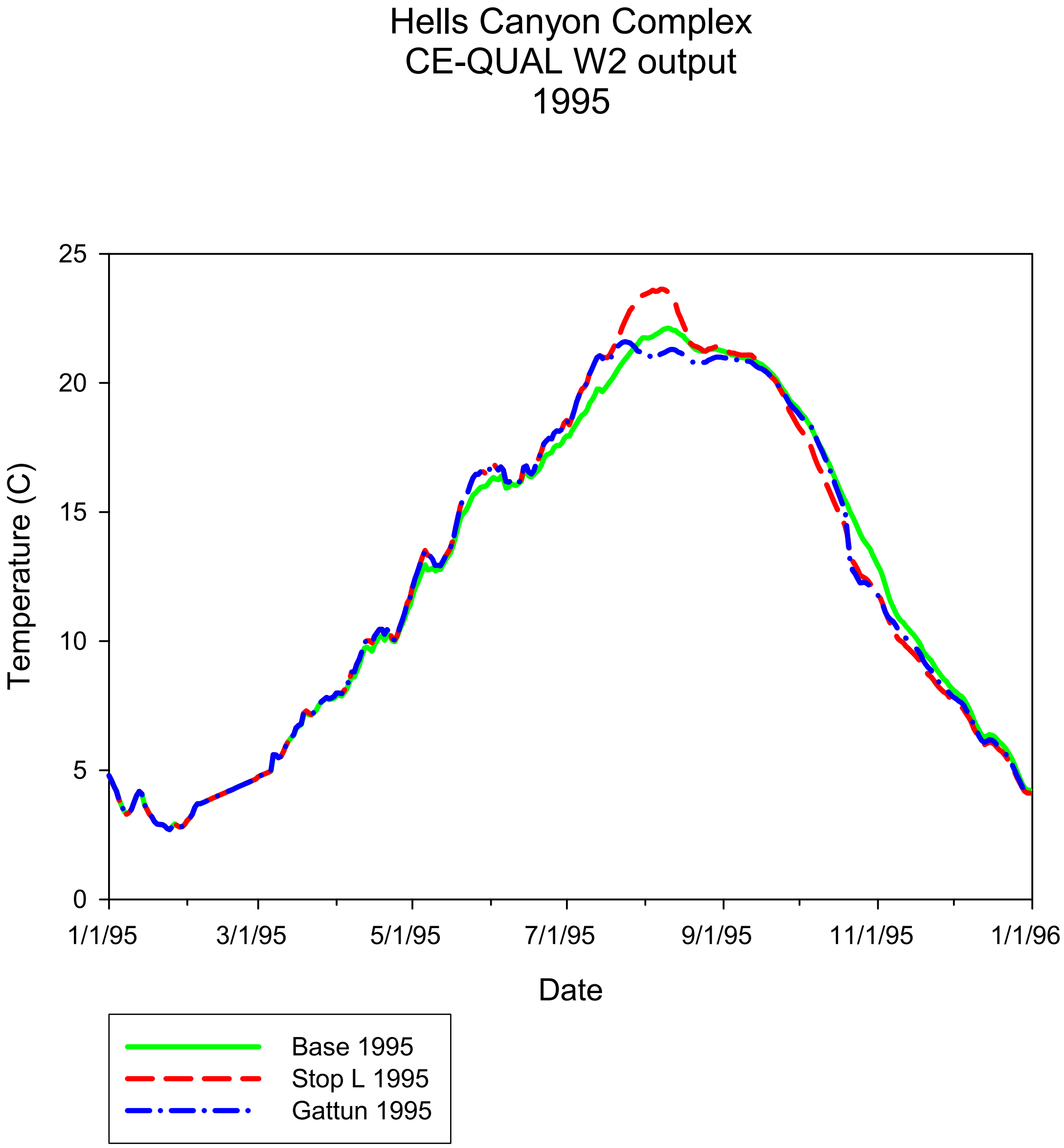
Conclusion

Idaho Power and the Hells Canyon Settlement Working Group continue to discuss the merits of installing and operating a TCS at Brownlee Dam. The implications of this modeling effort will be used to assess the effects, whether positive or negative, of a TCS on fall Chinook salmon, including spawning and migration, and other aquatic resources.

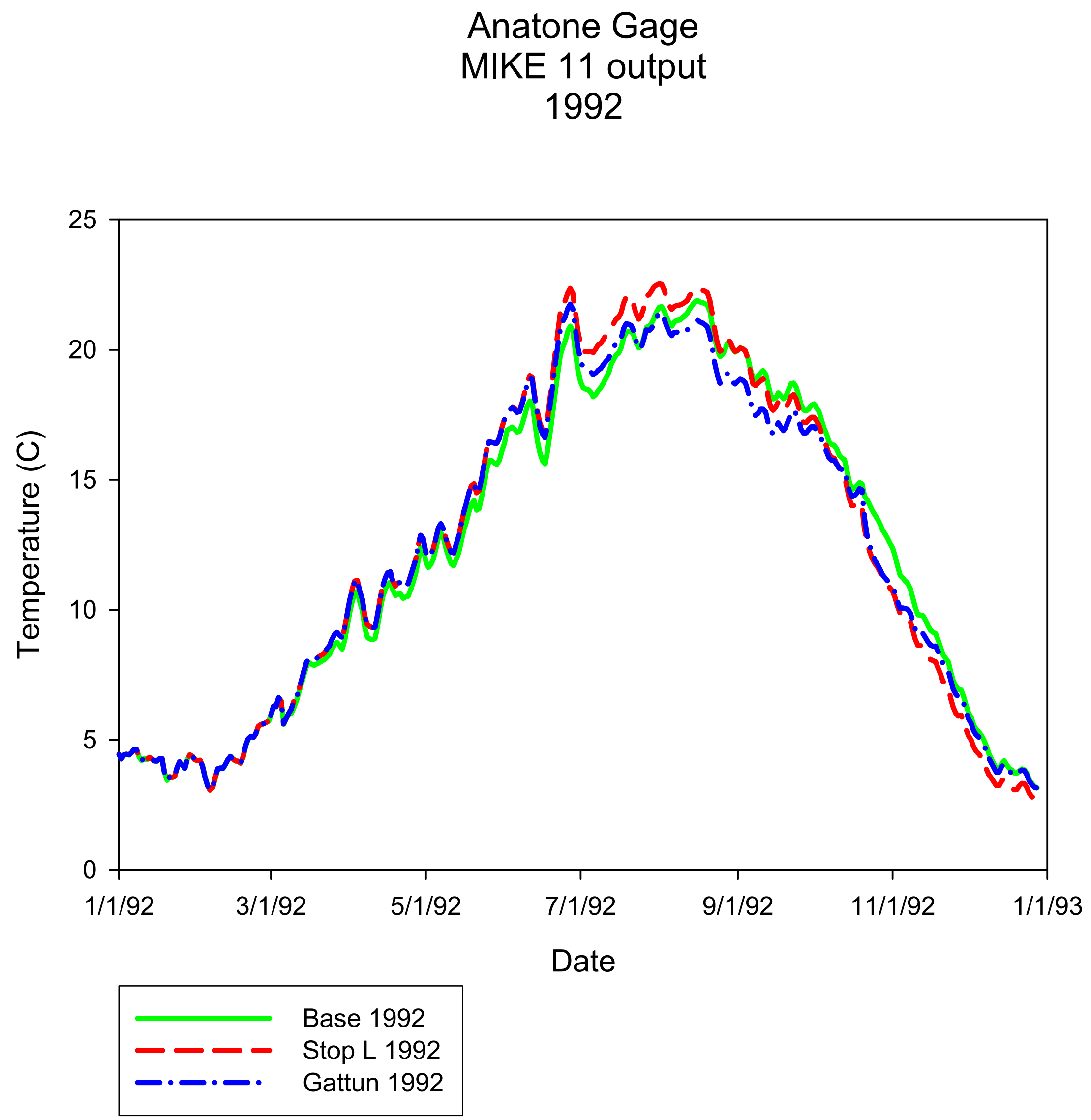
Appended Figures



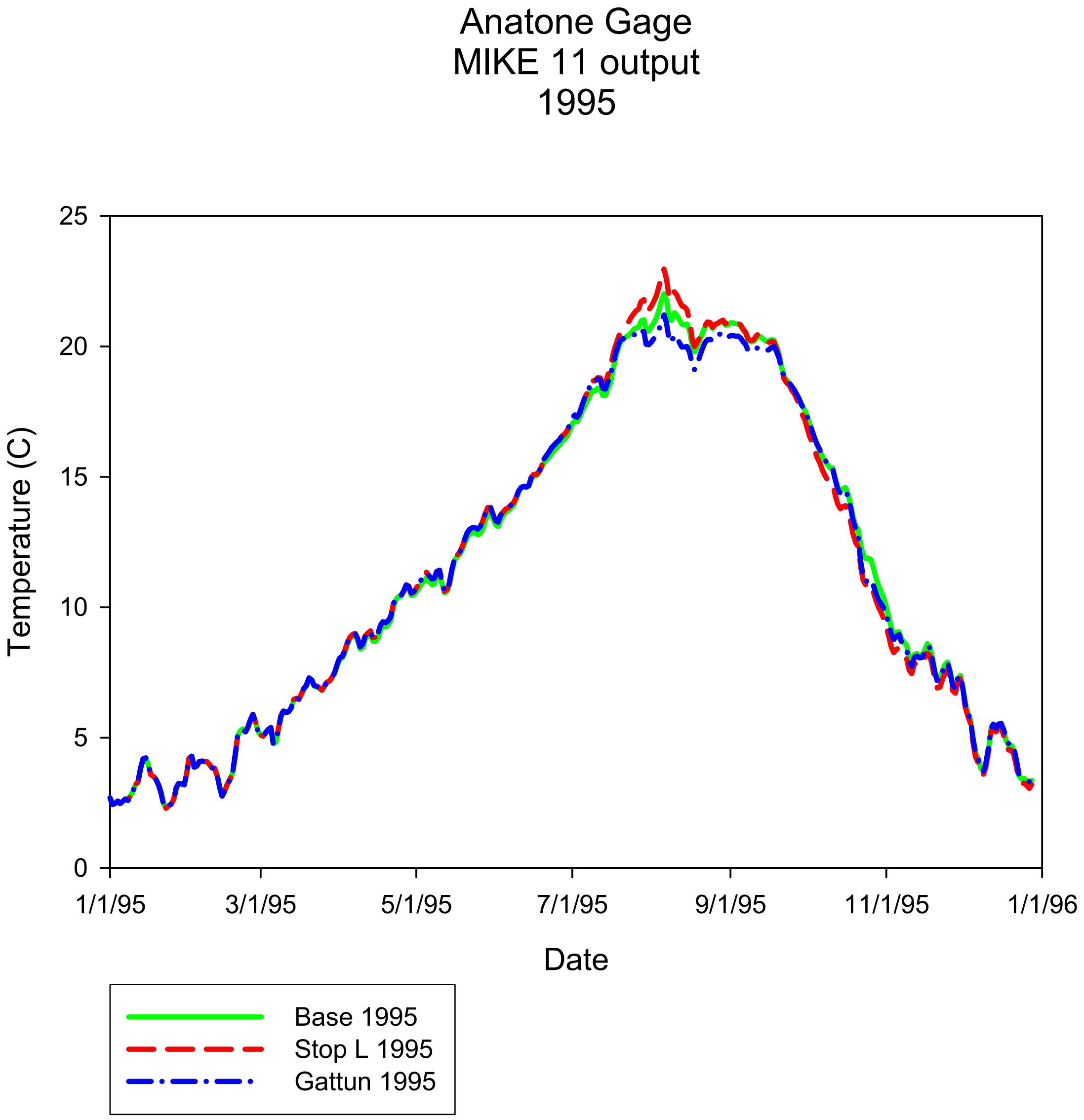
Appended Figure 1. Hells Canyon Complex CE-QUAL W2 modeled water temperatures below Hells Canyon Dam, 1992 of 1) Base conditions (no temperature control structures in Brownlee Reservoir), 2) Stop Log weir temperature control structure, and 3) Gated weir with tunnel temperature control structure.



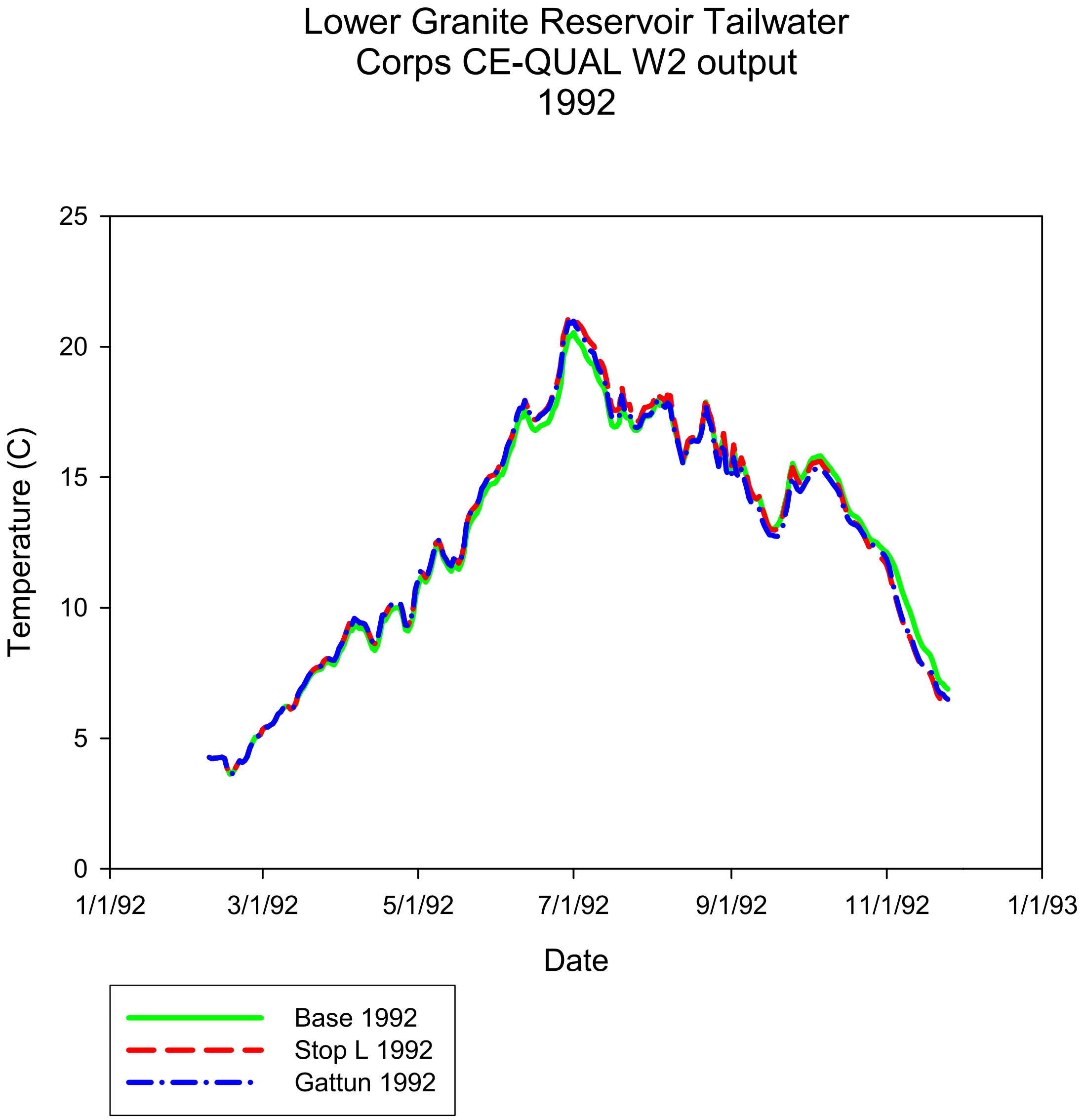
Appended Figure 2. Hells Canyon Complex CE-QUAL W2 modeled water temperatures below Hells Canyon Dam, 1995 of 1) Base conditions (no temperature control structures in Brownlee Reservoir), 2) Stop Log weir temperature control structure, and 3) Gated weir with tunnel temperature control structure.



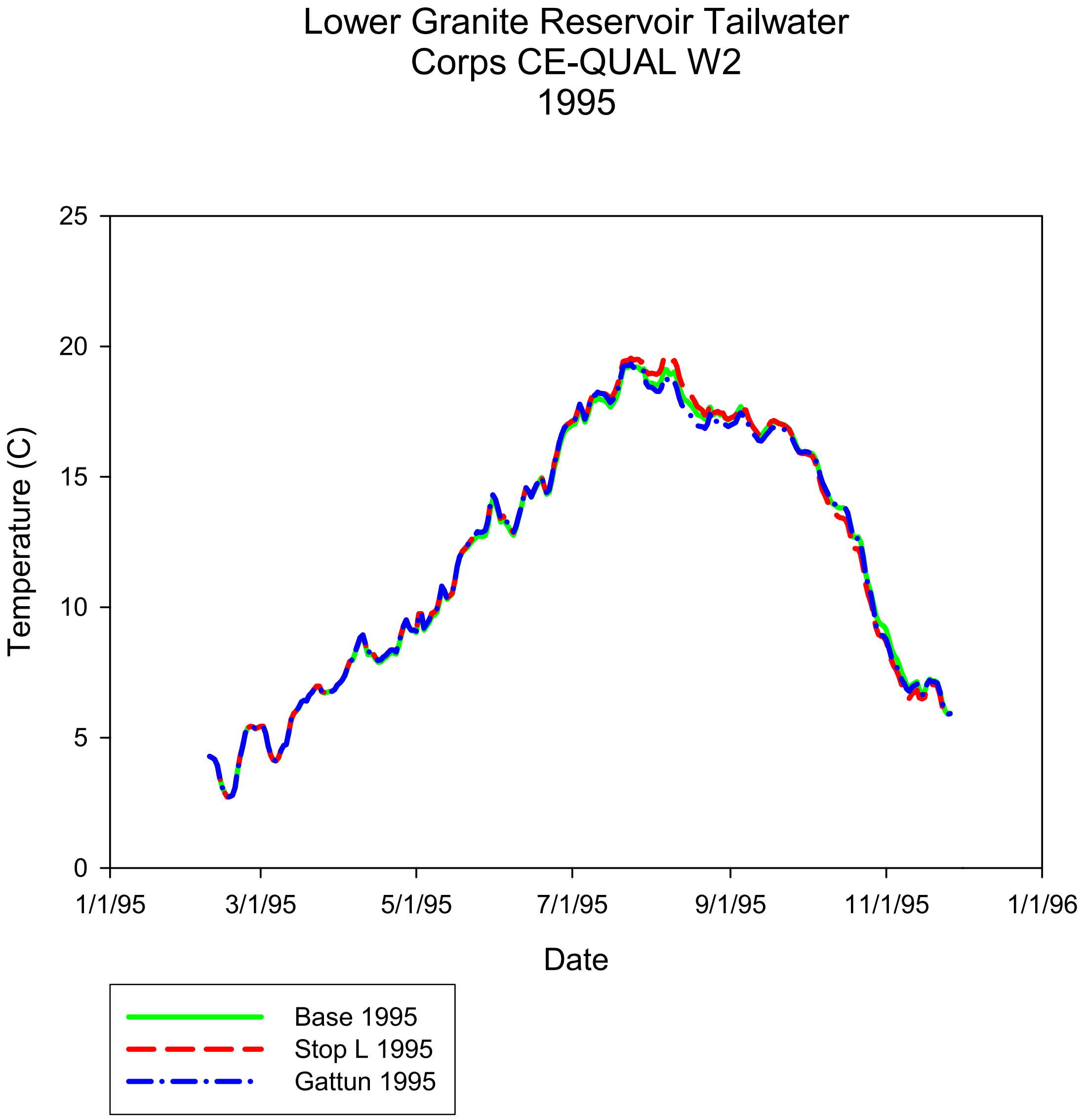
Appended Figure 3. Hells Canyon Complex Mike 11 modeled water temperatures at the Snake River Anatone Gage, 1992 of 1) Base conditions (no temperature control structures in Brownlee Reservoir), 2) Stop Log weir temperature control structure, and 3) Gated weir with tunnel temperature control structure.



Appended Figure 4. Hells Canyon Complex Mike 11 modeled water temperatures at the Snake River Anatone Gage, 1995 of 1) Base conditions (no temperature control structures in Brownlee Reservoir), 2) Stop Log weir temperature control structure, and 3) Gated weir with tunnel temperature control structure.



Appended Figure 5. Corps of Engineers CE-QUAL W2 modeled water temperatures at the Lower Granite Reservoir Tailwater, 1992 of 1) Base conditions (no temperature control structures in Brownlee Reservoir), 2) Stop Log weir temperature control structure, and 3) Gated weir with tunnel temperature control structure.



Appended Figure 6. Corps of Engineers CE-QUAL W2 modeled water temperatures at the Lower Granite Reservoir Tailwater, 1995 of 1) Base conditions (no temperature control structures in Brownlee Reservoir), 2) Stop Log weir temperature control structure, and Gated weir with tunnel temperature control structure.

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Responses to FERC Additional Information Request WQ-2(c)

Dissolved Oxygen Augmentation Using Forced Air

Appendix B

Hells Canyon Project
FERC No. P-1971-079

October 2005

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Hells Canyon Complex Final License Application
Additional Information Requests
WQ-1

Dissolved Oxygen Augmentation Using Forced Air

November 2004

Executive Summary

Mobley Engineering, Inc. has provided conceptual designs and cost estimates for forced air systems for the hydroturbine units at Brownlee Dam. Results from previous turbine venting tests and a calibrated bubble plume model were used to evaluate air flow requirements to obtain 1 mg/L and 2 mg/L uptakes as well as total dissolved gas levels. For all units, a 2 mg/L DO increase is likely to reach and may slightly exceed desirable total dissolved gas levels.

For Unit 5 an air supply building would be required on the exterior top deck level. Air supply piping would be routed down a stairway to the pump room and connected to existing compressed air water depression piping. Pressure requirements for Unit 5 were evaluated using a pipe flow program and a conceptual piping design. Two blowers each rated at 6,500 scfm and 900 to 1,000 HP would be operated to supply approximately 1 mg/L of DO uptake each as needed. Estimated capital costs are $1M to $1.5M for a one unit or two unit installation respectively. Operating costs are calculated separately.

For Units 1 – 4, the blowers could be installed on the draft tube level. Air supply piping would be routed to the existing vacuum breaker piping. Two blowers each rated at 6,500 scfm and 800 to 900 HP would be operated to supply approximately 1 mg/L of DO uptake each as needed. Estimated capital costs are $0.75 M to $1.2M for a one unit or two unit installation respectively. Operating costs are calculated separately.

Introduction

Forced air aeration utilizes compressors or blowers to force air into the draft tube, either through passages in the turbine or through the draft tube wall. Oxygen from this air is then dissolved into the water to increase the DO in the turbine discharges. The blowers are operated when the turbines are running. This alternative is similar to turbine venting, placing air in the draft tube for aeration and is generally applied only if turbine venting was unsuccessful at meeting desired dissolved oxygen uptake levels. Oxygen transfer is obtained in the turbulent flow of the draft tube and as the bubble rises to the surface in the tailrace. Long, deep draft tubes increase oxygen transfer efficiency by providing high hydrostatic pressure driving force and bubble-water contact time. Forced air systems include mechanical compressors or blowers, electric supply, air piping, and controls. Turbine efficiency is often reduced in proportion to the amount of air in the draft tube. Like turbine venting, water flow patterns in the turbine are changed with the introduction of air. Cavitation is typically reduced with the introduction of air but cavitation damage patterns may be changed. Mechanical equipment like a large air blower requires a significant amount of maintenance. Electric power requirements are large and may not be available without installation of additional station service capacity at the powerhouse.

Previous Experience:
Idaho Power currently utilizes forced air at American Falls Dam.

Forced air is also currently being used at two TVA projects, Tims Ford and Nottely. Both TVA projects are unmanned hydro stations. There are two forced air blowers at Tims Ford, a 350 HP 4,400-scfm Unit and a 200 HP, 3,400-scfm Unit. Both of these blowers force air into a distribution ring around the draft tube of the single 45MW Unit discharging about 4,800 cfs. Operation of the blowers is initiated with a single blower, then both as DO conditions decline. DO uptake is limited by TDG measured in the tailrace. As TDG approaches dangerous limits the operation of the penstock oxygen system is initiated to provide the desired uptake – generally operating with at least one blower. Installation of the Tims Ford system cost approximately $800,000 in 1993 (Harshbarger et. al. 1995)

Application of Forced Air to Brownlee Unit 5

Description

Unit 5 is a 265 MW unit with a turbine flow of about 12,000 cfs at normal operating conditions and peak efficiency. Forcing air into the draft tube of Unit 5 appears to be a viable option for increasing the dissolved oxygen in the turbine discharge. The centerline of the unit is situated 6-feet below the usual tailwater elevation, thus turbine venting is not feasible due to passageway pressures that are greater than atmospheric pressure.

If air were to be introduced through the vacuum breaker ports, the static pressure to be overcome should be on the order of 7 feet of water or about 3 psi. If air were to be introduced into the draft tube at the level of the discharge ring chamber, the static pressure to be overcome should be on the order of 6.5 psi. The draft tube pressure gage typically indicates 9 to 10 psi at peak efficiency with a maximum of 12 psi. These relatively low pressures suggest that a low pressure-high volume air blower(s) would be suitable to supply air for aeration at either location.

The size of the piping available and the area of the intricate passages beneath the head cover may limit the amount of air that can be introduced through the existing vacuum breaker system. The discharge ring chamber however appears to provide an area for air injection that is easily accessible and which could accommodate enough ports around the periphery of the draft tube to obtain good air distribution which increases DO uptake efficiency. It appears quite possible that existing depression air piping already present in the discharge ring chamber, may be modified to accommodate an additional air supply from a new blower or blowers.

An examination of available drawings and a tour of the Brownlee hydro facility disclosed an area on the top deck level of the plant which should be adequate and conveniently located for the installation of blowers to supply aeration air to Unit 5. Piping from this blower(s) could be routed into an existing building and down stairwells through four intermediate floors to the draft tube floor level. From there it could be connected to the existing depression air piping for introduction into the draft tube through the discharge ring chamber. A schematic sketch showing such an air supply system is shown as Figure 1.

Air Supply Requirements

The amount of injected air needed to raise the DO depends upon the efficiency of oxygen uptake as the flow passes through the draft tube. To determine the air requirements, a bubble plume model was used to track oxygen transfer from bubbles in the draft tube and tailrace.

Discrete-Bubble Model

A discrete-bubble model (DBM) that predicts the rate of oxygen transfer in diffused-bubble systems was applied to a draft-tube system and tailrace to simulate the effects of turbine aeration for the units at Brownlee. Key inputs are the water flow rate through the turbine, the air flow rate, and the initial bubble size. The model accounts for changes in the volume of individual bubbles due to transfer of oxygen and nitrogen (and hence changing partial pressure), variation in hydrostatic pressure, and changes in temperature. The bubble-rise velocity and mass-transfer coefficient, both known functions of the bubble diameter, are continually adjusted.

Calibration of the DBM for Predicting DO in Discharges from Brownlee Hydro

The model was set up for the draft tube geometries of Units 1- 4 and Unit 5, and then calibrated using test data collected in 2000 on Unit 4 to measure DO uptake through the unit over the full range of turbine operating conditions. Figures 2 shows how the model for Unit 4 at Brownlee matched the data collected during the testing in 2000. Predictions for TDG seemed high and were manually adjusted downward by 4% to better meet actual results yet still be safely conservative.

Since data were not available for Unit 5, information from a model calibration on a similar unit owned by SCE&G (Saluda Hydro Unit 5) was used for model settings for Unit 5 at Brownlee.

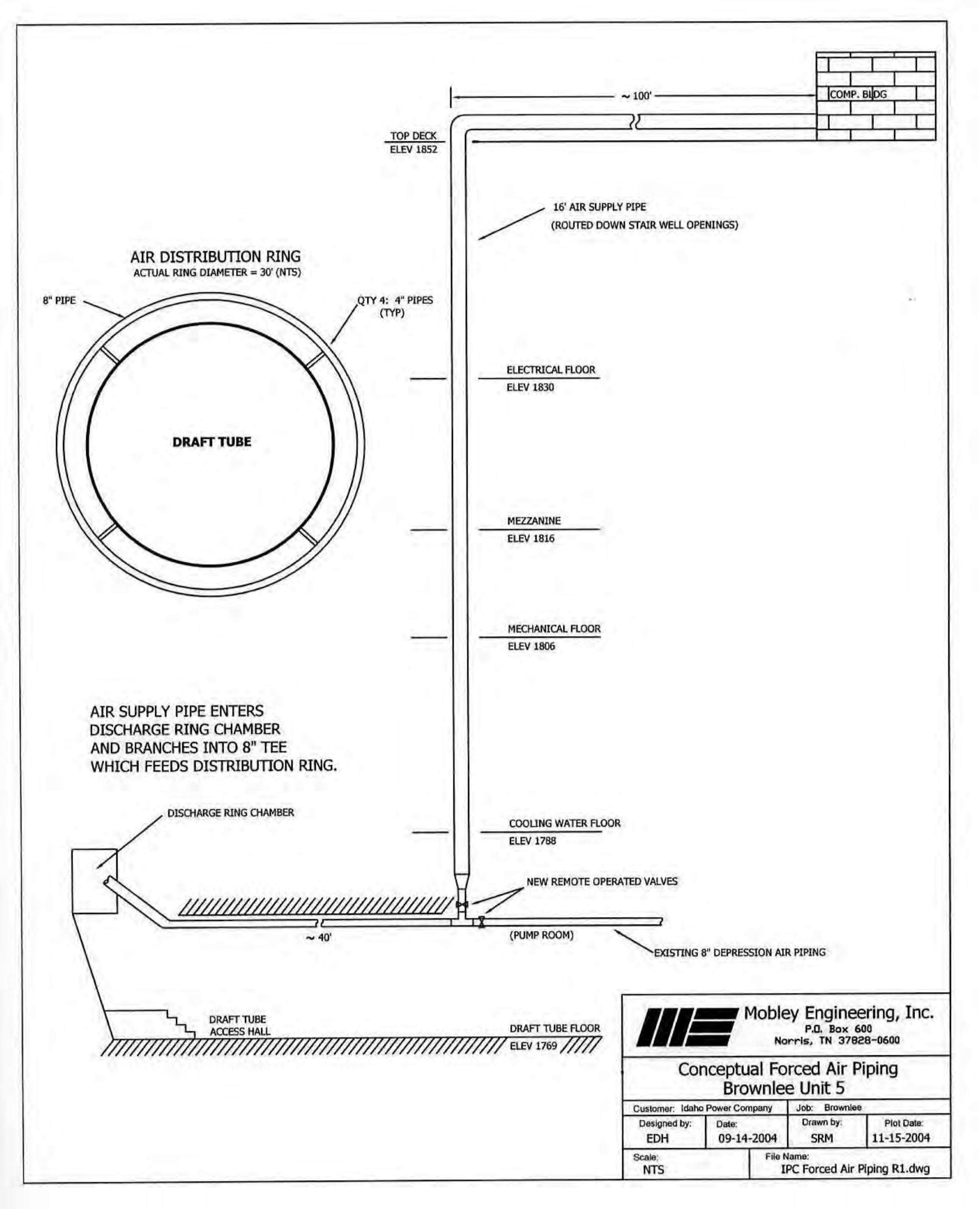
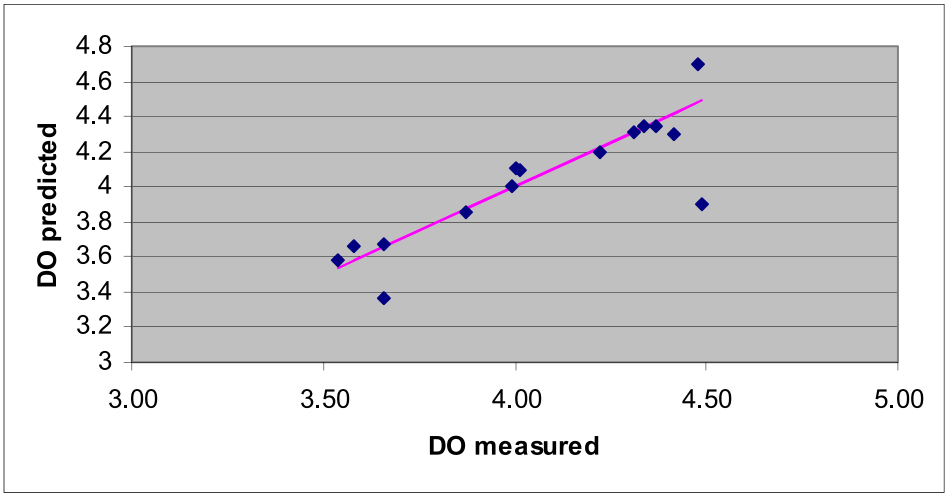
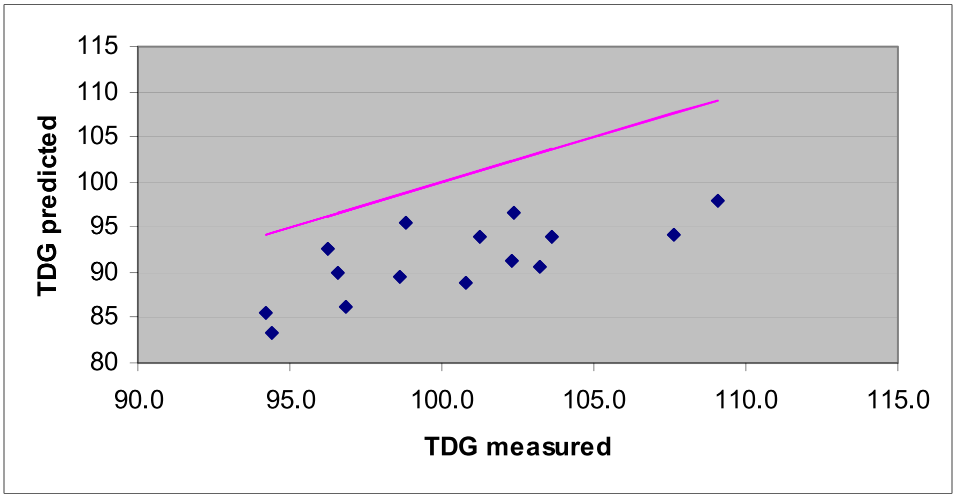


Figure 1: Conceptual Layout Drawing – Unit 5 Forced Air Piping





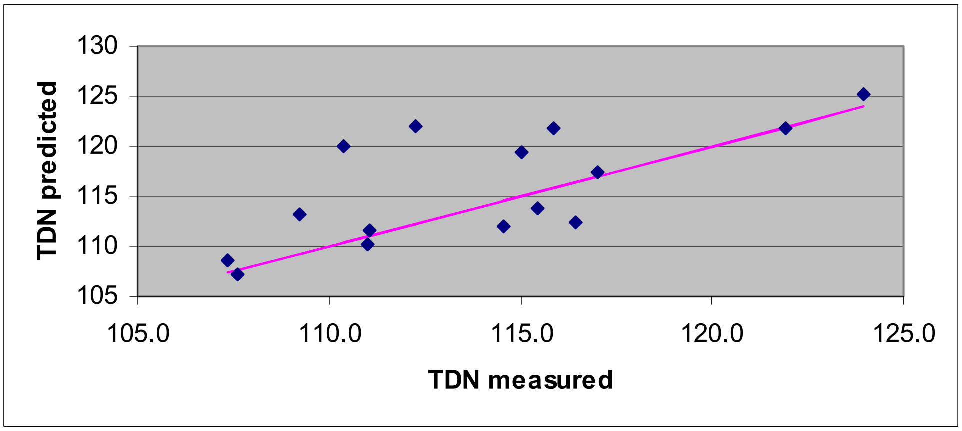


Figure 2: Example of Model Calibration Results for Brownlee Unit 4 Tests with Hub Baffles

The results of modeling the Unit 5 draft tube indicate that the oxygen transfer efficiency will be on the order of 40% decreasing with increasing air flow as shown in Figure 3.

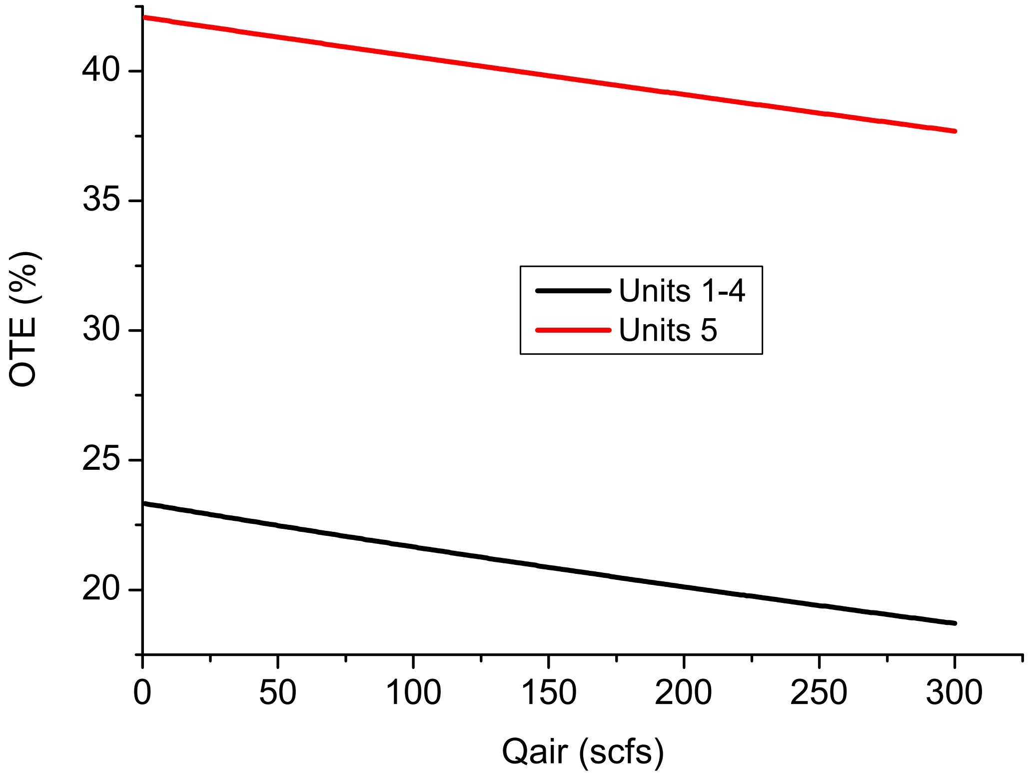
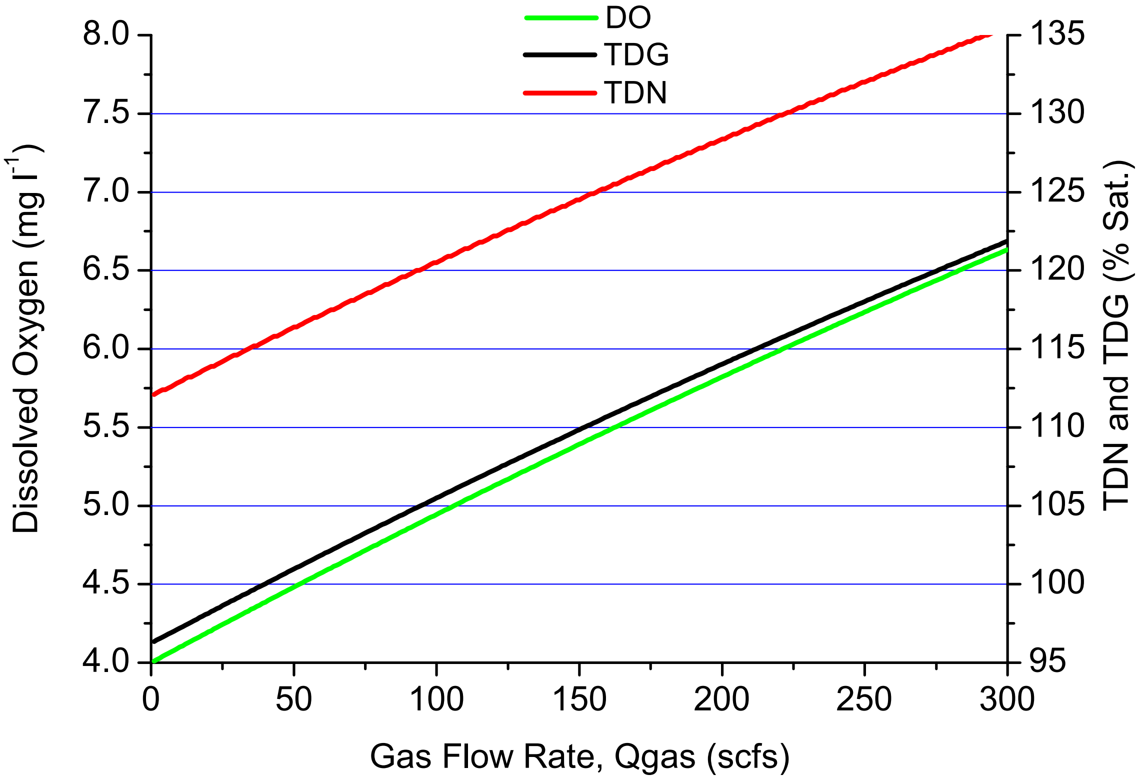


Figure 3: Predicted Oxygen Transfer Efficiency for Units 1-4 and Unit 5 Draft Tubes

The model predictions indicate that the tailrace DO of Unit 5 will be increased about 1 mg/L for every 107 cfs of air injected as shown in Figure 4.



For Unit 5 initial conditions:
Q = 12,000 cfs
Incoming DO content = 4.0 mg/L
Bubble radius = 1.3 mm
TDG = 96%
TDN = 110%
TWEL = 1802.6 ft
Water temperature = 21.75 °C

Figure 4: Predicted Dissolved Oxygen, Total Dissolved Nitrogen and Total Dissolved Gas for Unit 5

The amount of air that can be injected to increase dissolved oxygen may be limited by the resulting levels of total dissolved gas (TDG). As shown in Figure 3, preliminary modeling of the Unit 5 draft tube indicates that an air flow of about 215 scfs (13,000 scfm) results in 115% TDG, and a DO uptake of about 2 mg/L. This flow rate was used as the maximum design condition for Unit 5. The DBM considers only nitrogen and oxygen in tracking gas content of the water and bubbles. Other gases may need to be considered in future analyses.

Air Supply Pipe Sizing:

The pressure requirements for the air supply equipment will be a function of the draft tube operating pressure and piping losses in the supply piping. A preliminary evaluation of the air supply pressure requirements was performed using a pipe flow model (CFSIM-Schohl 2003). The following piping arrangement was evaluated:

- 16 inch pipe from the air supply equipment on the top deck (elevation 1852) down the stairs to the pump room (elevation 1769) – approximately 250 feet
- Tee into existing 8 inch depression air piping
- Existing 8 inch pipe from pump room to and around draft tube discharge chamber – approximately 250 feet total
- Four – 4 inch pipes into the draft tube wall
- 12 psig at the draft tube water flow

This evaluation indicated that a pressure of 27 psig would be needed to move 13,000 scfm of air through the air supply piping. Actual pipe routing, valves and fittings may result in additional pressure losses. Therefore a design condition of 30 to 35 psi was used for conceptual blower specifications.

Blower Description:

Two blowers were specified to provide a total of 13,000 scfm at 30 to 35 psig.

- Size - rough dimensions for each blower: (final dimensions will depend on motor selected)
    - Width - 80 inches (approximate)
    - Height to discharge flange - 57 1/4"
    - Overall height - 70" (Dependant on type and brand of motor selected)
    - Length - 104" (Dependant on type and brand of motor selected)
- Power requirements – 900 to 1,000 HP each
    - 13.8 KV motor
- Cooling requirements
- Noise level – 85 dBA
- Enclosure – required to control noise
-

Operation:

The blowers would operate with turbine operation. Operation of one blower would provide approximately 1 mg/L of DO uptake; two blowers would provide approximately 2 mg/L.

Costs

Capital Costs

Table 1 presents estimated capital costs for systems to provide 1 and 2 mg/L of DO uptake. These preliminary costs are on the order of plus or minus 50%. More detailed studies of the plant layout, pipe routing, power supply availability, etc. will be necessary to arrive at better estimates.

Brownlee Unit 5 Forced Air Aeration- Capital Cost Estimate			
To increase DO 1 mg/L		**To increase DO 2 mg/L**	
Blower (1 at 6,500 scfm)	$375,000	Blower (2 at 6,500 scfm)	$ 665,000
Building	$ 60,000	Building	$ 80,000
Equipment	$ 12,000	Equipment	$ 13,000
Electrical switch gear	$ 70,000	Electrical switch gear	$ 105,000
Lights, heat, etc	$ 15,000	Lights, heat, etc	$ 15,000
Pipes and fittings (12in)	$100,000	Pipes and fittings (16in)	$ 130,000
Power and control conduit	$ 12,000	Power and control conduit	$ 20,000
Power and control wiring	$ 25,000	Power and control wiring	$ 40,000
Cooling water pumps and piping	$ 10,000	Cooling water pumps and piping	$ 15,000
Transformers	$ 55,000	Transformers	$ 85,000
Valves	$ 25,000	Valves	$ 40,000
Fans	$ 35,000	Fans	$ 35,000
Distribution manifold	$ 50,000	Distribution manifold	$ 50,000
Subtotal	$844,000	Subtotal	$ 1,293,000
Engineering	$100,000	Engineering	$ 120,000
Total	**$944,000**	**Total**	**$ 1,413,000**

Table 1: Estimated Costs for Forced Air Installation at Unit 5

Operating Costs

The operating costs include blower power consumption costs, the turbine energy losses due to the injection of air and blower maintenance costs Blower power consumption costs can be estimated by the equation:

$$C=(hp \times 0.746kw / hp \times R \times T) / E_m$$

Where C = blower power consumption costs
hp = blower horsepower
R = cost of electricity ($/kwh)
T = number of hours operated
E_m = blower motor efficiency

Blower motor efficiency can be assumed to be 90%

Based upon previous experience for an air/water flow rate ratio 0.009 (107/12000) for a 1 mg/l increase, turbine efficiency loss would be on the order of 0.5%. For an air/water flow rate ratio 0.018 (215/12000) for a 2 mg/l increase, turbine efficiency loss would be on the order of 1%. Therefore, aeration induced energy losses can be approximated by the equation:

$$E_t = 0.01 \times P \times R \times T$$

Where:
E_t = cost of energy lost ($)
P = turbine power output (kw)
R = value of electricity ($/kwh)
T = number of hours of operation

Based upon past experience, blower maintenance costs could be expected to be on the order of $10,000/year.

The total annual operational costs of aeration using forced air would therefore be C + E_t + $10,000.

Application of Forced Air to Units 1 - 4

Description

Based upon the results of the tests conducted in August 2000 on Brownlee Unit 4, the amount of DO uptake available by applying turbine venting techniques to the existing turbines may be limited to less than 1 mg/L unless more costly modifications are made. Therefore, a forced air system using blowers to inject air into the existing vacuum breaker piping is being investigated.

Air Supply Requirements

The data from the 2000 tests indicate that the DO uptake efficiency for Units 1-4 would be on the order of 20% (as shown in Figure 3). Or that about 0.6 mg/L of DO uptake can be expected for every 1% air by volume in the draft tube as shown in the DBM results presented in Figure 5. Therefore, based upon a water flow of about 6000 cfs, an air flow of 210 cfs would be needed to increase the DO by 2 mg/L. TDG levels are predicted to be about 111% at this air input rate.

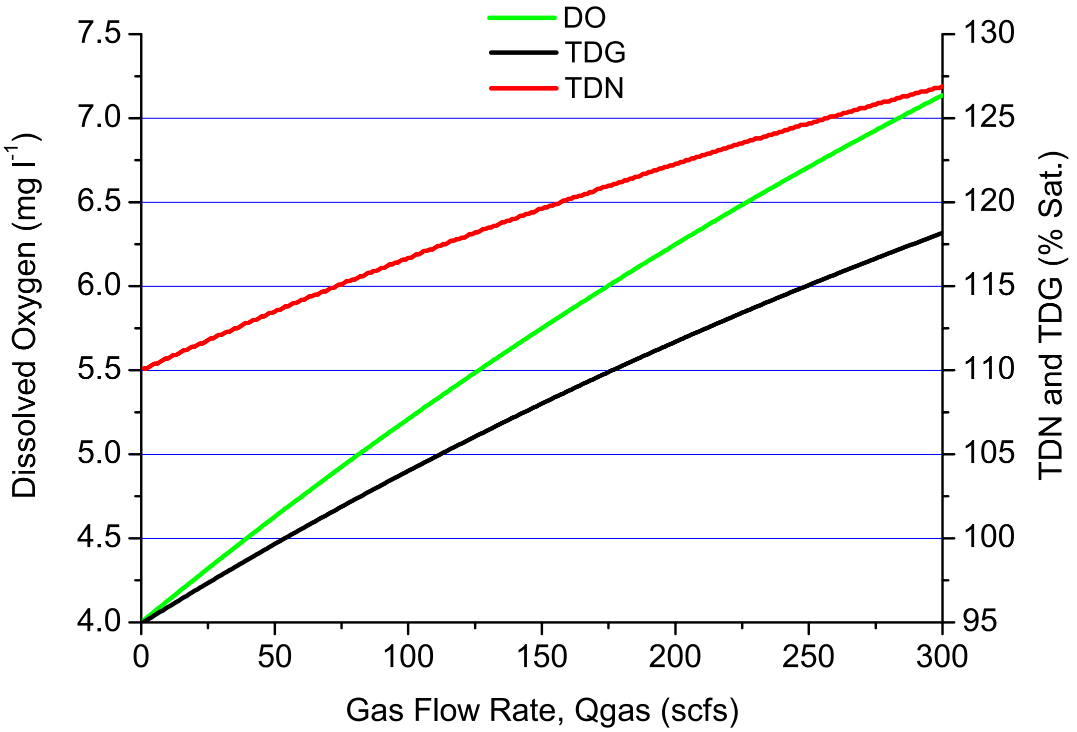


Figure 5: Predicted Dissolved Oxygen, Total Dissolved Nitrogen and Total Dissolved Gas for Units 1 – 4

For Units 1-4 initial conditions:
Q = 5000 cfs
Incoming DO content = 4.0 mg/L

Bubble radius = 1.3 mm
TDG = 96%
TDN = 110%
TWE = 1802.6 ft
Water temperature = 21.75 °C

Blower Description:

There appears to be sufficient space on the draft tube floor level to locate moderate sized blowers, and the vacuum breaker piping is accessible at convenient locations. Details of blower location and pipe routing would need to be further investigated.

Two blowers were specified to provide a total of 13,000 scfm at 20 to 25 psig.

- Size - rough dimensions for each blower: (final dimensions will depend on motor selected)
    - Width - 80 inches (approximate)
    - Height to discharge flange - 57 1/4"
    - Overall height - 70" (Dependant on type and brand of motor selected)
    - Length - 104" (Dependant on type and brand of motor selected)
- Power requirements – 800 to 900 HP each
    - 13.8 KV motor
- Cooling requirements
- Noise level – 85 dBA
- Enclosure – required to control noise
-

Costs

Table 4 presents estimated capital costs for systems to provide 1 and 2 mg/l DO uptake for Units 1-4. These preliminary costs are per unit and on the order of plus or minus 50%. More detailed studies of the plant layout, pipe routing, power supply availability, etc. will be necessary to arrive at better estimates.

Brownlee Unit 1 - 4 Forced Air Aeration- Capital Cost Estimate			
To increase DO 1 mg/L		**To increase DO 2 mg/L**	
Blower (1 at 6,500 scfm)	$375,000	Blower (2 at 6,500 scfm)	$ 665,000
Electrical switch gear	$ 70,000	Electrical switch gear	$ 105,000
Pipes and fittings (12in)	$100,000	Pipes and fittings (16in)	$ 130,000
Power and control conduit	$ 12,000	Power and control conduit	$ 20,000
Power and control wiring	$ 25,000	Power and control wiring	$ 40,000
Cooling water pumps, piping	$ 10,000	Cooling water pumps, piping	$ 15,000
Transformers	$ 55,000	Transformers	$ 85,000
Valves	$ 25,000	Valves	$ 40,000
Subtotal	$672,000	Subtotal	$1,100,000
Engineering	$100,000	Engineering	$ 120,000
Total	**$772,000**	**Total**	**$1,220,000**

Table 4: Estimated Costs (per unit) for Forced Air Installation at Units 1 - 4

Operating Costs

The operating costs include blower power consumption costs, the turbine energy losses due to the injection of air and blower maintenance costs. Blower power consumption costs can be estimated by the equation:

$$C=(hp \times 0.746kw / hp \times R \times T) / E_m$$

Where C = blower power consumption costs
hp = blower horsepower
R = cost of electricity ($/kwh)
T = number of hours operated
E_m = blower motor efficiency

Blower motor efficiency can be assumed to be 90%

Based upon previous experience for an air/water flow rate ratio 0.017 (105/6000) for a 1 mg/l increase, turbine efficiency loss would be on the order of 1%. For an air/water flow rate ratio 0.033 (210/6000) for a 2 mg/l increase, turbine efficiency loss would be on the order of 2%. Therefore, aeration induced energy losses can be approximated by the equation:

$$E_t = 0.02 \times P \times R \times T$$

Where:
E_t = cost of energy lost ($)
P = turbine power output (kw)
R = value of electricity ($/kwh)
T = number of hours of operation

Based upon past experience, blower maintenance costs could be expected to be on the order of $10,000/year.

The total annual operational costs of aeration using forced air would therefore be C + E_t + $10,000.

References:

Harshbarger, E. Dean, Mark H. Mobley, and W. Gary Brock, “Aeration of Hydroturbine Discharges at Tims Ford Dam using Penstock Oxygen Injection and Turbine Air Injection” ASCE 1st International Conference on Water Resources Engineering, San Antonio TX, August 1995

Schohl, Gerald, A. “Users Manual for LOCKSIM, Hydraulic Simulation of Lock Filling and Emptying Systems”, Tennessee Valley Authority, August 1998

Appendix A: Discreet Bubble Model Overview

In all oxygenation devices, gas bubbles in contact with water produce interfacial transfer of oxygen, as well as nitrogen and other soluble gases. Bubble size is a critical parameter in these diffused-bubble systems because it determines the interfacial surface area, bubble-rise velocity, and mass-transfer coefficient. In addition, bubble size may vary significantly as the bubbles pass through the system, especially when pure oxygen is used. For these reasons, Wüest et al. (1992) used a discrete-bubble model to account for changes in the volume (due to gas transfer, hydrostatic pressure, and surrounding water temperature) of individual bubbles rising within a bubble plume.

The discrete-bubble model, first adopted by Wüest et al. (1992), is applied to bubbles that travel in plug flow through the draft tube. The initial bubble size and the rate of bubble formation are assumed to be constant at a given water flow rate but are also functions of the water flow rate and are turbine specific. Bubble coalescence and mass transfer of gases other than nitrogen and oxygen are considered negligible. The water and air temperatures are assumed to be equal and constant.

The mass-transfer flux (for either oxygen or nitrogen) across the surface of a bubble is

$$J = K_L\left(C_s - C\right) \quad (\text{mol m}^{-2}\ \text{s}^{-1}) \qquad (1)$$

where K_L is the mass transfer coefficient, C_s is the equilibrium concentration at the gas/water interface, and C is liquid concentration. Henry's law is used to calculate the equilibrium concentration, or

$$C_s = HP_i \quad (\text{mol m}^{-3}) \qquad (2)$$

where H is Henry's constant and P_i is the partial pressure of the gas at a given location. Combining Equations 1 and 2 yields

$$J = K_L\left(HP_i - C\right) \quad (\text{mol m}^{-2}\ \text{s}^{-1}). \qquad (3)$$

Substituting the surface area of a bubble of radius r gives the rate of mass transfer for a single bubble as

$$\frac{dm}{dt} = -K_L\left(HP_i - C\right)\cdot 4\pi r^2 \quad (\text{mol s}^{-1}). \qquad (4)$$

The vertical location of the bubble is related to the bubble rise velocity, v_b, and the vertical water velocity, v, by

$$\frac{dz}{dt} = v + v_b \quad (\mathrm{m\ s^{-1}}) \qquad (5)$$

where z is the centerline distance in the draft tube. It is important to note that the sign of the bubble rise velocity, v_b changes depending on the location in the draft tube and the direction of flow. In the case of vertical, downward flow, the sign of v_b is negative (the sign of the water velocity, v, is always positive), resulting in longer contact time as the bubble is "rising" in downward moving water. Where the draft tube is horizontal, v_b is set to zero. It was assumed that the bubbles are still dispersed in the water at this point. However, at lower water flow rates coalescence was accomplished by using a larger bubble size at lower flow velocities, which effectively reduced the surface area to volume ratio, simulating the effect of bubble coalescence. For vertical, upward water flow, the sign of v_b is positive, resulting in shorter contact time as the bubble is now "rising" in the same direction as the moving water. Combining Equations 4 and 5 gives the mass of gaseous species transferred per bubble per unit distance of the draft tube

$$\frac{dm}{dz} = -K_L\left(HP_i - C\right)\cdot\frac{4\pi r^2}{v + v_b} \quad (\mathrm{mol\ m^{-1}}). \qquad (6)$$

The number flux of bubbles entering the draft tube, N, is calculated from the initial bubble volume, V_o, and the actual volumetric gas flow rate at the diffuser, Q_o, or

$$N = \frac{Q_o}{V_o} \quad (\mathrm{s^{-1}}). \qquad (7)$$

Multiplying Equation 6 by N and expressing it in terms of M, the molar flow rate of gas, yields

$$\frac{dM}{dz} = -K_L\left(HP_i - C\right)\cdot\frac{4\pi r^2 N}{v + v_b} \quad (\mathrm{mol\ m^{-1}\ s^{-1}}). \qquad (8)$$

Equation 8 is then integrated numerically, for both oxygen and nitrogen, to obtain the change in the molar flow rate when the gas bubble is in contact with the water. This value is used to incrementally calculate the aqueous-phase concentration as a function of time. Note that in Equation 8, H is a function of water temperature, while v_b and K_L are functions of r, the radius of the bubble. The bubble radius changes in response to decreasing hydrostatic pressure as well as the amount of oxygen and nitrogen transferred between the bubble and the water. As summarized in Table C-8, relationships for v_b and K_L were developed by Wüest et al. (1992) based on experimental data for bubble rise velocity (Haberman and Morton, 1954) and the mass transfer coefficient (Motarjemi and Jameson, 1978).

The discrete-bubble model has been verified with diffused-bubble oxygen transfer tests conducted in a 14-meter deep tank at three air flow rates. All of the test data were predicted to within 15 % (McGinnis and Little, 2002). The range of bubble diameters during the test (0.2 to 2 mm) spanned the region of greatest variation in rise velocity and mass-transfer coefficient. This approach has subsequently been successfully applied to airlift aerators (Burris and Little, 1998; Burris et al. 2002), the Speece Cone (McGinnis and Little, 1998), linear and circular bubble-plume diffuser (Wüest et al. 1992, Little and McGinnis, 2001, McGinnis et al. 2001) and side stream super-saturation systems.

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Exhibit 7.1-16

November 6, 2006, National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service's comments on the draft environmental impact statement (DEIS) for the Hells Canyon Hydroelectric Project

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Region
7600 Sand Point Way N.E., Bldg. 1
Seattle, WA 98115

F/NWR

VIA ELECTRONIC FILING

November 3, 2006

Magalie R. Salas, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, DC 20426

RE: National Marine Fisheries Service's comments on the Federal Energy Regulatory Commission's Draft Environmental Impact Statement for the Hells Canyon Hydroelectric Project (FERC Project No. 1971-079).

Dear Secretary Salas:

The National Marine Fisheries Service (NMFS) appreciates this opportunity to comment on the Draft Environmental Impact Statement (DEIS) for the Hells Canyon Hydroelectric Project (Project). This letter and enclosure provide: (1) NMFS' response to the Federal Energy Regulatory Commission's (FERC) Section 10(j) preliminary determination of inconsistency, as provided in the DEIS and FERC's letter to Robert Lohn dated August 2, 2006; (2) NMFS' comments on the deficiencies of the DEIS as a biological assessment for Endangered Species Act (ESA) purposes to initiate formal consultation, as promised in our letter of September 7, 2006; and (3) NMFS' comments on the DEIS.

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NMFS does not consider that FERC has initiated formal consultation under Section 7 of the ESA because the DEIS is inadequate as a biological assessment. The DEIS does not provide a sufficiently well-defined proposed action that forms the basis for consultation. The DEIS also does not adequately evaluate the effects of the alternatives on listed fish, does not provide a sufficient evaluation of the environmental baseline, and does not consider the effects on nine listed species that use the Columbia River migratory corridor. FERC needs to correct these deficiencies before formal consultation can begin.

NMFS has considerable expertise in anadromous fish issues in the Snake River basin. We have written biological opinions on the operation of both the Bureau of Reclamation water storage projects that lie upstream of the Project and the Federal Columbia River Power System (FCRPS) projects in the Snake and Columbia rivers which are located largely downstream of the Project. We participated in the relicensing of Idaho Power Company's (IPC) Mid-Snake River and C.J. Strike projects and have participated in the Hells Canyon Project relicensing process for over eight years. In short, we have

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thoroughly analyzed the effects of this Project and are aware of the history surrounding it and also understand the technical complexity of the environmental issues that surround it.

1. Comments on FERC's Section 10(j) Preliminary Determination of Inconsistency

FERC should reconsider its 10(j) decisions and accept recommended conditions provided to FERC by NMFS under Section 10(j) of the Federal Power Act (FPA). The recommended measures are consistent with applicable law because they provide the needed mitigation for the Project's impacts on anadromous fish and are based on substantial information in the record. FERC's rejection of some of NMFS' recommended conditions and modification of others in not warranted under Section 10(j) because FERC's alternatives do not provide adequate mitigation for Project effects, as required in Section 10(j), and in some cases, do not have support in the record.

- NMFS-4: FERC's mitigation for entrapment and stranding, a ramping rate of 4 inches per hour, will help reduce project impacts, but will not eliminate entrapment pools. Therefore, minimum flows of 11,500 cfs at certain times are needed to protect rearing salmon caught in entrapment pools.
- NMFS-7: FERC's rejection of monitoring downstream spawning habitat because it is now high quality is not a guarantee that it will remain unchanged, and therefore does not ensure that there is adequate mitigation for project effects. Monitoring of downstream spawning areas every five years is needed to ensure that important downstream spawning and rearing habitat is not degrading.
- NMFS-9: FERC's proposed assessment of the effectiveness of this measure using adult returns (to be incorporated into a 2009 report for further consideration by the Commission) is not scientifically credible, and therefore would not provide adequate mitigation for Project effects. IPC should provide 237 kaf of water from Brownlee Reservoir to enhance migration conditions in the lower Snake River between June 21 and July 31.
- NMFS-13b: Hatchery HGMPs and performance monitoring are necessary to ensure that IPC's hatchery program conforms with NMFS' policy on artificial propagation.
- NMFS-14: FERC's choice of denying the first step in reintroduction of fall Chinook salmon, as mitigation for the Project effect of blocked passage and inundated habitat, has no basis in the FPA because FERC does not provide adequate alternative means of mitigation, and should be reversed. A Water Quality Improvement Fund is an integral part of a phased approach to possible fall Chinook salmon reintroduction upstream of the project, and is needed to mitigate for the Project effect of blocked access to historic upstream habitat and inundated habitat, and is conceptually no different than the upstream habitat work that FERC found appropriate for bull trout. This work is consistent with NMFS' resource management goals and objectives for salmon and steelhead and furthers federal and state work in the Columbia River basin to restore the habitat of

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ESA listed species – especially Snake River fall Chinook salmon. Water quality monitoring upstream is needed to ensure that the mitigation measures are effective and clean up is proceeding according to criteria set out by NMFS. Egg-to-fry survival studies in historic spawning areas are necessary to determine when spawning gravels will be able to support spawning and rearing.

- NMFS-15: FERC's alternative of monitoring flows 17 miles downstream of the Project does not provide accurate information regarding project operations, and therefore is not a valid alternative form of mitigation for NMFS-15. Monitoring flows within 1 mile downstream of the Project is important to accurately measure compliance with license terms.
- NMFS-16 and17: FERC's rejection of passage studies during the term of the upcoming license denies the possibility of providing adequate mitigation for project effects in a timely manner, and therefore is not consistent with the FPA. Passage studies during the last 10 years of the license are needed to prepare for the second phase of reintroduction, passage during the term of the license after this upcoming one.

2. Comments on DEIS with Respect to Its Serving as a Biological Assessment

NMFS does not consider the DEIS to be adequate for FERC to use as a biological assessment to initiate formal ESA Section 7 consultation. The DEIS does not provide NMFS with a sufficiently defined proposed action, it does not sufficiently evaluate the effects of any alternative on ESA listed Snake River salmon and steelhead and nine other listed species that use the lower Columbia River migratory corridor, and it does not provide a sufficient evaluation of the environmental baseline (as we described in our scoping comments). NMFS remains committed to working with FERC or its designated non-federal representative to develop a proposed action that would avoid jeopardy and adverse modification of critical habitat, and a biological assessment that properly evaluates the environmental baseline and effects of the action. If FERC chooses to rely upon the DEIS as a biological assessment, FERC should issue a Supplemental DEIS that addresses the concerns raised by NMFS. A Supplemental DEIS would then be appropriate because there would be substantive changes to the proposed action and analysis of effects.

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In addition, NMFS disagrees with FERC's determination that the Project and its operations are not likely to adversely affect nine species of salmon and steelhead migrating in the lower Columbia River, estuary, and nearshore ocean environment. We recommend that FERC address this deficiency by including appropriate analysis of the environmental baseline and analysis of effects for this species in a biological assessment of Supplemental DEIS. The recent NMFS biological opinion on the U.S. Bureau of Reclamation's Snake River Basin projects would be a good source for this information: http://seahorse.nmfs.noaa.gov/pls/pcts-pub/sxn7.biop_results_detail?reg_ inclause_in=('NWR')&idin=22363

3. Comments on FERC's DEIS for the Hells Canyon Hydroelectric Project

FERC should make some significant changes to the DEIS to address NMFS' concerns. FERC should expand its reasonable range of alternatives to include one that would reflect the environmental baseline for the purposes of ESA consultation and another that would reflect federal and state recommended conditions (including NMFS' recommended conditions). We also provide many specific comments on sections of the DEIS that we recommend FERC accept.

In summary, NMFS requests that FERC accept its 10(j) recommended conditions to ensure there is adequate mitigation to address Project effects, to provide information necessary to initiate formal ESA consultation, and to revise the DEIS to address concerns raised by NMFS. It is likely that FERC would need to issue a Supplemental DEIS to address these concerns.

If you have any questions or wish to seek clarification regarding this letter or NMFS' enclosed comments, please contact Keith Kirkendall (503-230-5431) or Ritchie Graves (503-231-6891) of my staff.

Sincerely,

D. Robert Lohn

D. Robert Lohn
Regional Administrator

Enclosure

200611035026 Received FERC OSEC 11/03/2006 01:25:00 PM Docket# P-1971-079

cc: Service List

UNITED STATES OF AMERICA
FEDERALENERGY REGULATORY COMMISSION

Idaho Power Company	)	**Hells Canyon**
	)	**Hydroelectric Project**
	)	**FERC No. 1971-079**
	)	

NATIONAL MARINE FISHERIES SERVICE'S RESPONSE TO FERC'S SECTION 10(j) PRELIMINARY DETERMINATION OF INCONSISTENCY; COMMENTS ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) DATED JULY, 2006, AS A BIOLOGICAL ASSESSMENT;

AND COMMENTS ON THE DEIS FOR THE HELLS CANYON HYDROELECTRIC PROJECT

NOVEMBER 3, 2006

I. COMMENTS ON FERC'S SECTION 10(j) PRELIMINARY DETERMINATION OF INCONSISTENCY

The National Marine Fisheries Service (NMFS) is pleased that the majority of its 10(j) recommendations for the Hells Canyon Hydroelectric Project (Project or HCC) designed to (1) address the Project's impacts on water quality, quantity, and timing and (2) improve the effectiveness of the associated hatchery programs were incorporated into the Staff Alternative in the Draft Environmental Impact Statement (DEIS). Taken together, these measures will help to reduce (or provide meaningful mitigation for) the impacts of the proposed Project on water quality (dissolved oxygen and total dissolved gas); on spawning, incubating, rearing, and migrating ESA-listed Snake River fall Chinook salmon (downstream flow, temperature, dissolved oxygen, and total dissolved gas); and on juvenile Chinook salmon and steelhead migrating to sea during the spring freshet (flow). NMFS largely supports these aspects of mile downstream of Hells Canyon Dam – at the same location NMFS recommended a flow gage ought to be installed and operated (see our 10(j) comments above).

3.6.2.4 Temperature Control: The temperature of the Project release water is an issue of concern to NMFS and we worked extensively with IPC to investigate several temperature control measures at the project and various strategies for using these structures during the relicensing study period. Based on this information, NMFS concluded that these structures would not provide the substantial benefits to incubating, rearing, migrating, or spawning fall Chinook salmon that the agency had hoped would be attained with these structures. While we believe that this effort was thorough, we have no objection to further consideration or analysis of methods to improve discharge water temperatures, particularly if new or innovative approaches can be found.

3.6.2.6 Anadromous Fish Restoration: In this section FERC staff considers an array of agency recommendations regarding restoring anadromous fish to habitats upstream from Hells Canyon Dam and presents an outline of a phased reintroduction approach, including: development of a detailed fish passage plan and monitoring of water quality, followed by reintroduction efforts in the event certain benchmarks are achieved. NMFS objects both to the nature of the analysis and to the FERC staff proposal for the reasons listed below.

FERC staff's analysis conflates recommendations for reintroduction of spring Chinook salmon and steelhead into Project reservoir tributaries, with reintroduction of fall Chinook salmon into areas upstream from Brownlee Reservoir. These two actions are quite different in scale and scope and should be treated separately. FERC should separately consider tributary and mainstem reintroduction processes and analyze all agency recommendations regarding reintroduction, including NMFS' recommended phased approach beginning, during this license

Exhibit 7.1-17
November 6, 2006, Environmental Protection Agency (EPA) letter to the Federal Energy Regulatory Commission (FERC) on the draft environmental impact statement (DEIS) for the Hells Canyon Hydroelectric Project

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue
Seattle, WA 98101

November 3, 2006

Reply to
Attn Of: ETPA-088

EPA Ref: 03-078-FRC
FERC Project No. 1971-079

Magalie R. Salas, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, DC 20426

Dear Ms. Salas:

The U.S. Environmental Protection Agency (EPA) has reviewed the draft Environmental Impact Statement (EIS) for the proposed relicensing of **Hells Canyon Hydroelectric Project** (CEQ No. 20060325) located on the Snake River in Washington and Adams Counties, Idaho, and Wallowa and Baker Counties, Oregon. The project occupies approximately 5,640 acres of federal lands managed by the Bureau of Land Management and the U.S. Forest Service. The project is licensed to Idaho Power Company (Idaho Power). This review has been conducted in accordance with our authorities and responsibilities under the National Environmental Policy Act (NEPA) and Section 309 of the Clean Air Act.

The draft EIS evaluates the environmental impacts of relicensing the existing three components (dams, reservoirs, and powerhouses) that comprise the Hells Canyon Project, specifically the Brownlee, Oxbow and Hells Canyon dams, which provide 1,167 megawatts of power. The draft EIS assesses the environmental and economic effects of: continuing to operate the project with no changes or enhancements (no-action alternative); operating the project as proposed by Idaho Power (Idaho Power's proposal); operating the project as proposed by Idaho Power with additional or modified environmental measures ("staff alternative" or "preferred alternative").

The Hells Canyon Dam Complex (including Brownlee and Oxbow dams) has caused a shift in the annual temperature regime of the Snake River, with cooler temperatures in the winter through early summer and warmer temperatures from late summer through fall (draft EIS Section 3.5.1.2). The unnatural temperature shift has several adverse effects on salmon. Warm temperatures in the late summer and fall: 1) harm late migrating fall Chinook juvenile salmon on their journey to sea; 2) harm adult Chinook, Steelhead, and Sockeye migrating upriver to spawn; and 3) harm eggs in holding adults and in the gravel after deposition. Cold temperatures in the winter and spring delay the emergence of Chinook salmon fry causing them to migrate downstream later in the year during harmful summertime conditions. See EPA 2003 Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards.

Below Hells Canyon Dam, the State of Oregon's 13°C temperature criterion (for salmon spawning) that is applicable starting October 23 is exceeded for two to three weeks until mid-November, which adversely affects about 25 - 50% of the spawning distribution. The 20°C summer temperature criterion is exceeded late July thru mid-September and Oregon's natural thermal regime water quality standard is exceeded from August through October. See June 2004 IDEQ/ODEQ Snake River-Hells Canyon Temperature TMDL Section 3.6.

In light of these temperature issues, we are encouraged that modeling by Idaho Power indicates that temperature control structures (TCSs) can achieve significant improvements in the reach between Hells Canyon Dam and Lower Granite Dam, which could have a beneficial impact on water quality for over 100 river miles (see Enclosure 1). In particular, the modeling indicates that a TCS can achieve the 13°C salmon spawning criterion addressed in the approved temperature Total Maximum Daily Load (TMDL). Additionally, the modeling indicates that a TCS can provide significantly improved temperature conditions for rearing and migration, consistent with Oregon's 20°C summer temperature criterion and the natural thermal regime standard.

Despite the results of the modeling, the staff alternative does not incorporate the use of a TCS. Instead, the draft EIS concludes that "the potential benefits of installing a temperature control structure at Brownlee Dam would not be worth the cost" (page 566). We are concerned that, other than a footnote that presents a wide range of potential costs (3.9 - 28 million dollars annually) for construction and operation of a TCS, there is no further analysis in the draft EIS to support the conclusion that a TCS is not economically feasible. Given the potential benefits of a TCS (see Enclosure 1 – Benefits of Temperature Control Structures), we recommend that this issue be examined more fully in the final EIS.

We also recognize that as an alternative to installing a TCS, the staff alternative provides that Idaho Power would develop and implement a Temperature Management Plan in consultation with Idaho Department of Environmental Quality (IDEQ) and Oregon Department of Environmental Quality (ODEQ). However, the draft EIS provides little information on how this plan would be developed and what types of measures would be evaluated and implemented. Without additional detail on the proposed measures, including a preliminary analysis of the potential effectiveness of the measures to meet relevant temperature criteria, it is difficult to conclude that the staff alternative would result in an appropriate level of protection of these nationally significant aquatic resources. Accordingly, we recommend that the final EIS present more information on the basic timeline, milestones, and strategy for achieving water quality standards consistent with the existing TMDL. We understand that Idaho Power is seeking site specific criteria as a mechanism to obtain the Clean Water Act (CWA) Section 401certification, which would significantly affect the elements of the Temperature Management Plan. EPA has a number of concerns about the site specific criteria for this project, which are presented in our September 27, 2006 letter to the IDEQ (Enclosure 2).

Based on our review, we have assigned this draft EIS a rating of EO-2 (Environmental Objections Insufficient Information; see Enclosure 3).

In order to address the issues we have identified in our review, we recommend that the final EIS:

- Provide additional information about the economic feasibility of temperature control structures;
- Provide further documentation of TCS operational scenarios developed by Idaho Power, including detailed information on seasonal withdrawal strategies evaluated by Idaho Power (e.g., daily Brownlee release flows, daily TCS operations, blended outflow temperatures of preferred and alternative strategies);
- Provide additional model runs for TCS alternatives consistent with the management objectives described in the attached Modeling Recommendations (Enclosure 4);

- Provide additional analysis on the potential benefits to salmon from the TCSs (see Enclosure 1);
- Provide available information from the states of Idaho and Oregon regarding the status of outstanding temperature issues in the CWA Section 401 certification process; and
- Provide analysis of estimated project impacts on Snake River temperatures at the Washington border and compare it to applicable Washington water quality standards.

We would also like to work with you more directly on questions regarding the temperature model. In that regard, it would be helpful for our staffs to meet to discuss some of the more technical issues regarding the model. In order to facilitate that meeting, we would appreciate receiving all of the model files for the temperature model. With these files, we would be able to run the model, reproduce Idaho Power's results, and also run the model under alternative scenarios for affected states, tribes and fisheries agencies. This information will help us better understand the implications of each alternative. We look forward to working with you in that regard.

In summary, EPA believes that TCSs could provide significant environmental benefit and that there should be additional analysis of this issue. In addition, we believe that increased technical coordination between our agencies, Idaho Power, the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, the States and Tribal governments is important to ensure concerns are addressed in a timely manner for the various interrelated regulatory processes related to the proposed relicensing.

Thank you for the opportunity to review and comment on the draft EIS. If you have any questions regarding EPA's comments, please contact John Palmer, Region 10 Office of Water at (206) 553-6521, or Christine Reichgott, Manager, NEPA Review Unit at (206) 553-1601.

Sincerely,

//s//
Michelle Pirzadeh, Director
Office of Ecosystems, Tribal and Public Affairs

cc: IDEQ
ODEQ
NOAA

Enclosures:
1) Potential Benefits of Temperature Control Structures
2) EPA's September 27, 2006 letter to IDEQ
3) EPA Rating System for Draft EISs
4) Modeling Recommendations

Enclosure 1
Potential Benefits of Temperature Control Structures

The following table presents a number of benefits that are potentially attainable with a temperature control structure (TCS) at Brownlee Dam. These candidate management alternatives are developed in recognition that there are limits to availability of cold/warm water in the reservoir. Nevertheless, a combination of one or more of these alternatives could lead to significant improvements in fish habitat for over 100 miles of Snake River from Hells Canyon Dam to Lower Granite Reservoir.

Idaho Power Company (Idaho Power) and EPA modeling results using the RBM10 model (Yearsley, et al, 2001) are presented in a set of figures following the table. The IPC model provided estimates of river conditions immediately downstream of the hydroelectric dam complex with TCS operations. EPA has used this information as a basis to evaluate the attenuation of cold water releases between the complex and Lower Granite Dam (river mile 247 to mile 107). The EPA evaluation focuses only on the effects of temperatures released by the complex (flows are historic flows at Hells Canyon dam for all model tests). The year 1994, Idaho Power's selected example of a "medium-low" water year, was selected for the EPA model tests.

Temperature Control Period	Potential Benefits
Cooler Spawning Temperatures Operation: Cool water releases in the fall to attain the 13°C criterion earlier in the fall consistent with pre-project conditions (including the October 23 start date for the TMDL allocation). TCS Capability based on Idaho Power Modeling: Gated Weir/Tunnel and 35 kcfs Tower options for medium-low water year (1994) achieve 13°C. See AIR WQ-2(c) Figures 20 and 21, which are reproduced below in Figures 1 and 2. EPA Modeling Tests: No model scenarios for this period.	Increased survival and fitness of egg/fry that are spawned in October/early November when current temperatures exceed 13°C (approx. 25–50% of spawning distribution). This TCS operation would bring fall temperature conditions closer to pre-project conditions. The median date of fall Chinook fry emergence may be earlier due to 1) increased survival to emergence of eggs spawned in October/early November; and 2) an earlier median spawning date from a possible shift in spawning timing for the fall Chinook. This may lead to earlier out migration and better survival of juvenile fall Chinook through Lower Granite Dam.
Warmer Winter/Spring Temperatures Operation: Release warmer water (3-4°C) in January/February from the bottom of the reservoir, then switch to surface release once spring warming commences to warm temperatures modestly beginning in March.	This TCS alternative would bring winter/spring temperature conditions modestly closer to pre-project conditions. Warmer winter and spring temperatures may lead to earlier emergence and downstream movement of juveniles through Lower Granite Dam.

TCS Capability based on Idaho Power Modeling: Idaho Power has not reported potential scenarios for release of deep, warmer water in winter. Gated Weir/Tunnel and 35kcfs Tower options for medium-low water year (1994) show increases in spring temperatures beginning in March. See AIR WQ-2(c) Figures 20 and 21, which are reproduced below in Figures 1 and 2. EPA Modeling Tests: EPA does not have sufficient information on TCS capability/outcomes to run spring scenarios.	
Cooler Mid-Summer Temperatures Operation: Cool water releases in July (17-18°C at Hells Canyon Dam) TCS Capability based on Idaho Power Modeling: Gated Weir/Tunnel and 35kcfs Tower options for medium-low water year (1994) show the potential for cool water releases at a consistent temperature of approximately 18°C. See AIR WQ-2(c) Figures 20 and 21, which are reproduced below in Figures 1 and 2. EPA Modeling Tests: See Figures 3 and 4 for EPA modeling estimates of the effect of a 17-18°C release from Hells Canyon Dam.	Model estimates indicate a reduction of approximately 1.0 to 1.5°C in early July and approximately 1.5 to 2.0°C in late July, reducing temperature from 22.5°C to 21°C at Lewiston in late July. Vertical temperature profiles in Lower Granite Reservoir during Dworshak cold water releases indicate that the colder, more dense Clearwater River inflow subducts under the Snake River mainstem at the confluence, resulting in incomplete mixing and persistent high surface layer temperatures in Lower Granite Reservoir (Cook, et al, 2003; Cope, 2002). Reducing Snake River mainstem temperatures with a TCS improves surface layer temperatures in Lower Granite Reservoir and thereby augments the benefits of Dworshak releases. A significant number of juvenile fall Chinook outmigrate in July. Juveniles typically use the upper surface layer of the Snake River. Temperatures above 20°C are extremely harmful to these juveniles and a 1°C or greater reduction of temperature can provide substantial survival benefit.
Short-Term Summer Fish Operations	

Operation: Potential to release very cold water for short periods (days, weeks) to aid in juvenile migration. TCS Capability based on Idaho Power Modeling: Idaho Power has not reported any scenarios for short term release of very cold water in winter. EPA Modeling Tests: See Figures 5 and 6 for EPA modeling estimates of the effect of a 15-16°C release from Hells Canyon Dam.	This TCS alternative would substantially improve fish habitat conditions during the juvenile out migration period. EPA modeling indicates that a 15-16°C release from Hells Canyon Dam would reduce temperatures in the reach between the Salmon River and Lewiston by 1.5 to 2.5°C in early July, and by 2.5 to 3.5°C in late July. Late July temperatures can be reduced from 22.5°C to 20°C at Lewiston. See previous discussion of surface layer temperature improvements under “Cooler Mid-Summer Temperatures” above. EPA model results assumed 1994 Hells Canyon Dam outflows. Higher short-term outflows would result in greater short-term temperature reductions.
Cooler Late Summer Temperatures Operation: Cool water releases in September and October (17-18°C at Hells Canyon Dam). TCS Capability based on Idaho Power Modeling: Gated Weir/Tunnel and 35kcfs Tower options for medium-low water year (1994) show the potential for cool water releases at a consistent temperature of approximately 18°C. See AIR WQ-2(c) Figures 20 and 21, which are reproduced below in Figures 1 and 2. EPA Modeling Tests: See Figures 7 and 8 for EPA modeling estimates of the effect of a 17-18°C release from Hells Canyon Dam in September. See Figure 9 for estimates of the effect of a 15°C release from Hells Canyon Dam in October.	This TCS alternative results in 1.5 to 2°C cooler temperatures during September. Temperatures at Lewiston can be maintained near or below 18.5°C in early September. Temperatures can also be reduced below 16°C in early October. Adult Chinook and Sockeye salmon and Steelhead are all migrating above Lower Granite Dam in this timeframe. Current Snake River temperatures above Lewiston create a migration barrier in September. Dropping temperatures below 20°C would aid in the upstream migration of these species above Lewiston to the Salmon, Grande Ronde, Imnaha, and the Snake River Hells Canyon reach. Reduced temperatures (below 16°C) in October benefit pre-spawning adults.

Figure 1: Idaho Power Modeling Results. Hells Canyon Outflow Temperatures for Gated Weir and Tunnel Operations for Medium-Low Flow Year (1994)
(from Idaho Power, Sept 2005)

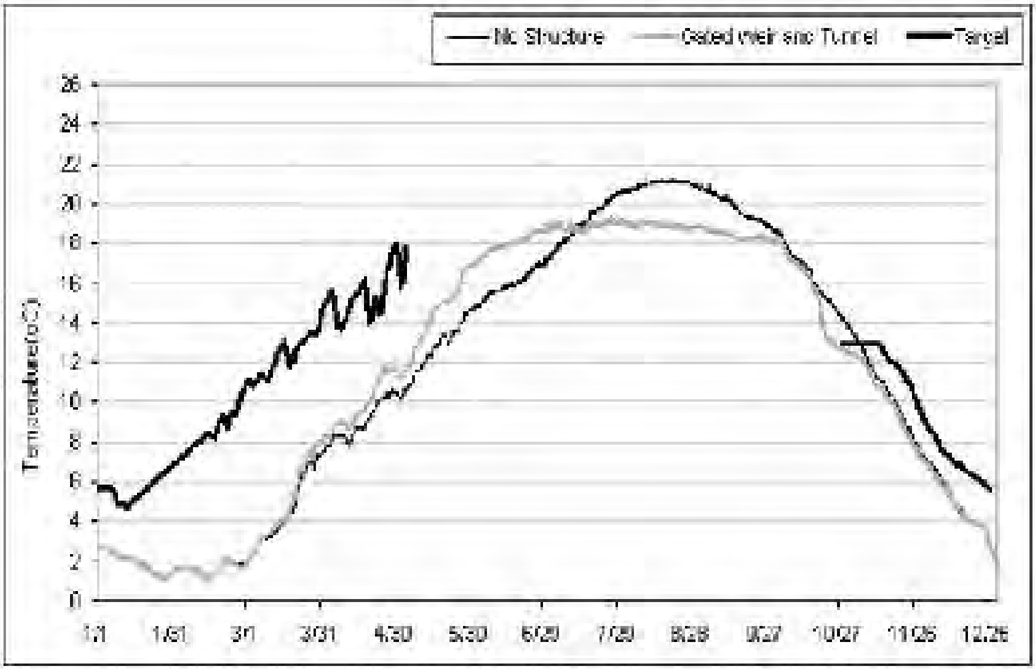


Figure 20. Medium-Low Water Year hourly Hells Canyon outflows for the Gattun and Base (No structure) using the current conditions model setup and OP-2 reservoir operations.

Figure 2: Idaho Power modeling results for 35 kcfs Tower Operations

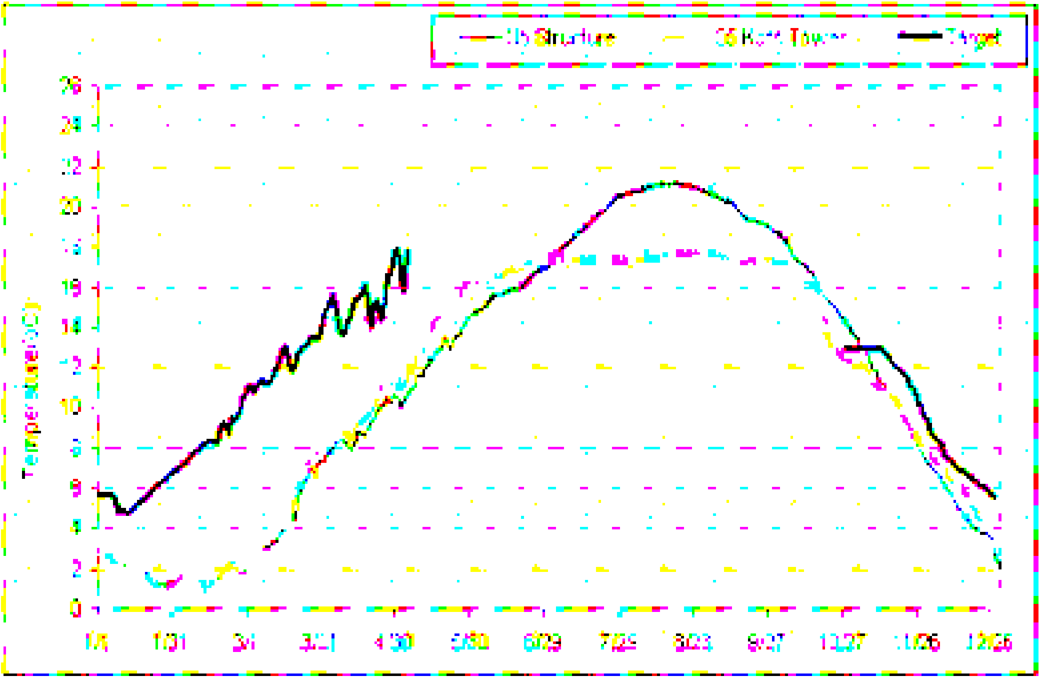


Figure 21. Medium-Low Water Year hourly Hells Canyon outflows for the 35T and Base (No Structure) using the current conditions model setup and OP-2 reservoir operations.

Figure 3: Juvenile Migration Season (Early July, 17°C at Hells Canyon Dam)

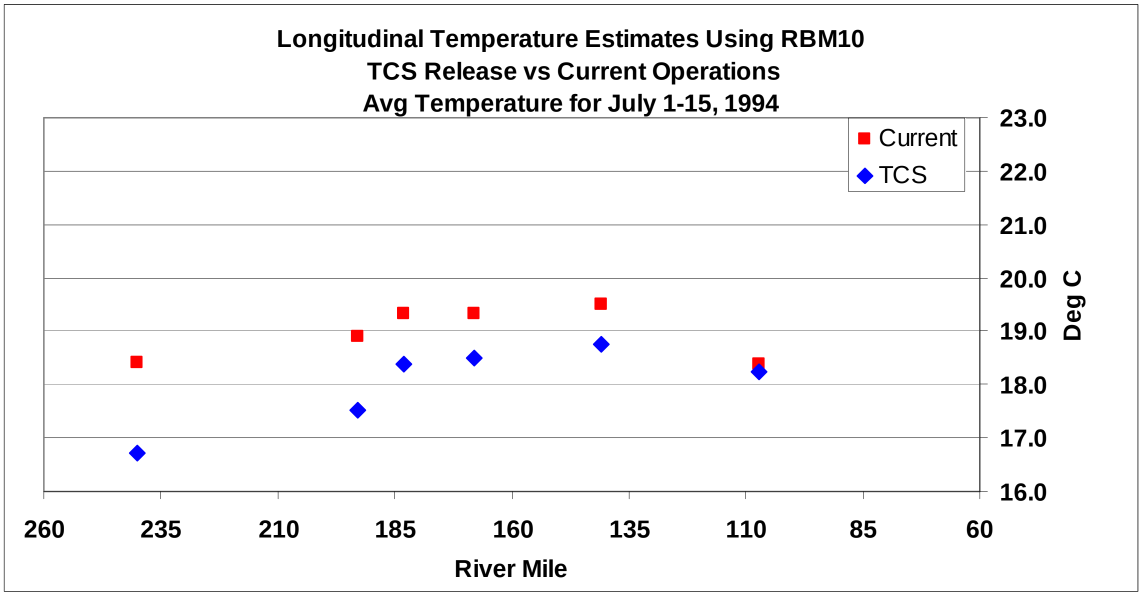
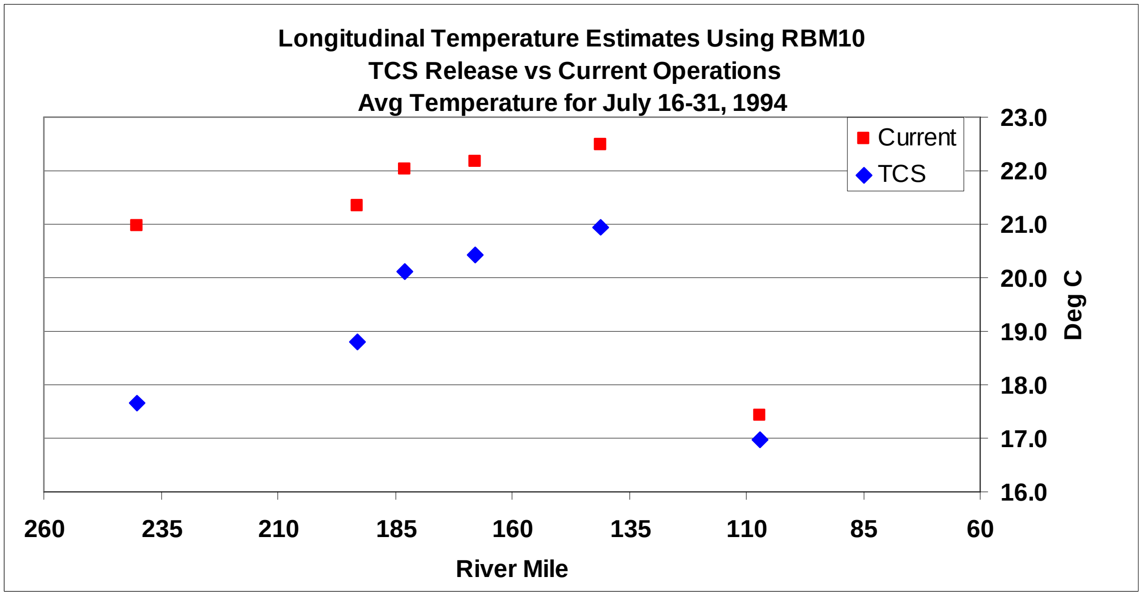


Figure 4: Juvenile Migration Season (Late July, 18°C at Hells Canyon Dam)



River Mile
240 – Below Hells Canyon Dam outflow
193 – Above confluence w/Salmon River
183 – Below confluence w/Salmon River
168 - Anatone
141 - Lewiston above confluence with Clearwater River
107 – Lower Granite Dam outflow (after mixing with colder subsurface flows provided by Dworshak Dam release in July).

Figure 5: Juvenile Migration Season (Early July, 15°C at Hells Canyon Dam)

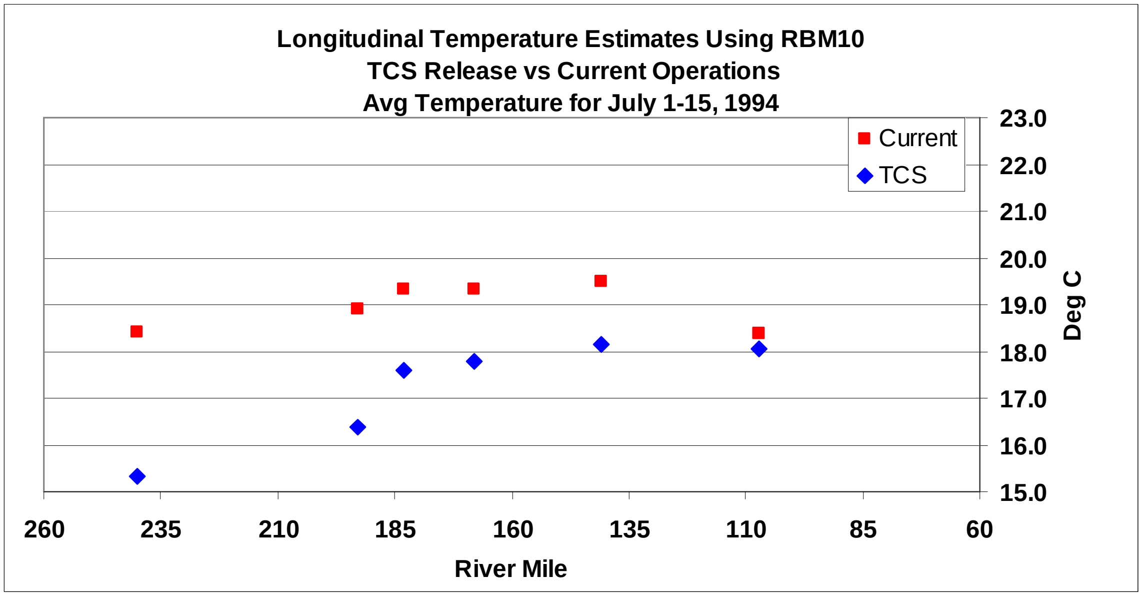
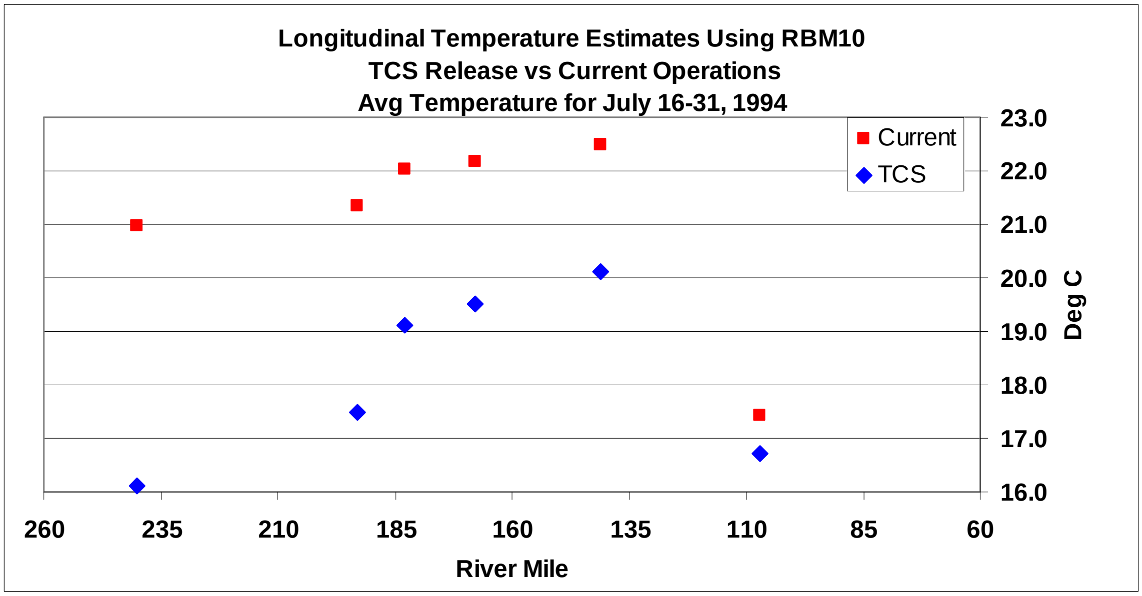


Figure 6: Juvenile Migration Season (Late July, 16°C at Hells Canyon Dam)



River Mile
240 – Below Hells Canyon Dam outflow
193 – Above confluence w/Salmon River
183 – Below confluence w/Salmon River
168 - Anatone
141 - Lewiston above confluence with Clearwater River
107 – Lower Granite Dam outflow (after mixing with colder subsurface flows provided by Dworshak Dam release in July).

Figure 7: Adult Migration Season (Early Sept, 18°C at Hells Canyon Dam)

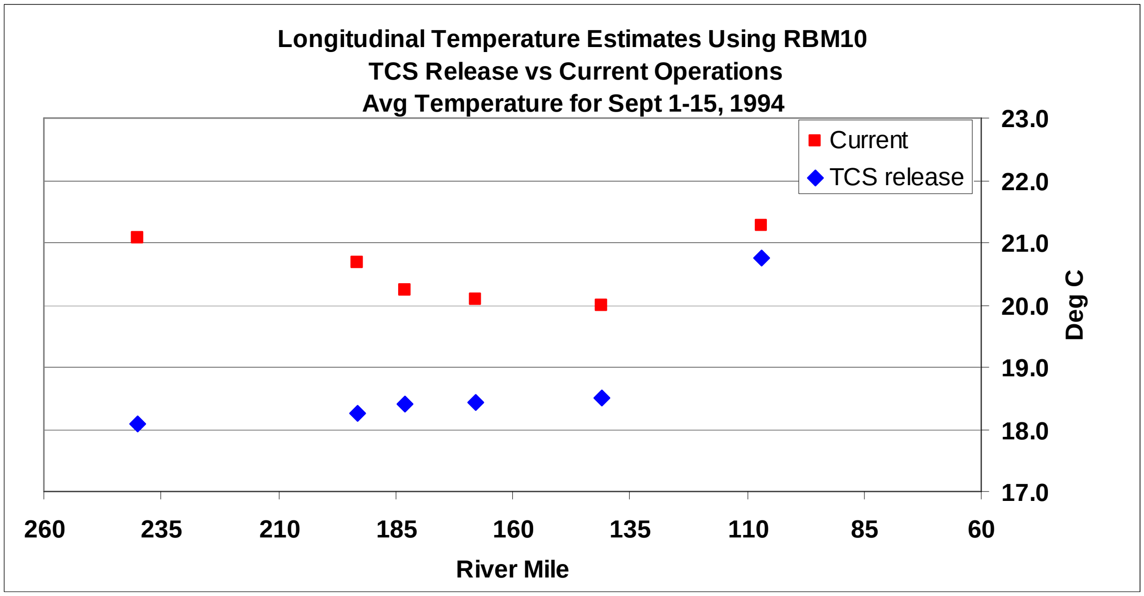
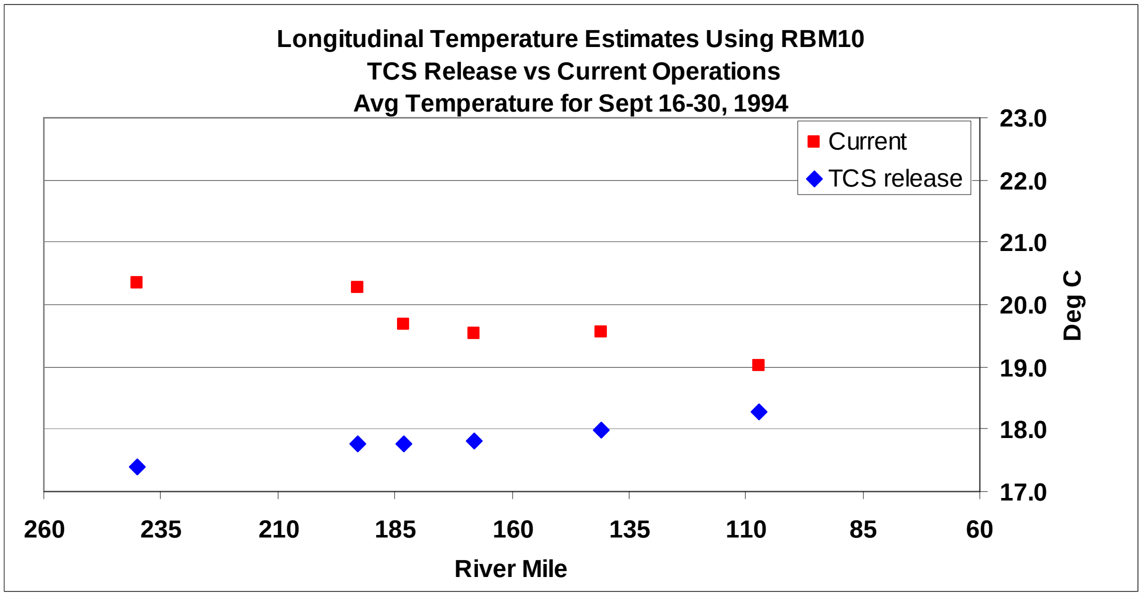
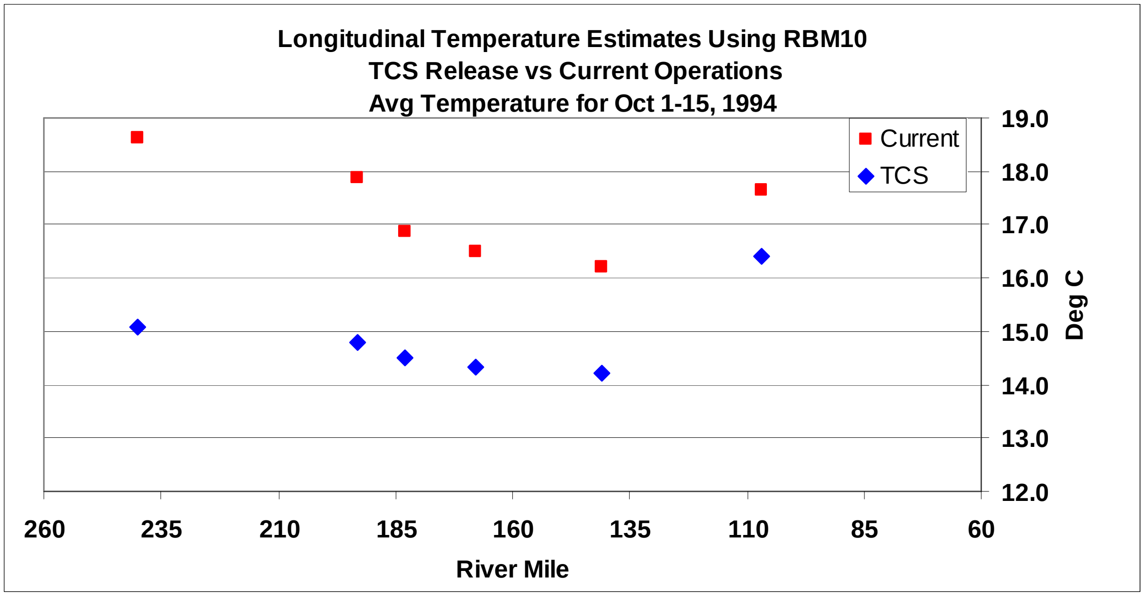


Figure 8: Adult Migration Season (Late Sept, 17°C at Hells Canyon Dam)



River Mile
240 – Below Hells Canyon Dam outflow
193 – Above confluence w/Salmon River
183 – Below confluence w/Salmon River
168 - Anatone
141 - Lewiston above confluence with Clearwater River
107 – Lower Granite Dam outflow

Figure 9: Adult Migration Season (Late Sept, 17°C at Hells Canyon Dam)



References

Modeling Analysis for this Document

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Other References

Cook, C.B., C.L Rakowski, M.C. Richmond, S.P. Titzler, A.M. Coleman, M.D. Bleich. 2003. Numerically Simulating the Hydrodynamic and Water Quality Environment for Migrating Salmon in the Lower Snake River. Pacific Northwest National Laboratory. Richland, WA. Prepared for the Bonneville Power Administration, U.S. Department of Energy. Contract DE-AC06-76RLO1830.

Cope, B. Temperature Simulation of the Snake River Above Lower Granite dam Using Transect Measurements and the CE-QUAL-W2 Model. EPA Region 10. EPA 910-R-02-008. Seattle, WA. September 2002.

Cope, B. Temperature Impacts in the Hells Canyon Reach of the Snake River. Memorandum from B. Cope to J. Jennings. EPA Region 10. September 16, 2003, and subsequent correction memo on October 15, 2003.

Idaho Power Company. Detailed Evaluation of Alternative Temperature Control Structures. Responses to FERC Additional Information Request WQ-2(c)). Hells Canyon Project. FERC No. P-171-079. September 2005.

Yearsley, J.R., Karna, D., Peene, S., Watson, B. Application of a 1-D Heat Budget Model to the Columbia River System. EPA Region 10. EPA 910-R-02-008. Seattle, WA. 2001.

Enclosure 2

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue
Seattle, Washington 98101

September 27, 2006

Barry Burnell, Administrator
Water Quality Division
Idaho Department of Environmental Quality
1410 North Hilton
Boise, Idaho 83706

Dear Mr. Burnell:

The letter is in response to your July 5, 2006 letter seeking our comments on Idaho Power Company's (IPC) request for site-specific temperature criteria to protect salmon spawning and egg incubation in the Hells Canyon reach of the Snake River. Based on our preliminary review we offer the following comments.

Although the concept of site-specific declining temperature criteria to protect salmon spawning and egg incubation has merit, the IPC's proposal is unlikely to be protective of salmon spawning and egg incubation. Of particular concern is the 16.5°C initial temperature criterion. There is a significant body of scientific evidence that indicates that temperatures less than 16.5°C are needed to protect both gametes in holding adults just prior to spawning and the eggs after they have been deposited in the gravel. This body of scientific research is summarized in *EPA Region 10's Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards* and supporting technical issue papers.

IPC cited a recent study by Geist *et al* in support of its proposal. Although this study indicated good success for eggs incubated at a 16.5°C initial temperature, the adult fish were held at 12°C prior to spawning. The adult holding temperature in this study calls into question the applicability of the results of this study. Under IPC's proposed criteria, pre-spawning Chinook salmon in the Snake River would likely be exposed to temperatures in the 16.5-18°C range.

The IPC proposal also suggests that attaining the current 13°C 7DADM criteria (applicable October 23rd) would result in prolonged egg incubation and emergence and increased mortality of out migrating juveniles in the late summer months due to exposure to elevated temperatures in the lower Snake and Columbia Rivers. We question the validity of this conclusion and the IPC proposal does not present scientific evidence supporting this conclusion. However, we believe this argument, even if demonstrated to be true, is probably not a basis for a site-specific criterion. Rather, we believe this argument is better suited as a basis for an alternative criterion in conjunction with a 40 CFR §131.10(g) use attainability analysis. The reason for this is that when approving a site-specific criterion, EPA must determine the alternative criterion protects the designated use, which in this case, is salmon spawning and egg incubation. When approving an alternative criterion associated with a use attainability analysis, EPA can consider other factors such as whether the human caused condition would cause more environmental damage to correct than leave in place or whether hydrologic modifications are feasible.

Thank you for the opportunity to provide our initial comments on the IPC proposal. Please contact John Palmer at (206) 553-6521 if you have further questions. I can be reached at 206-553-1906.

Sincerely,

/s/

Christine Psyk, Associate Director
Office of Water and Watersheds

cc: Lauri Aunan (ODEQ)
Paul Devito (ODEQ)
Colleen Fagean (ODFW)
Cindy Robertson (IDFG)
Keith Kirkendall (NOAA)
Jeff Foss (USFWS)
Chris Randolph (IPC)
Olney Pratt, Jr. (CRITFC)
Rebecca Miles (Nez Perce Tribe)
Jim Werntz (EPA)

Enclosure 3

U.S. Environmental Protection Agency Rating System for Draft Environmental Impact Statements Definitions and Follow-Up Action*

Environmental Impact of the Action

LO – Lack of Objections

The U.S. Environmental Protection Agency (EPA) review has not identified any potential environmental impacts requiring substantive changes to the proposal. The review may have disclosed opportunities for application of mitigation measures that could be accomplished with no more than minor changes to the proposal.

EC – Environmental Concerns

EPA review has identified environmental impacts that should be avoided in order to fully protect the environment. Corrective measures may require changes to the preferred alternative or application of mitigation measures that can reduce these impacts.

EO – Environmental Objections

EPA review has identified significant environmental impacts that should be avoided in order to provide adequate protection for the environment. Corrective measures may require substantial changes to the preferred alternative or consideration of some other project alternative (including the no-action alternative or a new alternative). EPA intends to work with the lead agency to reduce these impacts.

EU – Environmentally Unsatisfactory

EPA review has identified adverse environmental impacts that are of sufficient magnitude that they are unsatisfactory from the standpoint of public health or welfare or environmental quality. EPA intends to work with the lead agency to reduce these impacts. If the potential unsatisfactory impacts are not corrected at the final EIS stage, this proposal will be recommended for referral to the Council on Environmental Quality (CEQ).

Adequacy of the Impact Statement

Category 1 – Adequate

EPA believes the draft EIS adequately sets forth the environmental impact(s) of the preferred alternative and those of the alternatives reasonably available to the project or action. No further analysis of data collection is necessary, but the reviewer may suggest the addition of clarifying language or information.

Category 2 – Insufficient Information

The draft EIS does not contain sufficient information for EPA to fully assess environmental impacts that should be avoided in order to fully protect the environment, or the EPA reviewer has identified new reasonably available alternatives that are within the spectrum of alternatives analyzed in the draft EIS, which could reduce the environmental impacts of the action. The identified additional information, data, analyses or discussion should be included in the final EIS.

Category 3 – Inadequate

EPA does not believe that the draft EIS adequately assesses potentially significant environmental impacts of the action, or the EPA reviewer has identified new, reasonably available alternatives that are outside of the spectrum of alternatives analyzed in the draft EIS, which should be analyzed in order to reduce the potentially significant environmental impacts. EPA believes that the identified additional information, data, analyses, or discussions are of such a magnitude that they should have full public review at a draft stage. EPA does not believe that the draft EIS is adequate for the purposes of the National Environmental Policy Act and or Section 309 review, and thus should be formally revised and made available for public comment in a supplemental or revised draft EIS. On the basis of the potential significant impacts involved, this proposal could be a candidate for referral to the CEQ.

* From EPA Manual 1640 Policy and Procedures for the Review of Federal Actions Impacting the Environment. February, 1987.

Enclosure 4
Modeling Recommendations

EPA recommends the EIS contain a more detailed analysis of TCS options. The EIS should include a more detailed discussion on the projected impacts to salmon throughout the year for each option and include more detailed discussion on the costs to better understand economic feasibility of the options. Model inputs (elevation of selective withdrawals and flows) for each TSC option should be publicly available in order to better evaluate the management objectives, independently verify the model outputs, and allow for the development option customization.

EPA recommends that model runs be conducted to approximate the natural thermal regime to minimize adverse effects to salmon during criteria life stage periods in conjunction with providing summer cooling to mitigate dam impacts to fish. Specifically, EPA requests model runs for the Gated Wier/Tunnel, 12kcfs, and 35kcfs Tower options (for various flow conditions) under the following temperature objectives below Hells Canyon dam:

a) from January 1 thru May 14 increase current conditions by 2C (or as much as possible if a 2C increase in not feasible), but don't exceed 14C

b) from May 15 thru June 30 increase current conditions by 1C, but follow current conditions when temperatures reach 16C (not to exceed 18C)

c) from July 1 thru July 31target 18C

d) from August 1 thru August 31 allow temperature to rise to 20C if needed to store cold water

e) from September 1 thru September 30 target 18C or current condition, which ever is cooler

f) from October 1 to October 23 decrease temps to attain 13C by October 23, maintain temperatures in the 12-13C range until early November (when current temps reach 13C), then follow current condition cooling pattern the remainder of the year.

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Exhibit 7.1-18

November 15, 2010, United States (U.S.) Fish and Wildlife Service’s (FWS) comments on Idaho Power Company’s (IPC) water–quality application for the Hells Canyon Complex (HCC)

United States Department of the Interior
IDAHO FISH AND WILDLIFE OFFICE
1387 S. Vinnell Way, Room 368
Boise, Idaho 83709
Telephone (208) 378-5243
http://www.fws.gov/idaho

NOV 15 2010

Neil Mullane
Oregon Department of Environmental Quality
Headquarters Office
811 SW 6th Avenue
Portland, Oregon 97204-1390

Barry Burnell
Idaho Department of Environmental Quality
Headquarters Office
1410 North Hilton
Boise, Idaho 83706

Subject: Comments on Idaho Power Company's Water Quality Application for the Hells Canyon Complex Hydroelectric Project—Adams and Washington Counties, Idaho and Baker, Malheur, and Wallowa Counties Oregon—Comments Hells Canyon Hydroelectric Project FERC 1971 14420-2011-CPA-0011

Dear Mr. Mullane and Mr. Burnell:

The US Fish and Wildlife Service (Service) is providing comments on the September 2010 Water Quality Application (Application) submitted by the Idaho Power Company (Company) under section 401 of the Clean Water Act (CWA) for the Hells Canyon Complex (HCC) Hydroelectric Project (Project) FERC 1971. The Service does not support the current Application because it contains a solution for only one issue within an extremely complex set of problems. The challenge lies in addressing multiple water quality impact issues on a watershed scale for the southern Idaho/Oregon landscape, Snake River and the HCC. The Application proposes installing a hypolimnetic pumping system (HPS) at Brownlee reservoir. The HPS is designed to withdraw cold hypolimnetic water at Hells Canyon Dam to compensate for temperature exceedence. However, the Application no longer contains the Temperature Enhancement Mitigation Program (TEMP) proposal that the Company included as part of previous applications. The Service believes that, in order to protect, enhance, preserve or restore species within the entire Snake River basin, including downstream of the Project, water quality must be improved and maintained throughout the watershed, not just temperature at a single point below the dam. Therefore, we believe the TEMP program, as opposed to a HPS, would more holistically address the HCC's water quality issues on a watershed scale.

This is the Company's seventh application after the prior six were rejected by the Oregon Department of Environmental Quality (ODEQ) as failing to meet CWA water quality compliance at the Project. The Company's inability to obtain a CWA 401 Certification has delayed multiple processes. In particular, it has delayed the Federal Energy Regulatory Commission's (FERC) relicensing of the Project, the Service's section 7 consultation required under the Endangered Species Act (ESA), and implementation of mitigation measures for the Project. The current Application was submitted in part to fulfill requirements for temperature criteria at Hells Canyon Dam during a time period when discharge temperatures exceed criteria by about 2.5 °C or less for approximately 2 weeks in October. The exceedence time period and amount varies by water year type and corresponds to a time when fall Chinook spawning is beginning to occur and bull trout are returning from tributaries to the Snake River below Hells Canyon Dam (see Figure 6.1-5 of the Application).

Although the final HPS designs are not complete, the actual operational period and capacity could vary from 0 to 16 days at up to 8,000 cubic feet per second (cfs), depending on water year type and reservoir conditions. It is not currently known if the height of the HPS intake structure within the hypolimnion will be fixed or variable. With either option, contaminant transport, water quality, and bioavailability implication issues are anticipated. Numerous native fishes and invertebrates are affected by waters released through the HCC, including bull trout, redband trout, white sturgeon, mountain whitefish, summer steelhead, fall Chinook, and many others. These species are essential in maintaining the ecological integrity of the Snake River.

Contaminants in the Hells Canyon Complex

It is known that reservoirs usually serve as trapping mechanisms for any transported instream material. Thus, it is notable that the Snake River plain is one of the most intensively farmed areas in the U.S. There are over 2 million acres of farmland and urbanized areas in both Idaho and Oregon that are upstream of Brownlee Reservoir. Since 1958 the 60-mile-long Brownlee Reservoir has been trapping agricultural and industrial runoff products in its sediments and water. The reservoir also traps contaminants from atmospheric deposition. As such, Brownlee reservoir serves as a sink and bioreactor in a yearly dynamic balance which serves to process and reduce large scale movement of contaminants to the lower Snake River. These contaminants include pesticides, metals, nutrients, phosphates, nitrates, ammonia, particulates, and low or zero dissolved oxygen.

Hydraulic conditions in Brownlee reservoir change depending on water year types, which in turn affect water chemistry. This causes yearly variations of depth and length in temperature and dissolved oxygen. These variations affect redox conditions in the sediments and water column, especially at their interface, which affects the rate at which contaminants partition from sediment to the water column. Little is known about the mix and extent of contaminants in Brownlee reservoir and even less is known about transport of the chemicals from the sediments to the hypolimnion, metalimnion, and epilimnion in the reservoir. One of the more well known contaminants in Brownlee reservoir is mercury, a highly toxic metal which bioaccumulates within the food chain and is a documented human teratogen in its methylated form. The State of Idaho Department of Health and Welfare began to issue fish consumption advisories for Brownlee Reservoir in 2001. Mercury is methylated in bed sediments in a reducing, anaerobic environment. Partitioning or moving methyl-mercury from sediments to suspended organic matter in the low or zero dissolved oxygen areas of the hypolimnion may occur. A complete baseline characterization by water year type hydraulics and chemistry, including direct compartmental measurement and modeling of contaminants in Brownlee reservoir, is needed before adequate fate and transport mechanisms can be studied in response to building a fully operational HPS.

At this point, the effects of a deep water withdrawal system that may affect the dynamic processing balance in Brownlee reservoir are little understood. Furthermore, potential oxygen reduction and contaminant transport to downstream species is a threat of unknown magnitude.

This threat is significant for the aquatic food chain and fishes such as bull trout, salmon, redband trout and white sturgeon, which may be at vulnerable life stages during contaminant transport and uptake. Of particular concern is the prospect of up to 8,000 cfs of highly contaminated, deoxygenated cool water being the primary source (up to 62 percent) of the flow being delivered downstream of Brownlee Dam. This flow would be delivered at a time when total river flow may only be 13,000 cfs due to the flat operations period established to protect spawning fall chinook (see Table 7.1-2 of the Application). Likewise, this would also be the timeframe that sub-adult and post-spawn fluvial bull trout begin to migrate downstream to the Snake River where they overwinter until the following spring.

Need for a Water Quality Improvement Program

The lack of a TEMP proposal in the latest Application is of great concern to the Service because the proposal was designed to address adverse water quality issues in the Snake River above the HCC in a broad watershed-wide improvement approach. Both cool and warm water aquatic species communities exist in the impoundments and flowing sections of the Snake River, including but not limited to, redband trout, white sturgeon and bass. We reiterate that, in order to protect, enhance, preserve or restore those species within the entire Snake River basin, including downstream of the Project, water quality must be improved and maintained throughout the watershed, not just temperature at a single point below the dam. A well-developed TEMP program is integral for these activities. It is a necessary starting point that will require adequate long-term funding.

The TEMP program was being developed to address important impaired water quality issues such as temperature, dissolved oxygen, phosphorous, and other contaminants within the Snake River and its tributaries. Although not fully developed, the program was intended to help remedy water quality issues of the Snake River Basin on a watershed scale including both Oregon and Idaho. The Service believes the following issues in the Snake River watershed need to be addressed immediately: warming water and water quality degradation through water withdrawals and returns, impoundments, flow alteration, riparian habitat modification and climate change. Unfortunately, a watershed improvement program on the scale of TEMP will likely not be seen or proposed within the next 30 years or more if it is not established during this relicensing effort. The Service finds it disconcerting that, at present, the development of a TEMP program, which was seemingly close to settlement in 2009, has been withdrawn and is no longer part of the solution to water quality problems in both Oregon and Idaho. The Service views the end result of omitting a TEMP program from the Project's CWA 401 Certification is the loss of a primary funding source for the voluntary Total Maximum Daily Load (TMDL) programs in Oregon and Idaho.

The Service supports the development of a robust water quality improvement program as part of the Project relicensing, as noted most recently in our comments on the Project's Final License Application and Draft Environmental Impact Statement (EIS). Therein, we urged the Oregon and Idaho Departments of Environmental Quality and the FERC to address water quality issues including water temperature, Dissolved Oxygen (DO), Total Dissolved Gas (TDG), and adverse effects from agricultural chemicals and methyl-mercury. The upstream tributary habitat improvement and water quality benefit concept was recommended and supported by the National Oceanic and Atmospheric Administration (NOAA) Fisheries Service, the States of Idaho and

Oregon, the Nez Perce tribe in their comments on the Final License Application, and by FERC in its Final EIS for the Project. In addition, the current TMDL for the Snake River and its tributaries above Hells Canyon Dam, which are 303(d) limited, supports activities improving watershed health in Snake River tributaries in order to ameliorate mainstem Snake River water quality.

Project Affects on Listed Species

The Service is currently informally consulting with the Company to develop a biological assessment and subsequent Service biological opinion under section 7 of the ESA for the Project relicensing. There are nine listed species affected by the Project, the most notable being bull trout (*Salvelinus confluentus*), listed threatened, and its designated critical habitat within the action area. For the purpose of an ESA analysis, the current lack of HPS impact characterization is inadequate.

The current status of bull trout in the action area is not robust. The Project has created physical barriers to the bull trout's upstream and downstream migration and movement which has adversely affected population numbers. The metapopulation structure within the tributaries and reservoirs of the action area are fragmented as a result. Specifically, there has been a loss of large riverine migratory bull trout that once moved into tributaries of the Hells Canyon recovery area, notably Pine, Indian and Wildhorse Creeks. Also, the loss of anadromous fish passage at the Project has removed a significant food source for bull trout where they once co-evolved with salmon, steelhead, and lamprey above Hells Canyon dam.

The threats to listed species posed by the Project have to be collectively addressed to ensure the survival and recovery of bull trout in the Hells Canyon action and recovery areas. Due to the lack of toxicological data, the addition of the HPS represents a threat to bull trout of unknown extent that may offset any benefits of reduced temperature provided by the structure. This determination is based largely on the potential unknown impacts from rapid turbulence and release of water from the hypolimneon, and on resultant effects from contaminants, low dissolved oxygen, nutrients and solids transported to bull trout in occupied critical habitat. In addition, oxidation of withdrawn reduced sulfides, phosphates, ammonia and organic matter can place further oxygen demand on an already stressed system, especially the downstream water column over time. This may result in biotic accumulation or adverse impacts to bull trout and associated critical habitat in the reservoirs and Snake River downstream of Hells Canyon Dam.

The Service believes that analysis of the water quality problems that plague the Snake River need to be considered from a watershed and ecosystem scale. This is the appropriate scale that the Service will use to address bull trout threats for this analysis. This is also the scale for the Service to address threats to bull trout in our analysis of the CWA 401 Certification as part of the final FERC action to relicense the Project. In addition, Section 2(b) of the ESA clearly states that its purpose is to "provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved." Therefore, we support the aggressive implementation of the current TMDLs as a framework to continue the work of restoring bull trout habitat and other Trust resources in the Snake River Basin. The TMDLs will also serve to build additional partnerships for addressing fish and wildlife issues at a landscape level.

Conclusion

Unfortunately, history has shown that engineered solutions to a perceived resource problem addressing one narrow issue, in this case temperature, may have multiple adverse resource effects that may not be evident until final construction and operation. In the case of the HPS, the Service is concerned that we may again be creating a narrow solution to a discreet aquatic habitat issue while ignoring, and possibly damaging, other resources within the HCC and the Snake River watershed.

Thank you for the opportunity to review and comment on the HCC CWA Section 401 Application. If you have any questions on these comments, please direct them to either Michael Morse (208) 378-5261 or Jim Esch (208) 378-5099. We are eager to work with all stakeholders to reach a mutually beneficial relicensing solution at the HCC Project.

Sincerely,

Gary L Burton

for Brian T. Kelly, State Supervisor
Idaho Fish and Wildlife Office

cc: Oregon Department of Justice, Portland (Burkholder)
ODEQ, Portland (Fonseca)
ODEQ, Bend (Nigg)
OEPC, Portland (Sleeger)
IPC, Boise (Myers)
NOAA, Portland (Ritchie)
FERC, Portland (Hastreiter)
FWS, Portland (Mead)
FWS, La Grande (Miller)

Exhibit 7.1-19

January 27, 2011 National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service’s comments on Idaho Power Company’s (IPC) water quality application for the Hells Canyon Complex (HCC)

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
1201 NE Lloyd Boulevard, Suite 1100
PORTLAND, OREGON 97232-1274

January 27, 2011

Neil Mullane
Oregon Department of Environmental Quality
Headquarters Office
811 SW 6th Avenue
Portland, OR 97204-1390

Barry Burnell
Idaho Department of Environmental Quality
Headquarters Office
1410 North Hilton
Boise, Idaho 83706

Subject: Comments on Idaho Power Company's Water Quality Application for the Hells Canyon Complex Hydroelectric Project----Adams and Washington Counties, Idaho and Baker, Malheur and Wallowa Counties Oregon -----Comments Hells Canyon Hydroelectric Project FERC 1971

Dear Mr. Mullane and Mr. Burnell:

This letter provides the National Marine Fisheries Service's (NMFS) comments on the September 2010 Water Quality Application (Application) submitted by the Idaho Power Company (IPC) under Section 401 of the Clean Water Act (CWA) for the Hells Canyon Complex (HCC) Hydroelectric Project. NMFS does not support this application because it does not focus on the broader set of water quality issues at an ecosystem scale that affect anadromous fish in the Snake River.

We are providing additional information pertinent to IPC's 401 certification application, including recent information on the current status of Endangered Species Act (ESA) listed Snake River fall Chinook salmon (SR fall Chinook) which spawn, incubate, and rear in the Snake River downstream of the Hells Canyon Complex. SR fall Chinook are the species under our jurisdiction most affected by the quality of water discharged at the project.[1] Because SR fall Chinook are extant only in the Snake River downstream from the project and its tributaries, a broader consideration of how best to benefit SR fall Chinook in the Snake River would be more useful to your decision process than would a narrow focus on the Natural Seasonal Thermal Pattern (NSTP) standard.Your request specified your interest in NMFS's view of IPC's analysis of implementing ODEQ's Natural Seasonal Temperature Pattern (NSTP) narrative standard at the HCC. In attempting to respond to this request we recognized that there are differences among the parties on how to interpret this standard. EPA views the standard as applicable when needed to protect a designated beneficial use and has recommended applying the standard at the

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[1] Threatened Snake River steelhead are also migrating in the Snake River downstream of Hells Canyon Dam during this time.

HCC from early September until October 23 to protect migrating adult Snake River fall Chinook. (letter of October 26, 2010, from Michael Bussell, USEPA, to Neil Mullane, ODEQ). In its 401 application, IPC has evaluated the standard on a year-round basis. Given this range of possible interpretations, we have chosen to evaluate the possible return of the Snake River to its natural thermal pattern on a year-round basis to better inform your decision.

Background and History

SR fall Chinook once ranged as far upstream as Shoshone Falls (River Mile 615) and spawned in the Thousand Springs reach of the Snake River. Since the turn of the century, large-scale water developments reduced the range of most anadromous fish in the Snake River basin, including SR fall Chinook. Before Brownlee Dam was completed in 1958 (River Mile 285), SR fall Chinook primarily used spawning habitat near Marsing, ID, downstream from IPC's Swan Falls Dam at River Mile 458.

The original Federal Energy Regulatory Commission (FERC) license for the HCC included passage measures that ended up not being effective, and IPC funded hatcheries as mitigation for lost access to historical upstream habitat. Since that time, upstream habitat has become unsuitable for spawning and rearing due to pollution and habitat alteration. The main causes of pollution are heavy nutrient loading that decreases the available oxygen and causes algae mats that reduce intergravel flow, as well as increased levels of sediment that could also cover the SR fall Chinook eggs before they get a chance to hatch. Due to the dams, Snake River fall Chinook are currently limited to a single population consisting of the Hells Canyon reach of the Snake River, and the lower reaches of the Clearwater and Grande Ronde rivers.

Relicensing

Throughout the relicensing process, NMFS has taken the position that the upstream habitat should be restored to support SR fall Chinook. NMFS submitted recommended terms and conditions to the FERC under Sections 10(j) and 10(a) of the Federal Power Act (FPA), including recommendations for improving upstream water quality and fish habitat, and for conducting fish passage studies once the habitat can support anadromous fish. FERC did not adopt these measures in its final environment impact statement (FEIS) for the project.

An extensive body of information has been developed through the relicensing process regarding: the potential for anadromous fish reintroduction into habitats upstream from the project; the water quality of the project and its effects on SR fall Chinook use of the receiving water; and approaches for mitigating those effects. Additionally, NMFS now has considerable information on SR fall Chinook and is developing a recovery plan for them.

Status of SR Fall Chinook

SR fall Chinook continue to be listed as threatened under the ESA. Their abundance has increased substantially since the late 1990s (Figure 1). In the most recent brood years for which full adult returns are available, the abundance of hatchery-produced fish has increased and the abundance of naturally produced fish has decreased. There are several lines of information that suggest the decreased abundance of naturally produced fish is primarily due to the limited amount of rearing habitat that is available to juveniles in the Snake River especially in the upper Hells Canyon reach (upstream of the confluence with the Salmon River to Hells Canyon Dam).

Connor and Tiffan (2010)[2] indicated that juvenile SR fall Chinook abundance in the Snake River has increased over time (1995 to 2008), that the recent mortalities of fish from the upper Hells Canyon reach has increased by about 35% compared to the earlier period with little hatchery supplementation; and growth rates have decreased by about 0.6 to 0.7 (between tagging in the Snake River nearshore areas and Lower Granite Dam).

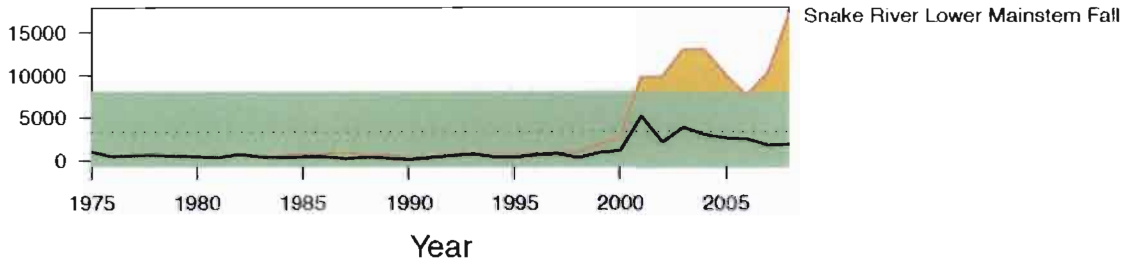

Figure 1. Abundance of SR Fall Chinook salmon in the Snake River by brood year. The black line represents naturally produced fish, the red line represents total abundance of naturally and hatchery produced fish; the dotted line represents the average total abundance across the period (green area denotes 1 standard deviation around the mean; orange area indicates exceedences above 1 standard deviation). Source: NMFS – Northwest Fisheries Science Center "Salmon Population Database: https//www.webapps.nwfsc.noaa.gov/ and NMFS unpublished data.

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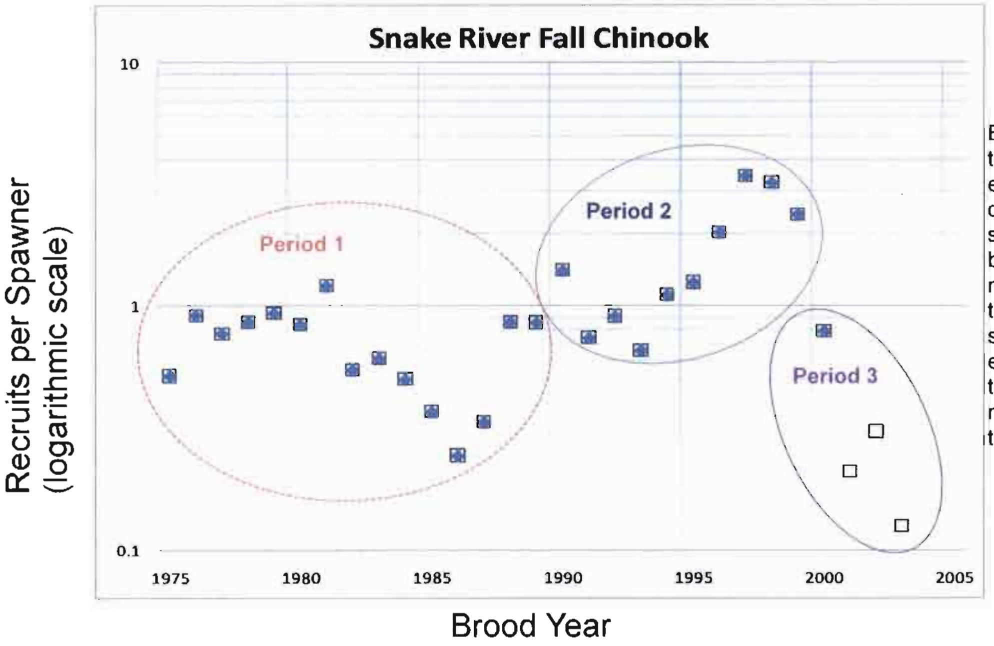
[2] Connor, W.P. and K.F. Tiffan. Research, monitoring, and evaluation of emerging issues and measures to recover the Snake River fall Chinook salmon Evolutionarily Significant Unit (ESU) - Annual Report 2008 (Chapter 2).



Brood year spawner to spawner estimates. Filled diamonds: parent spawner estimate below 75% of minimum abundance threshold. Open squares: parent escapement greater than 75% of minimum abundance threshold.

Figure 2. Recruits per spawner estimates for Snake River fall Chinook by brood year. Period 1 denotes the brood years prior to proposed listing under the Endangered Species Act; Period 2 denotes the brood years that were affected by measures to improve their survival (most notably the provision of stable spawning flows from the Hells Canyon Complex, cool-water releases from Dworshak Dam on the Clearwater River, and supplementation with hatchery fish by the Nez Perce Tribe); and Period 3 denotes recent years in which the productivity of naturally produced fish has declined after adult spawner abundance generally exceeded 10,000 adults. Source: NMFS – Northwest Fisheries Science Center "Salmon Population Database: https//www.webapps.nwfsc.noaa.gov/ and NMFS unpublished data. NOAA Tech Memo NMFS-NWFSC-66. Good et al. 2005. Updated Status of Federally Listed ESU's of West Coast Salmon and Steelhead. 598 p. June 2005.

The authors also note that the upper reach is narrow and rearing habitat is relatively limited; predation in the upper reach is the most likely cause of the observed mortalities; redd counts and Lower Granite reservoir temperatures are the best predictors of smolt growth rates; and smolt growth decreased as hatchery release number increased. Taken together, this information provides strong, though preliminary, evidence for a density-dependent response in the apparent mortality of naturally produced subyearling Chinook from the upper Hells Canyon Reach.

In other words, the abundance and productivity of naturally produced SR fall Chinook in this reach does not appear to be limited by water temperatures in the reach, but by the amount of quality juvenile rearing habitat (space) available in the reach. Reduction of water temperatures during the fall migration/spawning season, as proposed by IPC, would have no effect on the habitat available to juvenile SR fall Chinook which inhabit the river from the time of emergence (March and April) through emigration (May through August). However, as we describe in more detail below, the water used to change the water temperature downstream could have significant adverse effects on SR fall Chinook and their critical habitat.

NMFS agrees with Connor and Tiffan's assessment that the population of SR fall Chinook downstream from Hells Canyon Dam is likely approaching the carrying capacity of available juvenile habitat.[3] Given that this population growth has taken place under the existing water temperature regime, we conclude that the current water temperature regime is not limiting the SR fall Chinook population downstream from the project, and that reduction in fall water temperatures to comply with the established water temperature criteria would not be likely to substantially improve the abundance or growth rate of the population.[4]

The available habitat is supporting all the juvenile fall Chinook it can, or nearly so. To further increase the abundance of fall Chinook, additional suitable habitat would have to become available. From the perspective of benefiting SR fall Chinook, the most effective way to achieve this would be to improve the upstream historical habitat and make reintroduction above the project a viable option. This would result in two populations, and be a very significant action to further NMFS's goal of recovery of Snake River fall Chinook.

Temperature Enhancement Mitigation Program (TEMP) Proposal (upstream habitat improvement)

With over 1 million acre-feet of storage, and active seasonal storage and withdrawal operations, the HCC creates thermal inertia effects (slow to warm in the spring, slow to cool in the fall) and a cropping of annual peak and minimum temperatures in the discharge stream. This effect results in the project exceeding specified water temperature criteria at the beginning of the specified spawning season (October 23 through April 15).

In 2003, IPC submitted its initial request for certification under Section 401 of the Clean Water Act and has withdrawn and resubmitted its application six times since, primarily in response to the water temperature issue. Earlier in this process, IPC proposed to meet its water temperature responsibilities by reducing the heat input to Brownlee reservoir by implementing an upstream water temperature remediation program termed TEMP. The TEMP program shared many similarities with NMFS's recommended upstream habitat improvement program. Although focused primarily on water temperature reduction, TEMP included a number of measures in the suite of possible actions that would also reduce nutrient and sediment loading (e.g. land fallowing, water leasing, and irrigation return flow artificial wetland development). By reducing nutrients and sediment loads as well as water temperatures, TEMP would benefit reintroduced SR fall Chinook by reducing sedimentation and algal blooms in the river above the HCC. Poor intergravel

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[3] Another hypothesis is that high proportions of hatchery spawners are resulting in less fit juveniles and decreased productivity of the naturally produced segment of the ESU. While this hypothesis has not been disproved, there appears to be little causal evidence to support it.

[4] Although there is no strong indication that temperatures in the Hells Canyon reach of the Snake River are negatively affecting adult SR fall Chinook in any substantial way, cooler fall water temperatures could potentially result in lower pre-spawning mortality among returning adults and earlier initiation of spawning (assuming attainment of temperatures around 16 degrees C occurred earlier in the season and adults began spawning at that time). This would not increase the amount of available habitat, and therefore would not address the underlying need for additional habitat.

flow, caused by algae and sedimentation, has been identified as a causal agent for the poor egg-to-fry survival documented during IPC's reintroduction studies. Although the TEMP proposal was less focused on fish habitat improvements than NMFS' 10(j) recommendation, and IPC proposed a lower level of funding, NMFS strongly supports the adoption of a TEMP-like program because it would accelerate the attainment of water quality conditions necessary for the reintroduction of SR fall Chinook salmon into historically productive habitat.

IPC's Temperature Control Structure (TCS) Proposal

IPC's most recent 401 application proposes to meet ODEQ's numerical water temperature standard for spawning salmon by pumping cooler water from deep in Brownlee reservoir into the intake channel for the Brownlee powerhouse, cooling the discharge to the Snake River at Hells Canyon Dam. This plan itself causes NMFS concern due to water quality issues associated with nutrients and toxics; however, it does not cause us concern with respect to temperature. NMFS currently considers juveniles to be the limiting life-stage of the SR fall Chinook population and juveniles reside in the river only from emergence (March-April) through emigration (May-July) and thus would be unaffected by the proposed TCS. The proposed TCS would not provide any additional spawning and rearing habitat, which is what is needed to benefit the species at this point. NMFS does not believe that meeting spawning water temperature standards would appreciably increase either the abundance or the productivity of the spawning aggregate in the Hells Canyon reach of the Snake River.

We are also concerned that by entraining water from depth in Brownlee reservoir into the discharge stream from the project, additional risks to the existing SR fall Chinook population and its critical habitats would be incurred. These risks include low dissolved oxygen concentrations, high nutrient (nitrogen and phosphorus) concentrations resulting in high biological oxygen demand, and toxins (DDT and other pesticides and herbicides and heavy metals, particularly methyl-mercury). These conditions result from the extremely high nutrient loads entering Brownlee reservoir, and the biological and chemical processing of these nutrients within the reservoir. IPC would need to mitigate for the dissolved oxygen, nutrients and toxics levels to avoid adverse impacts to anadromous fish and critical habitat.

Natural Seasonal Temperature Pattern Standard

As shown above, the abundance of SR fall Chinook has improved substantially since their listing under the Endangered Species Act, to the point that the population is now limited by available physical habitat for juveniles. This increase in SR fall Chinook abundance has occurred during the current water temperature regime. It is NMFS' view that the current water temperature regime downstream from Hells Canyon Dam is more beneficial to SR fall Chinook than the natural regime, primarily due to warmer fall and winter water temperatures that accelerate fry emergence.

Assuming the same spawn timing distribution, NMFS substantively agrees with IPC's assessment that; 1) emergence would be delayed by about two weeks under the natural water temperature regime, compared to the current thermal regime, and 2) that current SR fall Chinook emergence timing in the extant Snake River habitat is similar to that which would be expected in the historically productive Marsing reach upstream of the project.

We believe that modifying discharge water temperatures to meet the NSTP standard would incur larger risks than potential benefits for Snake River fall Chinook. As discussed above, we have several concerns about the approach proposed by IPC to meet the fall spawning numeric water temperature criteria. The proposal incurs risks to the SR fall Chinook ESU that are made more compelling because the ESU consists of a single population, largely dependent on the Hells Canyon reach of the Snake River and the operations of the Hells Canyon Complex.

Conclusions

1. While NMFS generally supports the use of the NTSP standard, the application of this standard to the Hells Canyon Project would likely not appreciably improve either the abundance or productivity of SR fall Chinook because limited juvenile rearing habitat (after emergence in the spring) appears to be the primary limiting factor for SR fall Chinook in the Hells Canyon reach of the Snake River.

2. The potential adverse effects of IPC's water temperature mitigation plan need to be well-defined and adequately mitigated. Defining these effects could be accomplished through modeling of the chemical, physical, and biological processes in the two downstream reservoirs, and in the free-flowing Hells Canyon reach. Once these effects are defined, they need to be mitigated to avoid adversely affecting SR fall Chinook and their critical habitat.

3. Restoring historical upstream habitat for Snake River fall Chinook salmon to the point where it will again be able to support spawning and rearing is the most effective action for improving survival and recovery, by creating conditions for successful upstream reintroduction.

4. Lastly, river temperatures upstream of, and within Brownlee reservoir have been, and will continue to be altered by global climate change. We advice that it would be prudent to model how expected increases in air temperatures and altered hydrology over the coming decades are likely to affect the volume of cool-water within Brownlee Reservoir that the proposed structure relies upon. These results would likely inform the DEQs' views as to the longer-term efficacy of the proposed structure.

Thank you for the opportunity to comment. Please contact Keith Kirkendall at 503-230-5431, Keith.Kirkendall@noaa.gov of my staff if you have any questions.

Sincerely,

Bruce Suzumoto
Assistant Regional Administrator
Hydropower Division

Document Content(s)

Idaho Power.PDF...1-8

Exhibit 7.1-20

December 6, 2010, Oregon Department of Environmental Quality (ODEQ) additional information request (AIR) to Idaho Power Company (IPC)

1859

Oregon

Theodore R. Kulongoski, Governor

Department of Environmental Quality
811 SW Sixth Avenue
Portland, OR 97204-1390
503-229-5696
TTY 503-229-6993

December 6, 2010

Chris Randolph
Director, Environmental Affairs
Idaho Power
P.O. Box 70 (83707)
1221 W. Idaho St.
Boise, ID 83702

Re: Additional Information Requests (AIR), Hells Canyon Complex (HCC)
Application for Certification under Clean Water Act § 401

Dear Mr. Randolph:

Thank you for your application for §401 certification dated September 24, 2010. ODEQ appreciates the work completed by Idaho Power Company (IPC) to submit a complete § 401 application. While this most recent submittal contains information related to meeting temperature standards, additional information is necessary for ODEQ to complete its review and analysis. ODEQ requests IPC provide additional information for several parameters as described below.

Temperature

Salmon and steelhead spawning

To attain the project's temperature load allocation based on the salmonid spawning criterion of 13°C, applicable downstream of the Hells Canyon dam, IPC proposes to install a hypolimnetic pump system (HPS) to pump cold water from the hypolimnion of Brownlee Reservoir. IPC developed a flow weighted average equation to estimate the effect of pumping cold Brownlee Reservoir water on the outflow temperature from Hells Canyon dam. Presented on page 151, the equation appears to model mixing of cold hypolimnetic water from Brownlee Reservoir directly with the outflow from Hells Canyon dam. However, the cold water from Brownlee will be mixed with warmer water from Brownlee, which will travel through Oxbow and Hells Canyon reservoirs. This water will be warmer than the coldest water available in the hypolimnion. The equation appears to assume the following:

1. The temperature of the cold water modeled from Brownlee (noted as "temp hypo") will be the same temperature as the temperature of the water that will actually be mixed from the hypolimnion and the metalimnion.
2. The temperature of the cold water will remain constant throughout the time period of water withdrawal.
3. The water discharged from Brownlee will not warm up as it travels through Oxbow and Hells Canyon dam.

The equation does not address the possible attenuation of cold water as it moves through the Hells Canyon complex. In order for ODEQ to evaluate the potential for the HPS to attain water quality standards, IPC must provide an analysis of the temperature expected below the Hells Canyon dam.

For the proposed HPS please provide a detailed evaluation of the potential effectiveness of the system to meet the 13°C criterion as allocated in the Snake River TMDL. The modeling should simulate the flow of water as it moves through the three dam complex and address the possible attenuation of the cold water as it moves through the complex. The temperature of water discharged from Hells Canyon reservoir should be modeled for representative flow years. Please answer the following questions (which are followed by suggested plots or documentation):

1. What is the point of maximum temperature impact of HCC? Show longitudinal plots of predicted change in temperature from 'current project operations' to 'without project.' In the longitudinal plots please include locations corresponding to the inflow and outflow of each reservoir, the location representative of 12 hours travel time downstream, and at the Oregon/Washington border. See Khangaonkar and Yang (Khangaonkar, T. and Yang, Z. 2008. Dynamic Response of Stream Temperatures to Boundary and Inflow Perturbation Due to Reservoir Operations. River Research and Applications. 24(4): 420 – 433) and DEQ's Mainstem Willamette TMDL (http://www.deq.state.or.us/wq/tmdls/docs/willamettebasin/willamette/chpt4temp.pdf) for discussion. Please include discussion of whether the point of maximum impact is expected to change under different flow regimes or under different project operations.
2. What is the predicted temperature at the point of maximum impact for the entire year compared to 'current project operations' and 'no project'? Plot temperature of outflow from Hells Canyon reservoir. Plot simulated seven day moving average of the daily maximum temperature from Hells Canyon outflow. Model these temperatures over the representative flow years used in the FLA (1992, 1994, 1995, 1999 and 1997) (time series plots).
3. How is the 13.3 °C (as a 7-day average of the daily maximum) target derived? Please provide additional justification for the target. The SR-HC TMDL indicates a spawning target of 13.0 °C minus a 10% safety factor applied to the difference between the criteria and the upstream temperature.
4. What is the predictive uncertainty? Please discuss sources of uncertainty. See U.S EPA's 2009 Guidance on the Development, Evaluation, and Application of Regulatory Environmental Models for additional information.

Natural seasonal thermal pattern

The application does not contain a proposal to address the natural seasonal thermal pattern (NSTP) as required under OAR 340-041-0028(4)(d). As noted in the § 401 application, the water quality standards do not contain a definition for NSTP. IPC asserts that there is no published ODEQ internal management directive that offers further explanation of NSTP. However, the April 2008 document "Temperature Water Quality Standard Implementation – A DEQ Internal Management Directive" addresses NSTP and states that "fall cooling and spring warming of river temperatures should not be significantly delayed as a result of the management of the dams and reservoirs (pg. 47)." ODEQ needs to determine IPC's ability to comply with the NSTP narrative criterion. ODEQ therefore requests that IPC model cold water releases prior to the beginning of spawning period using the HPS. Specifically, provide the following information:

1. Model release of cold water to shift maximum temperature outflow from Hells Canyon dam. Plot annual thermal pattern with cold water releases to move summer peak closer to that represented by pre-dam data at river mile 273. Plot the seasonal thermal pattern below Hells Canyon dam and at the Oregon/Washington border.
2. Based on these modeling results, determine whether there is sufficient cold water in Brownlee to meet the spawning criterion and shift the thermal pattern as described in item #1.
3. If there is insufficient cold water to increase fall cooling and attain the 13°C spawning criterion, please demonstrate what downstream cooling can be achieved with the HPS and available cold water from the hypolimnion in Brownlee Reservoir.
4. Does Figure 6.1-11 assume that spawning occurs on the same date for each location? Provide data, model, assumptions and supporting information used to derive Figure 6.1-11 on page 53.
5. What are the accumulated thermal units and predicted accumulated thermal units for other possible thermal regimes? Please consider scenarios where IPC uses available water to provide warmer water

earlier in the spring, warmer water throughout winter, and no warming or cooling relative to upstream temperature.

Migration

What is the impact of proposed changes related to the migration criteria? Although the Hells Canyon complex has not been determined to be a source of impairment impacting the migration use, please provide documentation and graphs showing that proposed changes will not adversely cause or contribute to an exceedance of the migration criteria. Please use the questions related to spawning use to direct your response.

Reasonable assurance and monitoring plan

The § 401 application does not contain a section on reasonable assurance to meet the temperature load allocation or a temperature monitoring plan. Please provide these sections. Please propose a compliance point or points that will allow for data collection through the Hells Canyon reach to determine attainment of the temperature load allocation, and NSTP during the applicable seasons.

Conceptual project risk assessment

IPC describes the potential risks of operating the HPS as primarily related to discharge of low dissolved oxygen water with elevated levels of toxics. IPC must describe what water quality conditions, throughout the project, could be exacerbated by the discharge of water from Brownlee Reservoir's hypolimnion. IPC must discuss all available data indicating these risks and define data gaps. IPC must also propose mitigation measures for these possible impacts. Issues of concern include the possible effects of ammonia toxicity downstream of the complex, biochemical oxygen demand increase, release of pesticides from sediment and the methylation of mercury.

Antidegradation

IPC notes that blending of cooler water from Brownlee Reservoir may further degrade downstream conditions and have an effect on beneficial uses downstream (pg. 146). In order to complete its review of the § 401 application, ODEQ will need to complete an antidegradation review. Please describe specifically how water quality within Brownlee Reservoir and downstream water quality and beneficial uses will be affected by the blending of cooler water from Brownlee Reservoir.

Biocriteria

Under water quality criteria designed to protect biological integrity (biocriteria -OAR 340-041-0011) waters must be of "sufficient quality to support aquatic species without detrimental changes in the resident biological communities." Please describe how the HPS may affect the resident biological communities within and downstream of Brownlee Reservoir, including the lower reservoirs and Snake River downstream of the complex.

Dissolved Oxygen

Brownlee Reservoir dissolved oxygen and algae

The proposed HPS will alter the hydrodynamics of Brownlee Reservoir and impact the dissolved oxygen concentration and algae population. Under the proposed HPS and aeration scenario, please predict the dissolved oxygen concentration in the metalimnion and transition zone in Brownlee Reservoir and the chlorophyll *a* concentration in the epilimnion. Please provide the same predictions under the HPS and phosphorus trading scenario.

IPC notes that installation and operation of the HPS at Brownlee will affect outflow dissolved oxygen. The application states that aerating runners designed for Brownlee turbines may be capable of increasing dissolved oxygen concentrations by 2.5 mg/L for 5,000 cfs flows. The modeling was conducted based on an incoming dissolved oxygen concentration of 2.0 mg/L and water temperatures of 23° C. However, the data provided with the application show that incoming dissolved oxygen concentrations at the time of HPS operation are likely to be below 1.0 mg/L. The application also acknowledges the likely presence of anoxic products in the pumped water, but the oxygen demand of these products was not accounted for. Please model the affect of the aeration runners using boundary conditions based on data collected in the reservoir. Also, please provide an estimate of the affect of the aeration runners on the TDG levels below Brownlee Reservoir.

Downstream dissolved oxygen

IPC used the CE-QUAL-W2 model to simulate dissolved oxygen levels downstream from the HCC. Please answer the following questions about the downstream dissolved oxygen modeling:

1. How was a SOD level of 0.1 g O_2/m^2/day chosen? Please provide a justification for this value, or provide a sensitivity analysis for the SOD parameter.
2. Why were only the first five dates of IGDO data used to develop the water column dissolved oxygen target?
3. What is the impact of assumed boundary conditions (i.e. SOD and algae concentrations) on the calculated load?

Reasonable assurance and monitoring plan

IPC notes that the Brownlee Reservoir aeration system will increase DO levels in the vicinity of the diffuser. In low water years, however, modeling indicates that some anoxia can occur upstream of the diffusers. IPC notes that in extreme cases these conditions could extend to the surface (pg. 168). In the dissolved oxygen monitoring plan section, IPC proposes to document the injection of 1,125 tons per year of dissolved oxygen to Brownlee Reservoir. Please propose a compliance point or points which will allow for data collection to determine attainment of the applicable dissolved oxygen criterion within the metalimnion of Brownlee Reservoir.

IPC has at its disposal a calibrated water quality model (CE-QUAL-W2) that can be used to evaluate the impact of proposed HPS on temperature, dissolved oxygen and other parameters of concern.

ODEQ would like to evaluate the model runs, including model input and model design. ODEQ requests IPC provide documentation of the model calibration and scenarios used to evaluate the proposed mitigation measures.

In order to complete the § 401 application review and decision within the statutory one year deadline, ODEQ requests the additional information described in this letter be provided to ODEQ by February 7, 2011. ODEQ may identify further information needs as we continue our evaluation of the § 401 application. If you have any questions please contact Marilyn Fonseca at (503) 229-6804 or Eric Nigg at (541) 633-2035.

Sincerely,

Neil Mullane

Neil Mullane
Water Quality Division, Administrator

cc: IPC, James Tucker
EPA, Portland, Mary Lou Soscia
EPA, Seattle, John Palmer
IDEQ, Doug Conde
IDEQ, Barry Burnell

IDEQ, Tonya Dombrowski
USFWS, Gary Burton
USFWS, Michael Morse
USFWS, Russ Holder
Shoshone-Bannock Tribes, Nathan Small
Nez Perce Tribe, Greg Haller
CRITFC, Julie Carter
Burns Paiute Tribe, Jason Kesling
CTUIR, Carl Merkle
ODEQ, Eric Nigg
ODEQ, Dan Turner
ODEQ, Marilyn Fonseca
ODFW, Colleen Fagan
ODFW, Ken Homolka
WRD, Mary Grainey
WRD, Ron Kohanek
Governor's Natural Resource Office, Suzanne Knapp
ODOJ, Kurt Burkholder
American Rivers, Brett Swift
Trout Unlimited, Kate Miller
Idaho Rivers United, Kevin Lewis
NOAA Fisheries, Ritchie Graves

Exhibit 7.1-21

Hells Canyon surface collector with temperature management component, conceptual design report executive summary

Hells Canyon Surface Collector with Temperature Management Component

Conceptual Design Report Executive Summary

1.0 Background

Portions of Idaho Power Company's (IPC) bull trout passage plan are based on the Federal Power Act §18 Fishway prescription issued by the U.S. Fish and Wildlife Service (FWS) specific to bull trout. In the §18 fishway prescription, the FWS did not describe the size of the monitoring weir for Pine Creek. However, in the FERC FEIS (FERC 2007, p 666), FERC staff recommended a facility that would be operable up to the 90th percentile of flows in an average water year. FERC staff further recommended that this weir be used to evaluate the potential for the reintroduction of salmon and steelhead into the Pine Creek basin and to use the facility as a collection point for outmigrating juvenile anadromous fish as part of the evaluation. IPC estimates that a weir would need to operate up to a range of 2000-2500 cfs in order to effectively collect juvenile steelhead and spring Chinook outmigrants leaving Pine Creek during typical spring-time flows. The facility would also need to operate at very low flows (30-50 cfs) during the early fall period to collect bull trout that may be outmigrating from Pine Creek to over winter in the Snake River.

While a weir at Pine Creek was originally considered as the fish passage alternative (CH2M Hill 2003), recent flood events which have resulted in significant bedload movement and flood damage at the proposed Pine Creek Weir site have caused IPC to reevaluate that decision. Results of an engineering risk/issue analysis (McMillen 2012) and hydrology summary (Morehead 2012) indicates that the flashy and unpredictable nature of flows in the basin combined with the high potential for mobilization of large bedload and debris would result in extensive damage to a collection facility located near the mouth of Pine Creek. Operating the facility to prevent this damage would require the proposed Obermeyer gate to be lowered during periods of high flows; an operation that would result in no fish collection.

This concern over building a collection facility that would have a high risk of damage and not achieving the intended objective of fish collection caused IPC staff to re-evaluate the feasibility of fish collection at Pine Creek and consider other fish passage alternatives for the Pine Creek/Hells Canyon Reservoir area. This paper summarizes the option of installing a fish collection system on the upstream face of Hells Canyon Dam (HCD). It also includes the addition of a temperature management component to the structure.

2.0 Hells Canyon Dam Surface Collector

IPC requested McMillen LLC to review a previous preliminary design (McMillen and CH2M Hill 2005) of an intake structure at HCD and consider opportunities for providing fish passage through a surface fish collector and also access to cool water in Hells Canyon Reservoir for downstream temperature management (McMillen 2013). The surface draw and fish collection aspect of the structure would be used to maintain the cool water storage and stratification of the reservoir during lower flow years as well as attract downstream migrants (Figures ISO 1–4).

A CE-QUAL-W2 model for Hells Canyon Reservoir, developed by Portland State University, indicates that a volume of water between 17,000 and 20,000 acre-feet of cool (< 13°C) water would be stored during a lower flow water year if the existing submerged cofferdam (constructed during construction of HCD) located upstream of HCD is increased in height and water is drawn into the powerhouse from the depths of the reservoir behind that cofferdam through a constructed intake structure.

As initial steps in developing the conceptual design, a Computational Fluid Dynamic (CFD) model was developed for the HCD reservoir approximately one mile upstream of the proposed structure. The CFD model was used to determine the flow patterns within the reservoir and evaluate the ability of the surface collector to create surface draw conditions. The flow patterns were evaluated to determine the zone of influence which downstream fish migrants would enter and be drawn into the surface collector. A range of flow conditions were evaluated to observe the potential flow patterns created by the surface collector and the anticipated fish guidance and collection. In general, the CFD model confirmed the surface collector would create attractive flow conditions in the far field and near field zones throughout the powerhouse flow range (up to 30,000 cfs). As the flow increases above 30,000 cfs, it appears that the surface collector would provide effective fish attraction up to a total river flow of 45,000 cfs to 60,000 cfs. The flow patterns within the near zone in the reservoir immediately upstream of the surface collector tends to favor the powerhouse over the sluiceways. Overall, the analysis indicates the surface flow conditions would promote fish attraction and collection.

The temperature management portion of the structure takes advantage of the area located between each of the turbine intakes to install a pump station used to withdraw cool water from upstream of the existing coffer dam and deliver it to the dam tailrace. The pump and pipeline design approach is based on standard technology and equipment.

2.1 Fish Collection

The fish collection facilities are patterned after an intake screen system which has been constructed, tested, and operated at the U.S. Army Corps of Engineers' (USACE) Lower Snake and Columbia River Dams. The intake screens and fish collection systems installed at these facilities have proven effective in guiding and collecting juvenile out migrants that enter the powerhouse intakes. These systems utilize intake screens installed within the turbine conduit that are designed to guide downstream migrants out of the turbine intake up into a bypass system.

Though HCD has a much higher operating head at 210 ft versus 110 ft at the Lower Snake and Columbia River dams, a fish collection system still appears to be feasible at HCD using the same basic design principles used at the lower Snake and Columbia dams. However, the limited size and higher velocities associated with the HCD penstock at the location of the bulkhead slot does not allow installation of intake gates within the bulkhead slot. The physical configuration of the dam intake also does not provide sufficient space for installation of a collection gallery type of passage system within the existing dam footprint. As a result, a new steel intake structure would be required on the upstream face of the existing dam to house the fish collection facilities. Construction of a new facility allows the screening system design to be optimized in terms of hydraulic flow conditions as well as size and operation. The new intake could also be designed to maximize the surface draw nature of the project operation.

Using the technology used at other[1] projects, the proposed fish collection system would consist of:

- Intake structure
- Submerged Traveling Screens (STS)
- Vertical Barrier Screens (VBS)
- Fish Collection Conduit
- Fish Collection Barge
- Fish Transport System

A more detailed description of each of these components is provided in the following paragraphs. Isometric drawings are provided in Figures ISO 1–4.

2.1.1 Intake Structure

A new intake structure will be constructed upstream from the existing HCD. The steel frame structure is designed to allow an incremental installation of steel modules from the bedrock foundation to the main intake deck. The rock line slopes downhill from the west to the east resulting in an increased support structure height at Unit 1 as compared to Unit 3. The structure consists of three individual towers located at each of the dam intake openings with infill framing between each of the towers to create a full connected steel hydraulic structure. Each tower is vertically supported at each corner by steel pipe columns filled with a self-consolidating cementitious grout. The base sections of the towers consist of steel braced frames. The upper section at the intake openings are a combination of steel braced frames and moment frames providing redundancy in the structure design. The braced and moment frames were utilized along the upstream face to resist lateral racking loads. Areas along this face which fell above or below the main flow regions of the intake were assumed to be braced, while the main flow regions were assumed to be moment frames to limit impact across the opening to fish passage. Reinforced precast concrete panels were used for the separation walls between

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[1] USACE projects using similar intake structure, STS, VBS, fish collection conduit and transport system technology include Lower Granite, Little Goose, Lower Monumental, and McNary dams juvenile bypass systems. Similar bypass systems, dewatering screens and fish sampling facilities are found at John Day and Bonneville (1st and 2nd powerhouse) dams. Pacificorp (Swift Dam), Puget Sound Energy (Upper/Lower Baker), and Portland General Electric (Pelton Round Butte) projects utilize similar fish collection barges fitted with dewatering screens, evaluation facilities, holding raceways and transport systems.

the intake bays. Reinforced steel plates are used within the pump upwells to hydraulically isolate the regions to control flow.

The new intake structure is 172 feet long (east to west), 48 feet from the face of the intake to the face of the existing concrete dam, and over 145 feet tall. The floor and ceiling of the turbine were projected from the existing intake arrangement to provide smooth hydraulic transition through the new intake to the existing penstock intake.

2.1.2 Submerged Traveling Screens (STS)

Each turbine intake is fitted with two Submerged Traveling Screens (STS). The STS extends out into the turbine intake to intercept fish moving through the intake guiding them towards the collection pipe. STS have been used extensively by the USACE on the Snake and Columbia River hydroelectric systems. In general, two basic types of STS screens have been tested and used by the USACE: (1) standard-length submerged traveling screens (SSTS) which are approximately 20 ft long, and (2) extended-length submerged bar screen (ESBS) which are 40 ft long. The length of screen required is normally selected based on the depth of the fish as they pass through the turbine intake. The HCD surface collector was designed to allow installation of a maximum 40-foot-long STS. As the design advances, hydraulic model testing of the screen lengths coupled with biological studies of the anticipated travel patterns within the Hells Canyon Reservoir will be used to refine and select the final STS length. The basic design approach will be patterned after the USACE system, with refinements to fit the site specific characteristics of HCD.

2.1.2.1 Standard-Length Submerged Traveling Screen

The Standard-Length Submerged Traveling Screen (SSTS) is a standard length screen that has been used extensively on the USACE projects. The SSTS is 20-feet-long and of sufficient width to completely span the intake. The SSTS has an outer support frame which is designed to slide in the existing dam gate slots for screen deployment and retrieval. An inner frame provides the structural support for the screen mesh. Porosity plates are mounted to the inner frame. Varying the plate porosity is an effective means to control the water velocities through the screen. The inner frame is pinned to the outer frame with a pivot point near the top of the screen assembly. When deployed, the inner frame is supported by two strut arms deployed from the bottom of the screen assembly. The SSTS is deployed by lowering the screen assembly down a bulkhead slot in a vertical position. Once the SSTS reaches the desired elevation, the strut arms are extended which causes the inner frame to rotate about the pivot point. The STSS is normally deployed with the top of the screen located near the base to the VBS. The strut arms are extended until the inner frame has been rotated to the desired operating angle, usually around 45 to 55 degrees.

2.1.2.2 Extended-Length Submerged Bar Screen

The extended-length submerged bar screen (ESBS) is 40-feet-long and fits the width of the turbine intake. The ESBS assembly consists of three frames: (1) an outer frame that slides down into the existing gate slots that is used for the screen deployment and retrieval; (2) an inner frame made up of two outer support beams and two inner beams that support the brush cleaning system tracks; and an intermediate frame that connects the inner and outer frames and is used to set the deployment angle of the screen. Porosity plates span the space between the outer support beams of the inner frame. Similar to the STS, porosity plates are used to control the water velocity through the screen. The flat screen surface consists of wedge wire screen material supported with intermediate structural supports and off the external frame. A brush cleaning system is used to sweep the screen surface. The brush is parked at the end of the screen when not in use.

2.1.3 Vertical Barrier Screens (VBS)

Located immediately downstream from the STS, a Vertical Barrier Screen (VBS) is designed to pass the upwell flow through the screen panel and back to the turbine intake. The VBS at HCD will be designed to pass up to 10 percent of the total turbine flow, or a maximum of about 1000 cfs. Each VBS is approximately 80-feet-tall by 20-foot-wide with a 3.0 foot depth. The VBS has a steel frame with a stainless steel perforated plate panel inserts which form the screen panel. The top 2/3 of the VBS will be a traveling screen and will be fitted with one or two traveling belts which consist of roller drive chains with a plastic mesh. The bottom 1/3 of the VBS will have stainless steel wedge wire bar screen panel inserts in addition to the perforated plates. The VBS will be delivered in two sections with a pinned connection between the traveling screen and wedge wire screen sections. This basic design approach is patterned after the USACE installations. A detailed evaluation of the hydraulic performance of the VBS at the HCD installation will be required to ensure effective hydraulic performance and fish protection. The USACE design approach provides a solid basis for the conceptual design presented herein.

2.1.4 Fish Collection Conduit

The flow diverted up the screen slot carries the juvenile fish upward with sufficient velocity to trap the fish within the vertical water column. Weir boxes are located near the top of the upwell slot. Fish are attracted to the flow passing over the weirs and into a collection conduit located on the upstream side of the upwell slot. The collection conduit will carry fish with approximately 120 cfs of transport water to the fish collection barge. The weir crest would adjust automatically to maintain a constant flow of 20 cfs per weir box throughout the potential reservoir operating range. The conduit would range from 30 inches in diameter on the east side of the surface collector to 60 inch on the west side and is sized to maintain a minimum transport velocity of 2 fps. As an alternative approach, an orifice type design similar to the USACE installations could be considered as part of the advanced design development.

2.1.5 Fish Collection Barge

A fish collection barge, approximately 90 feet long by 66 feet wide with an overall height of approximately 12 feet, is located on the west end of the surface collector. The barge is designed to float, eliminating the need for a deep foundation support as well as allowing operation under varying flow conditions within the reservoir. The total flow exiting the collection conduit and entering the barge is constant at 20 cfs. The fish, with limited transport water, will continue through a dewatering screen where all but 3 to 5 cfs is removed. The approach velocity at the dewatering screens will meet NMFS criteria of 0.4 fps. A capture velocity exceeding 8 fps is likely required to prevent fish from holding within the dewatering screen structure or attempting to swim back into the collection conduit. The screened water will be pumped back into the forebay or used to supply the holding raceways and sample tanks. Fish transportation flumes or pipes will carry fish from the dewatering screens to the holding raceways or evaluation facility.

A fish sampling and evaluation facility will be provided adjacent to the holding raceways. The facility will be used to conduct monitoring and evaluation of the collected fish, as well as provide enumeration of the total fish moving through the system. Depending on the time of year, a large number of non-target fish species (crappie spp.) could enter the surface collector. Sorting these fish out from the target species may be required prior to routing the fish to the holding raceways. A total of three holding raceways will be provided with two raceways allocated to juvenile fish holding and one for adult fish and non-target species. The raceways are approximately 45-feet-long by 6-feet-wide with an operating water depth of 4 feet. Each raceway will be fitted with a powered fish crowder used to move fish from the raceway to a crowding channel where they will be directed to either the sampling and evaluation facility or directly to a fish transport pod.

2.1.6 Fish Transport System

Juvenile fish which are collected and held on the collection barge will be transported downstream for release. On several recent projects, such as the Baker River Hydroelectric Complex, fish transport pods have been developed for floating surface collectors to provide more flexibility in fish transport timing and numbers through the migration period. The pods typically have a 250 to 500 gallon capacity which corresponds to a fish holding capacity of 38 lbs of fish assuming transport loading density of 0.15 lbs/gallon. Due to the short transport distance and time, the loading density could be increased to 0.25 lbs/gallon or additional loads transported during peak day outmigration periods.

The fish pods are fitted with full life support systems which include air tanks and diffuser stones, mixers, battery backup power systems, and temperature monitors. Chillers are often provided if long transport times are anticipated. For the Hells Canyon Project, the short transport time would not require chillers. The fish pod would be lifted from the juvenile collection barge up to the transport truck which consists of a flatbed 1-ton truck fitted with a steel frame. The pods fit into the frame and are positioned at a slight angle to support fish release. Dogging pins are inserted between the frame and the pod to lock the pods down to the truck. The main advantage of the fish pod system over a conventional fish hopper and transport truck is the elimination of the water-to-water transfer between the fish hopper and the truck. The fish are routed directly to the fish pod on the juvenile holding barge, and then lifted to the transport truck.

2.2 Temperature Management Component

As part of the analysis, IPC has explored options for accessing cool water stored in Hells Canyon Reservoir and releasing it below HCD. During lower flow years, cool water (generally < 13^{o}C) is stored in HC reservoir. The temperature component being proposed as a part of the surface fish collection system is designed to deliver up to 1000 cfs of stored water from the lower levels of Hells Canyon Reservoir to the tailrace of HCD. In an effort to increase the volume of cooler water available, the preliminary design includes the extension of the height of the existing cofferdam and integrating a water pump and delivery system in the design of the surface fish collector. Beyond the coffer dam raise, the cooling system design consists of two primary components: intake pipelines and a pump station/downwell chamber.

2.2.1 Coffer Dam Raise

An existing submerged cofferdam is located approximately 800 feet upstream from HCD (Figure ISO 1). The cofferdam was constructed as part of the original HCD construction and used to divert the Snake River into a diversion tunnel located on the right bank of the river. The structure was constructed from rock and fill material across the entire river channel to a height of about 100 feet. As currently configured, the cofferdam causes stored cooler water to accumulate on the upstream side of the cofferdam.

In an effort to increase the volume of water behind the coffer dam, the existing cofferdam will be raised approximately 50 feet from its current elevation. The dam raise will improve surface draw conditions and prevent the mixing of the cool water with warmer surface water through water releases at the new surface collector. The increased cofferdam height also provides more cool water storage behind the cofferdam.

The dam raise would consist of setting approximately 25 cofferdam cells with concrete stoplogs installed between the cells. The cells would be 20-feet-wide by 30-feet-long and 50-feet-high. The cells would be filled with clean gravel fill to provide stability. The final dam raise would be over 900 feet in length.

2.2.2 Cool Water Intake and Pipelines

To access the cool water and carry it to the dam, two 9-foot-diameter pipelines will extend from the dam to the upstream side of the existing cofferdam. The pipelines will exit the bottom of the pump wells located within the new steel intake structure. The pipes will then follow a bench on the west side of the reservoir which extends from the dam upstream tying into the top of the existing cofferdam. The water pipelines will then extend down the upstream face of the cofferdam to the reservoir bottom.

At the inlet side of the pipes, a simple intake structure with a trashrack will be installed. The trashrack bar spacing will be set to exclude debris yet provide unobstructed flow into the pump station. Due to the depth of the pipe intakes (approximately 195 feet) and limited duration of use, fish screens will not be installed.

2.2.3 Pump Station/Downwell

Flow will pass through the pipes approximately 900 feet to the pump stations located within the surface collector structure. The pump station is divided into a pump chamber and a separate downwell chamber. Large volume, low head submersible propeller pumps will be mounted on the isolation wall located between the two pump chambers. The pumps will pump from the pump chamber into the downwell. Two 10-foot by 10-foot fabricated steel gates are located on the east and west wall of the downwell. The gate openings can be adjusted to roughly control the amount of water released into each turbine. Two pumps are proposed for each pump chamber providing a capacity of approximately 500 cfs per pipeline and chamber. Removable panels are provided on the intake deck to access the pumps for removal, inspection, and maintenance.

3.0 Construction Schedule

3.1 Planning and Design Phase

A physical model is proposed to provide more defined data on the hydraulic flow conditions through the proposed structure. The physical model effort will require approximately one year to complete from initiation through the final report preparation.

3.2 Geotechnical and Surveying

Geotechnical explorations and analysis will be required prior to advancing the detailed final plans and specifications. Extensive exploration work was completed as part of the original dam construction and will serve as a starting point in developing the foundation design. Some geotechnical information will also be required on the existing cofferdam to accomplish the dam raise. It is anticipated the field investigation work could take as long as one year to complete.

3.3 Preliminary Design

The results of the geotechnical investigations, survey, and physical modeling would be incorporated into a preliminary work effort. The focus of the preliminary design is to advance the conceptual design to address the foundation design, structural analysis, and hydraulic design aspects of the structure. The FEM analysis would be updated based on the recommended foundation loads and a more detailed analysis of the structure walls completed. Additional research on the STS and VBS screens would be completed and incorporated into the proposed design. The hydraulic design of both the fish collection system and the cool water system components of the structure would be completed to set the final hydraulic gradelines and facility configuration. The mechanical and electrical design aspects of the project including pump and piping sizing, fish screen sizes and cleaning systems, fish handling equipment, jib and gantry crane sizing, and confirmation of the electrical loads would be completed. It is anticipated that the preliminary design work effort would require approximately six months to complete.

3.4 Final Design

Preparation of the final design plans and specifications including consultation with state and federal resource agencies will require approximately 18 to 24 months to complete. Formal submittals the resource agencies will be required at 30%, 60%, 90% and 100% levels of completion. Upon completion of the final design period a formal submittal to FERC will be required.

3.5 Construction

Construction of the surface collector will require two years to take advantage of the low flow periods. The main structure is designed to be erected in sections allowing the work to be sequenced with a minimum of one powerhouse unit off line while divers are in the water. The module arrangement of the surface collector will allow the individual structural sections to be placed from a barge mounted crane located in the dam forebay. The cofferdam raise could be achieved in one construction season during the summertime lower flow periods.

4.0 Potential Temperature Benefit

The operation of a Surface Collector combined with raising the height of the existing cofferdam a total of 50 feet in Hells Canyon Reservoir should result in the accumulation of additional cool (<13°C) water (from what currently accumulates behind the existing cofferdam) to be stored through the summer. The potential change in stored water volume was modeled by Portland State University (PSU) using CE-QUAL-W2 with a simulated surface withdrawal of various depths and a coffer dam raise of various heights (Berger and Wells 2013a, Berger and Wells 2013b). Also included in the PSU modeling was a simulation of pumping stored water from the lower depths of HC Reservoir into the turbine intakes. This was done by including a withdrawal near the bottom of the reservoir just upstream of the coffer dam. This withdrawal simulated pumping at a rate of 1000 cfs beginning on October 23 through the end of the year. The end of the year was selected to assess how long any temperature benefit of pumping from the bottom of the reservoir may persist. Berger and Wells (2013b) noted that a combination of a 50 foot coffer dam raise and a surface collector with a withdraw depth of 65 feet stored the largest volume of water below 13°C. The output from this modeling effort was used to estimate the potential decrease in Hells Canyon outflow temperature as it relates to the 7-day average maximum (7DAM) Salmonid Spawning criteria on October 29 (i.e. 13.3°C, or 14.5°C). The modeled temperature output from the pump was mass balanced with the modeled turbine temperature to estimate what the decrease in temperature would be with pumping (Figures 5 and 6).

The CE-QUAL-W2 modeling showed that surface withdrawal from the collector without pumping water from behind the cofferdam created slight cooling beginning in September and continuing through October 23 when the water pumping was started. Pumping the water from behind the cofferdam at a rate of 1000 cfs created cooling of the 7DAM outflow temperature that tapered up to about 1°C on October 29 (Figures 5 and 6). In order to compare these results to numeric temperature criteria, the actual modeled HCD outflow 7 DAM was used to calculate the difference between the baseline and surface collector model runs. This difference was then subtracted from the measured 7DAM values in 1992 and 2002. This is in contrast to comparing the actual model output to the criteria and is more appropriate because model error and bias occurs in both runs (Rounds 2007). The results show that the cooling is likely sufficient to meet the Idaho site specific criterion for salmonid spawning of 14.5°C (Figures 7 and 8). In these model years the cooling would be more than sufficient when including the human use allowance (0.3°C) with the Idaho criterion for a resultant criterion of 14.8°C.

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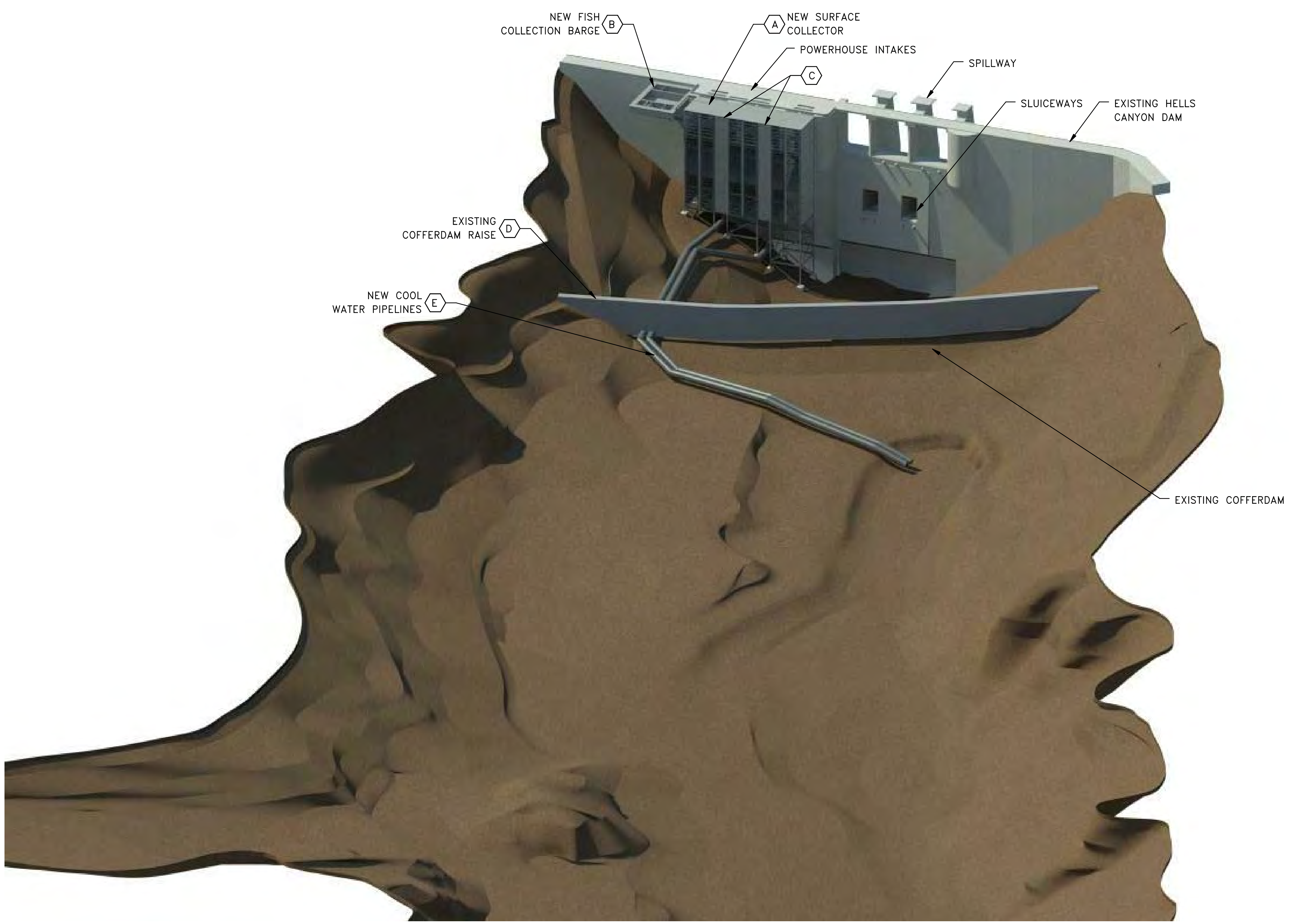

OVERALL FACILITY LAYOUT

SCALE: NONE

SHEET NOTES:

1. BATHYMETRIC MAPPING AND AS–CONSTRUCTED DRAWINGS PROVIDED BY IPC, JULY 2012.

MAJOR PROJECT COMPONENTS:

A NEW SELF–SUPPORTED FABRICATE STEEL SURFACE COLLECTOR LOCATED IMMEDIATELY UPSTREAM OF THE EXISTING POWERHOUSE INTAKE. THE SURFACE COLLECTOR WILL SPAN THE ENTIRE WIDTH OF THE POWERHOUSE AND WILL INCLUDE THE FOLLOWING EQUIPMENT:
  (1) SUBMERGED TRAVELING SCREENS (STS) – 2 PER GENERATING UNIT FOR A TOTAL OF 6
  (2) VERTICAL BARRIER SCREENS (VBS) – 2 PER GENERATING UNIT FOR A TOTAL OF 6
  (3) TRASHRACK ON THE FACE OF THE NEW INTAKE STRUCTURE
  (4) COLLECTION CONDUIT RANGING IN SIZE FROM 30" TO 60" ACROSS THE SURFACE COLLECTOR FROM EAST TO WEST
B FISH COLLECTION BARGE FITTED WITH DEWATERING SCREENS, PUMPBACK STATION, HOLDING RACEWAYS, SAMPLING AND EVALUATION AREA, FISH TRANSPORT PODS, AND TRUCK LOADING JIB CRANE AND ACCESS AREA.
C TWO COOL WATER PUMP STATIONS FITTED WITH TWO HORIZONTAL SHAFT, AXIAL FLOW PUMPS WITH A CAPACITY OF 250 CFS EACH. PUMP DOWNWELL CHAMBER HAS 2–FABRICATED STEEL GATES.
D RAISE THE EXISTING ORIGINAL CONSTRUCTION COFFERDAM BY 50 FEET TO PROVIDE AN EFFECTIVE SURFACE DRAW AND STORE COOL WATER.
E TWO 9 FOOT DIAMETER COOL WATER PIPELINES EXTENDING FROM UPSTREAM OF THE EXISTING COFFERDAM TO THE SURFACE COLLECTOR.

REV	DATE	BY	DESCRIPTION
A	2/8/13	MDM	DRAFT CONCEPTUAL DESIGN REPORT

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

MCMILLEN, LLC

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IDAHO POWER

IDAHO POWER COMPANY

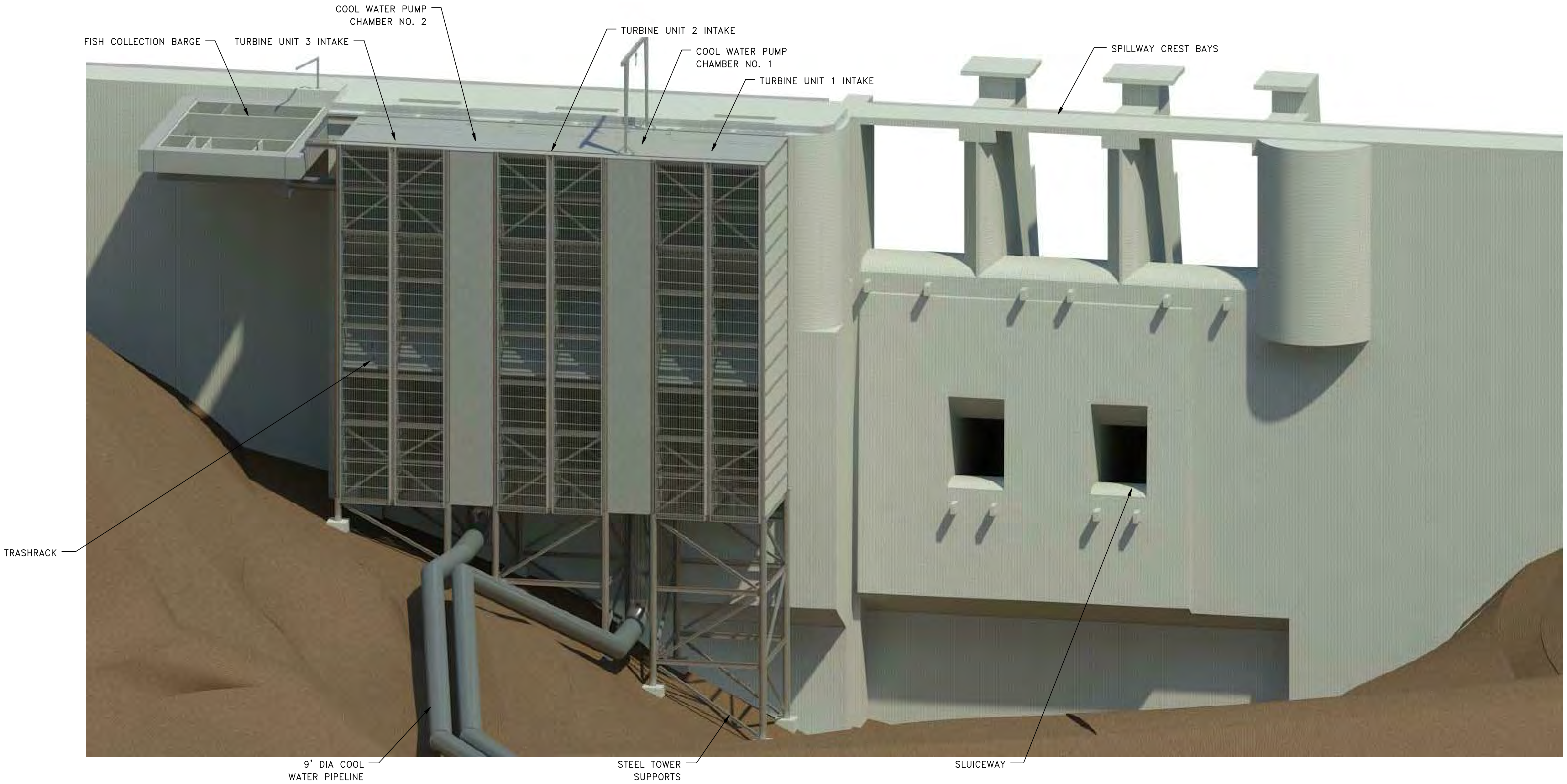
HELLS CANYON DAM SURFACE COLLECTOR

OVERALL FACILITY LAYOUT

DESIGNED M. McMILLEN
DRAWN R. GUERRERO
CHECKED M. McMILLEN
ISSUED DATE 2/8/13

DRAWING
ISO1

SCALE: NONE



SURFACE COLLECTOR ISOMETRIC 1

SCALE: NONE

REV	DATE	BY	DESCRIPTION
A	2/8/13	MDM	DRAFT CONCEPTUAL DESIGN REPORT

WARNING

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HELLS CANYON DAM SURFACE COLLECTOR

SURFACE COLLECTOR
ISOMETRIC 1

DESIGNED M. McMILLEN

DRAWN R. GUERRERO

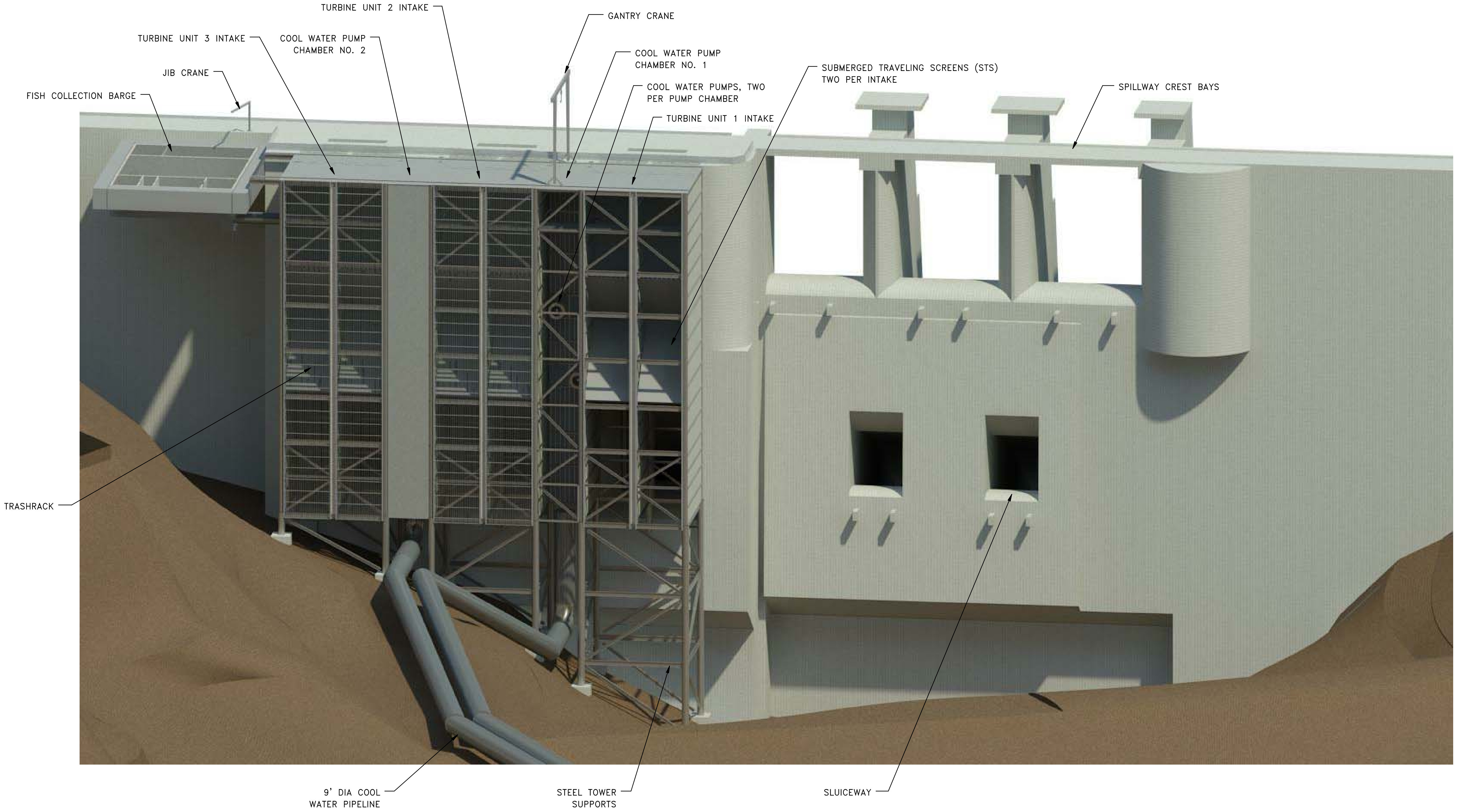
CHECKED M. McMILLEN

ISSUED DATE 2/8/13

DRAWING

ISO2

SCALE: NONE



SURFACE COLLECTOR ISOMETRIC 2

SCALE: NONE

REV	DATE	BY	DESCRIPTION
A	2/8/13	MDM	DRAFT CONCEPTUAL DESIGN REPORT

WARNING

0 1/2 1

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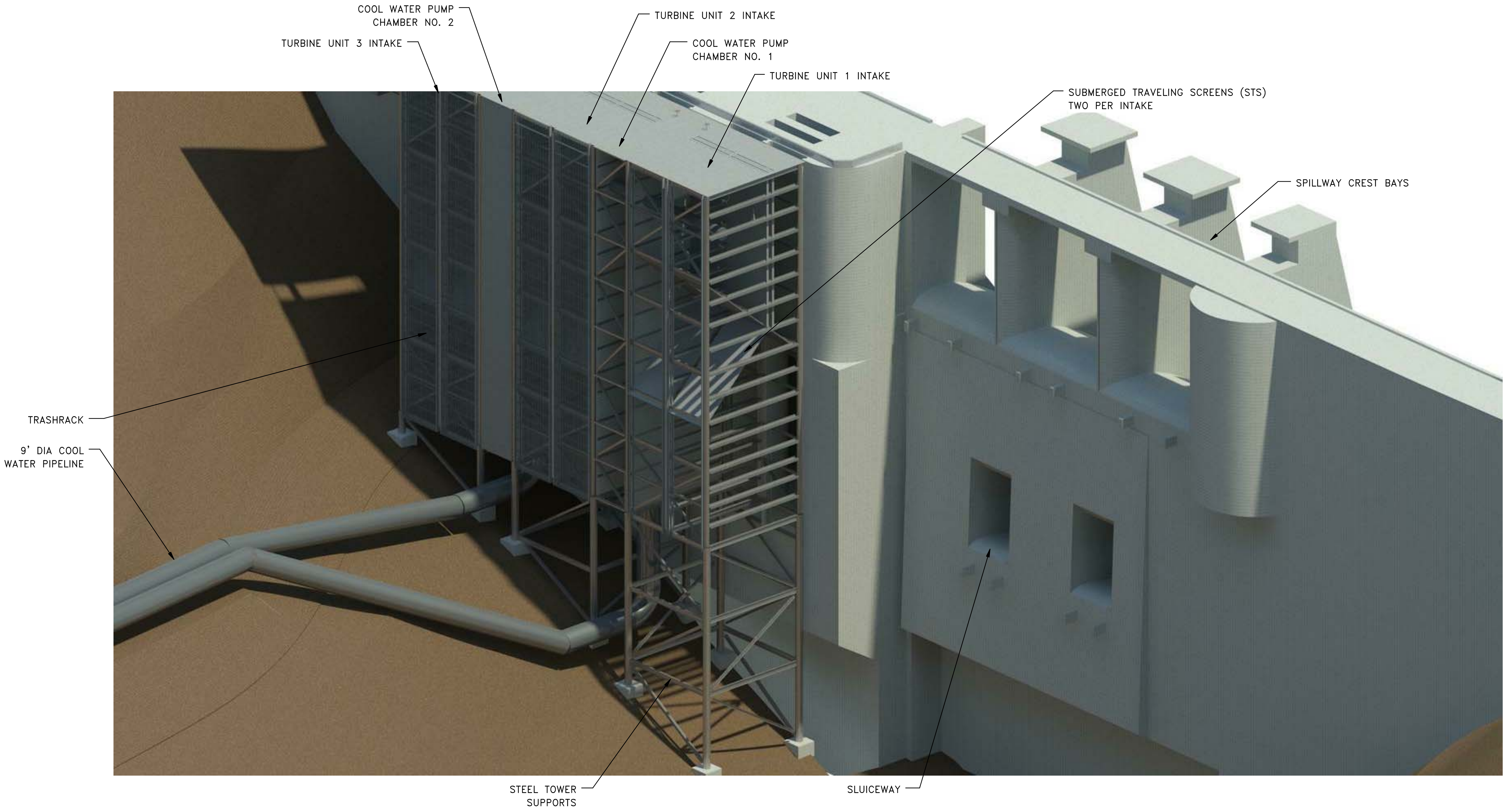
SURFACE COLLECTOR
ISOMETRIC 2

DESIGNED M. McMILLEN
DRAWN R. GUERRERO
CHECKED M. McMILLEN
ISSUED DATE 2/8/13

DRAWING
ISO3

SCALE: NONE



SURFACE COLLECTOR ISOMETRIC 3

SCALE: NONE

REV	DATE	BY	DESCRIPTION
A	2/8/13	MDM	DRAFT CONCEPTUAL DESIGN REPORT

WARNING

0 1/2 1

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SURFACE COLLECTOR
ISOMETRIC 3

DESIGNED M. McMILLEN
DRAWN R. GUERRERO
CHECKED M. McMILLEN
ISSUED DATE 2/8/13

DRAWING
ISO4

SCALE: NONE

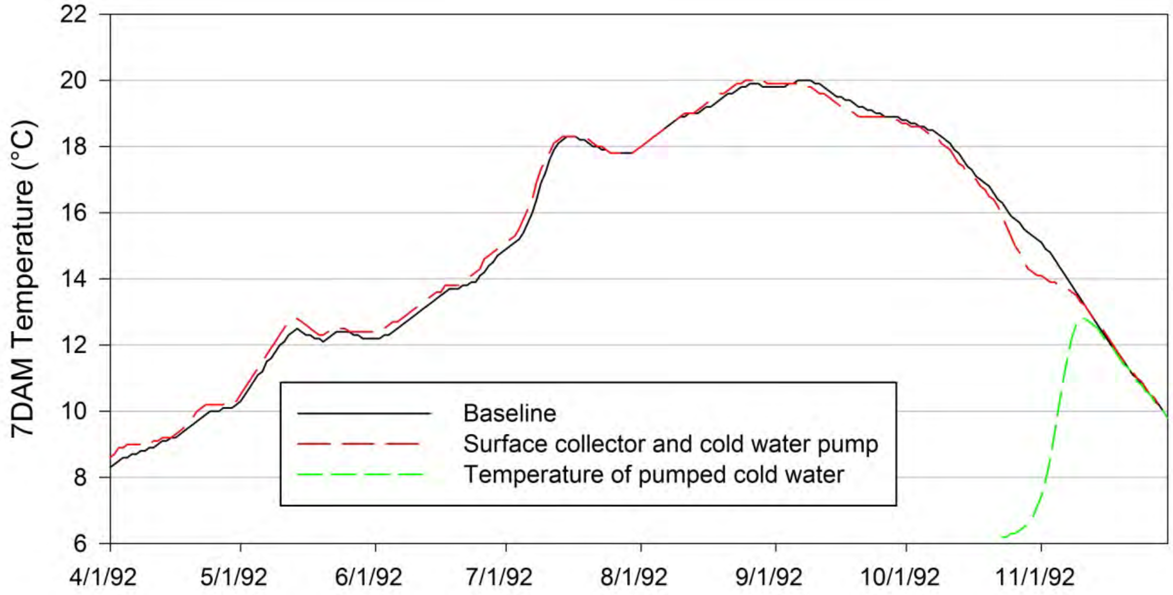

Figure 5. **1992** CE-QUAL-W2 modeled Hells Canyon outflow 7 day average maximum (7DAM) temperatures comparing baseline and with operation of the surface collector and cool water pump.

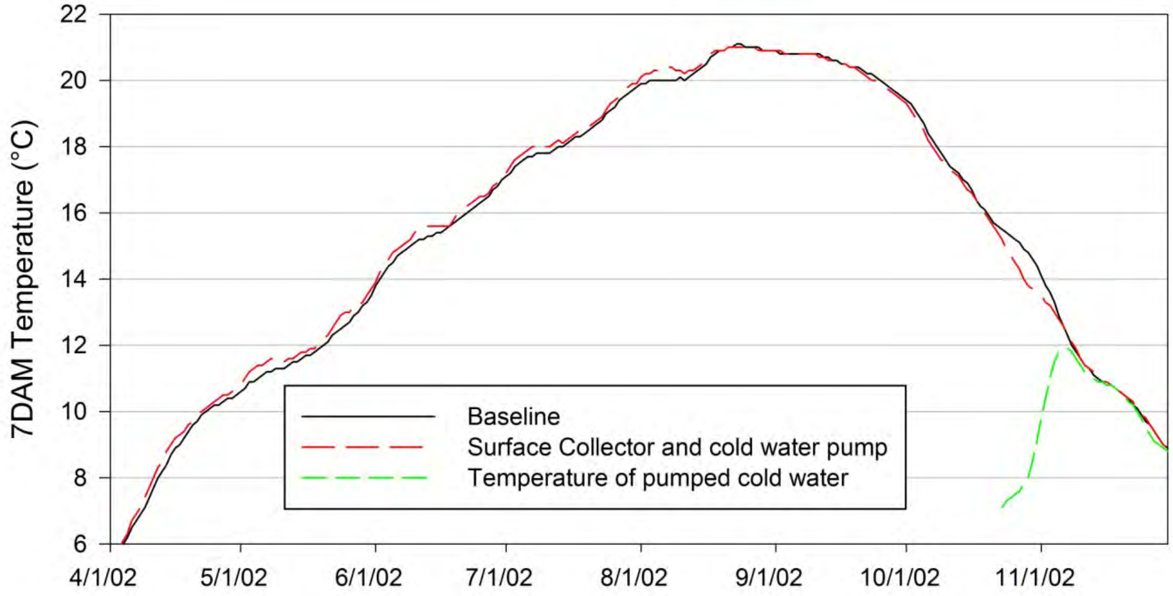

Figure 6. **2002** CE-QUAL-W2 modeled Hells Canyon outflow 7 day average maximum (7DAM) temperatures comparing baseline and with operation of the surface collector and cool water pump.

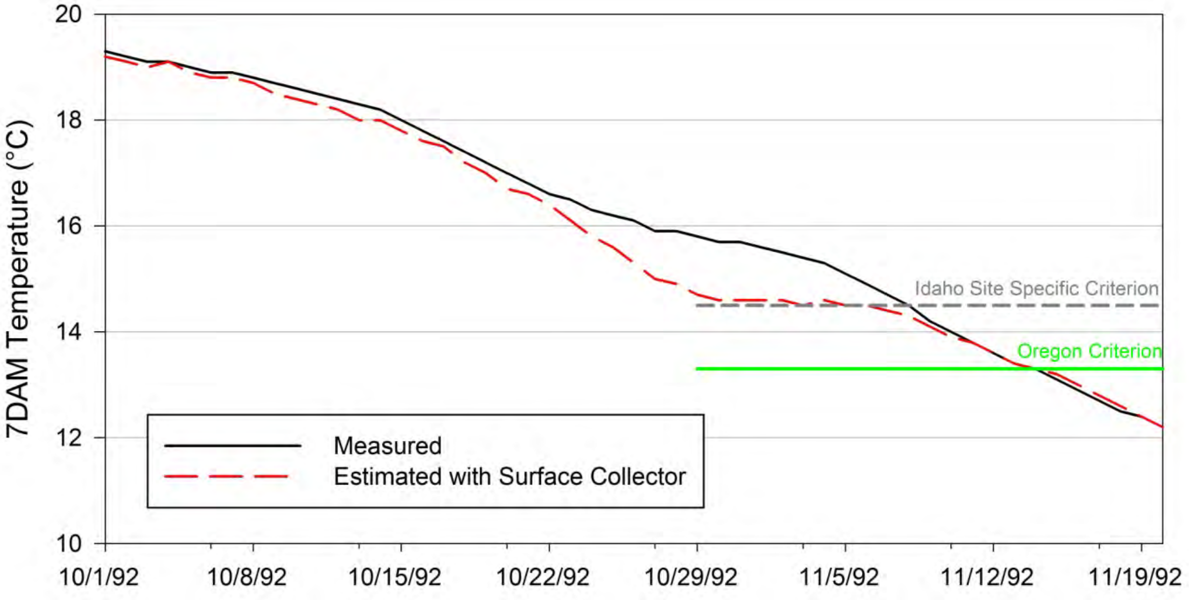

Figure 7. **1992** measured Hells Canyon outflow 7-day average maximum (7DAM) temperature and estimated temperature with the surface collector and cool water pump compared to the Idaho and Oregon Salmonid Spawning temperature criteria.

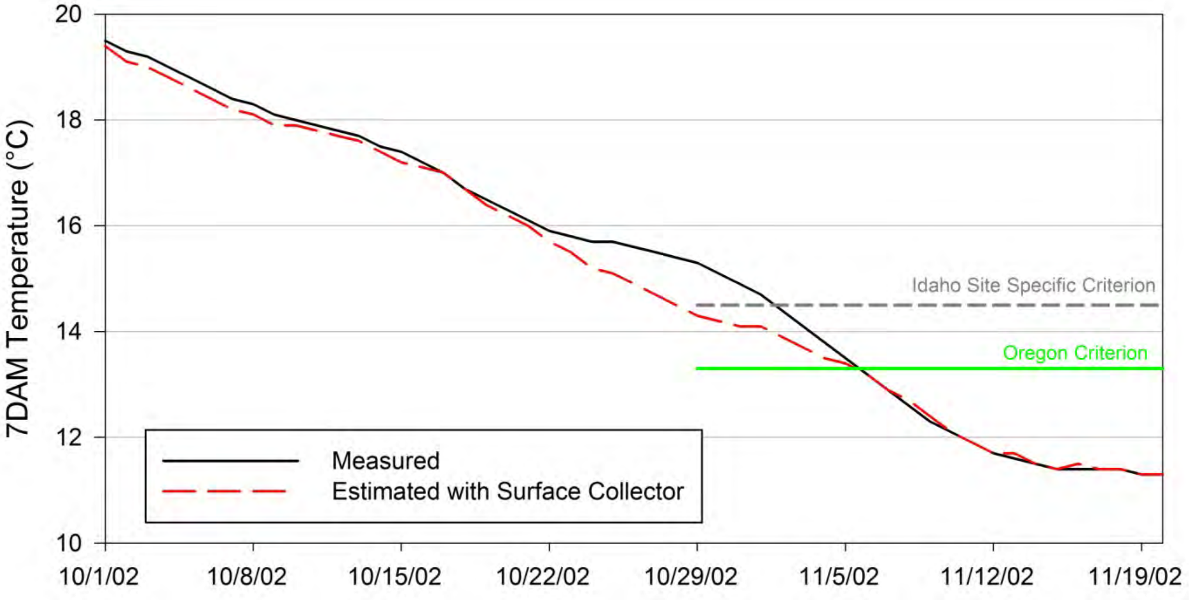

Figure 8. **2002** measured Hells Canyon outflow 7-day average maximum (7DAM) temperature and estimated temperature with the surface collector and cool water pump compared to the Idaho and Oregon Salmonid Spawning temperature criteria.

Exhibit 7.2-1

Riverside Operational Water Quality Improvement Report 2014 Annual Report

Riverside Operational Water Quality Improvement Project

2014 Annual Report

Prepared for: Idaho Power Company

Riverside Irrigation District

Prepared by: Jack Harrison, PhD, P.E., HyQual, P.A.

Scott King, P.E., SPF Water Engineering, LLC

Scott Mooney, Control Engineers

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Date: February 6, 2015

Riverside Operational Water Quality Improvement Project

2014 Annual Report

Prepared for: Idaho Power Company

Riverside Irrigation District

Prepared by: Jack Harrison, PhD, P.E., HyQual, P.A.

Scott King, P.E., SPF Water Engineering, LLC

Scott Mooney, Control Engineers

Date: February 6, 2015

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Acknowledgements: This report is the first status report for the Riverside Operational Water Quality Improvement Project (ROWQIP) and is intended to provide the supporting documentation to ensure the project is transparent, reliable, and verifiable. While this work is funded by Idaho Power Company (IPC), under the direction of Ralph Myers, it is the commitment by Riverside Irrigation District (RID), and their manager Andy Bishop, that leads to these substantial water quality improvement presented below. This report provides the water quality data collected by Scotts Hoskins, canal operations staff with RID, and relies on canal discharge verification data collected by IPC Water Management.

Photo on cover: Newly installed local SCADA system control panel at Boise River diversion with automatic gates in background.

Executive Summary

IPC is proposing to address its dissolved oxygen (DO) load allocation assigned to the transition zone and metalimnion of Brownlee Reservoir in the Snake River–Hells Canyon total maximum daily load (SR–HC TMDL) (IDEQ and ODEQ, 2004) by implementing the Riverside Operational Water-Quality Improvement Project (ROWQIP). During 2014, the Riverside Irrigation District (Riverside) operated its primary delivery facility (Riverside Canal) in a way that reduced the loads of phosphorus and other pollutants discharged from the Riverside Canal to the Boise and Snake rivers.

As part of the ROWQIP, the Boise River diversion to the Riverside canal and four major spills from the canal have been automated and were controlled during the 2014 irrigation season by a supervisory control and data acquisition (SCADA) system. In addition to recording real-time flow data, the SCADA system monitored tributary inflows to the canal and automatically adjusted the Boise River diversion and spills to increase the phosphorus delivered to Riverside irrigators while decreasing phosphorus discharged to the Boise and Snake rivers. In doing so, canal inflows from phosphorus-rich tributaries were preferentially utilized for irrigation, while canal diversion from the Boise River and canal spills to the Boise and Snake rivers were minimized. To assess changes in water quality, data were collected bi-monthly at seven canal and inflow locations.

Using the flow and water quality data collected in 2014, a Riverside Canal mass balance model was used to calculate the load reductions occurring over the 183-day irrigation season. The model results show that the load reduction achieved by the ROWQIP exceeded a phosphorus reduction target of 30,000 lbs for the season. The model-calculated annual load reduction exceeds the equivalent Snake River phosphorus load reduction of 15,000 lb/yr, which is comparable to the SR-HC TMDL dissolved oxygen allocation, and thus fulfills IPC’s DO requirements as identified in the SR–HC TMDL.

This supporting information provides details of the project and the load reduction calculation methods needed to support 401 Certification, along with the methods used to ensure the project performance is transparent, reliable, and verifiable. Additional information on the project and its development is provided in Harrison et al., 2014.

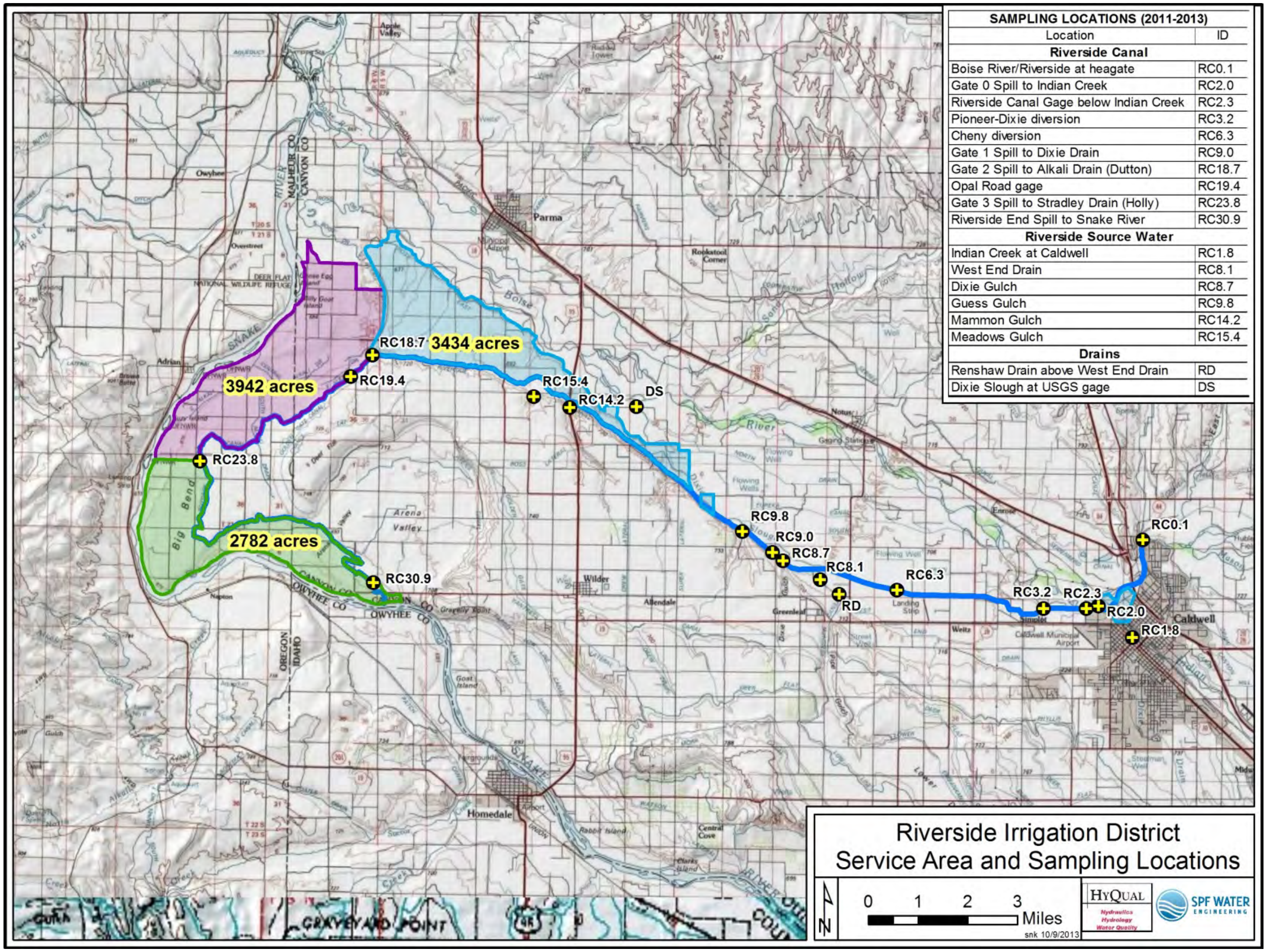
Riverside Irrigation District

The RID is located at the western end of the Boise River valley, near the confluence of the Boise and Snake Rivers (Figure 1). The RID diverts water from the south bank of the Boise River near Caldwell (Figure 1: RC0.1), and receives inflows from other tributary streams and drains along its length. The main canal (Riverside Canal) flows northwesterly and crosses US Highway 95 approximately five miles southeast of Parma, Idaho. The canal turns westerly then southwesterly, crossing into Oregon approximately two miles southeast of Adrian, Oregon. The canal then flows south and east, re-crossing the state line into Idaho, before draining into the Snake River approximately four miles west of Wilder, Idaho (Figure 1: near Rc31_3).

The RID delivers water to approximately 230 water users for agricultural purposes, with principal crops being onions, sugar beets, wheat, potatoes, alfalfa, beans, and hops. According to Idaho Department of Water Resources records, the RID water rights authorize irrigation of 10,158 acres within a District boundary totaling 13,082 acres (the later estimated via GIS mapping). The Riverside Canal is also used to deliver water for irrigation of 2,348 acres within the service area of the Pioneer Dixie Ditch Company, and for 454 acres at the Cheney Diversion (Figure 1: Rc3_2 and Rc6_3, respectively). Thus, the total irrigated acreage supplied by the canal is over 12,000 acres.

SCADA System

As a key part of the ROWQI project, an automated canal control system was designed, constructed and implemented. The system includes automatic control of spill gates and real-time flow monitoring of the canal flows, tributary inflows, and spills. Cellular communications equipment and a centralized server are used to control the upper reach of the Riverside Canal operations by a supervisory control and data acquisition (SCADA) system. With this equipment, in place and operational as of 2014, RID can prioritize use of drainage water flowing into their canal and limit the amount of canal discharge (i.e., spill) that flows unused to the Boise and Snake Rivers.



SAMPLING LOCATIONS (2011-2013)	
Location	ID
Riverside Canal	
Boise River/Riverside at heagate	RC0.1
Gate 0 Spill to Indian Creek	RC2.0
Riverside Canal Gage below Indian Creek	RC2.3
Pioneer-Dixie diversion	RC3.2
Cheny diversion	RC6.3
Gate 1 Spill to Dixie Drain	RC9.0
Gate 2 Spill to Alkali Drain (Dutton)	RC18.7
Opal Road gage	RC19.4
Gate 3 Spill to Stradley Drain (Holly)	RC23.8
Riverside End Spill to Snake River	RC30.9
Riverside Source Water	
Indian Creek at Caldwell	RC1.8
West End Drain	RC8.1
Dixie Gulch	RC8.7
Guess Gulch	RC9.8
Mammon Gulch	RC14.2
Meadows Gulch	RC15.4
Drains	
Renshaw Drain above West End Drain	RD
Dixie Slough at USGS gage	DS

Figure 1. RID Riverside Irrigation District, irrigated acreages divided into general delivery areas, and sampling locations.

Modeled Load Reductions

The Riverside Canal (RC) model was developed to estimate the daily total phosphorus (TP) loads that are delivered to RID irrigators under different canal operations (Harrison et al. 2014). A simplified schematic diagram (Figure 2) shows conceptually how the canal is structured with water diverted from the Boise River and a tributary containing drainage water discharging into the canal. Any excess drain water then "spills" back to the river downstream of the diversion and tributary along with agricultural runoff. The change in TP load in the river is calculated using delivered water, which is adjusted for runoff. The use of delivered water reduces the uncertainty of model load reductions by relying on the same measurements for canal inflows and agricultural water delivery.

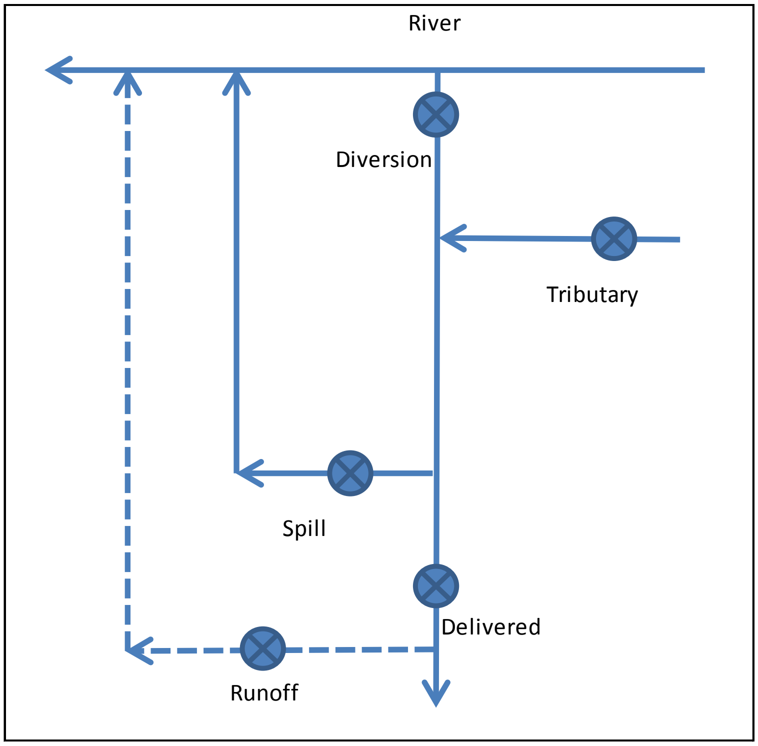


Figure 2. Simplified schematic of ROWQIP showing main components of the phosphorus-reduction calculation methodology.

The 2014 water-quality-focused canal operations were designed to maximize the use of high-nutrient agricultural and municipal drainage water on RID agricultural lands. This was accomplished by minimizing diversion of the comparatively higher-quality (lower phosphorus) Boise River, resulting in the greater utilization of the lower quality (higher phosphorus) water from the tributaries for delivery to irrigators.

To calculate annual phosphorous load reduction under 2014 operations, flow data collected at the Boise River diversion and other inflows locations (i.e., tributaries) are used to model the flow and phosphorus concentrations along the canal. Next, flows for "Baseline" operations were modeled with the Boise River diversion based on Riverside's decreed water rights from the River totaling of 271.5 cfs (http://www.idwr.idaho.gov). Then, the 2014 flow and Baseline flow models were used to calculate concentrations along the canal using a mass balance approach. Finally, the load reduction was calculated as the difference between operations (Table 1).

Table 1. Average annual loads for 2014 and Baseline operations, and TP reduction based average model results.

		Total Phosphorus	
	Flow	Conc.	Load
	(cfs)	(mg/L)	(lb/d)
Yr 2014 Operations			
Diversion	67	0.21	76
Tributary	276	0.61	906
Spill	100	0.52	279
Delivery	**242**	**0.54**	**703**
Baseline Operations			
Diversion	271	0.21	302
Tributary	276	0.61	906
Spill	305	0.41	679
Delivery	**242**	**0.41**	**529**
TP Reduction		**0.13**	**174**

The primary function of the Riverside Canal model was to calculate "comparable" concentrations for the water delivered under each of the operations (Table 1). The change in concentration of the water delivered to irrigators, which is the primary goal of the ROWQIP, was used directly to calculate the TP load reduction because quantity of water delivered for irrigation is the same for both operations (i.e., the change in TP load delivered can be calculated by multiplying 242 cfs by 0.13 mg/L and converting to 174 pounds per day).

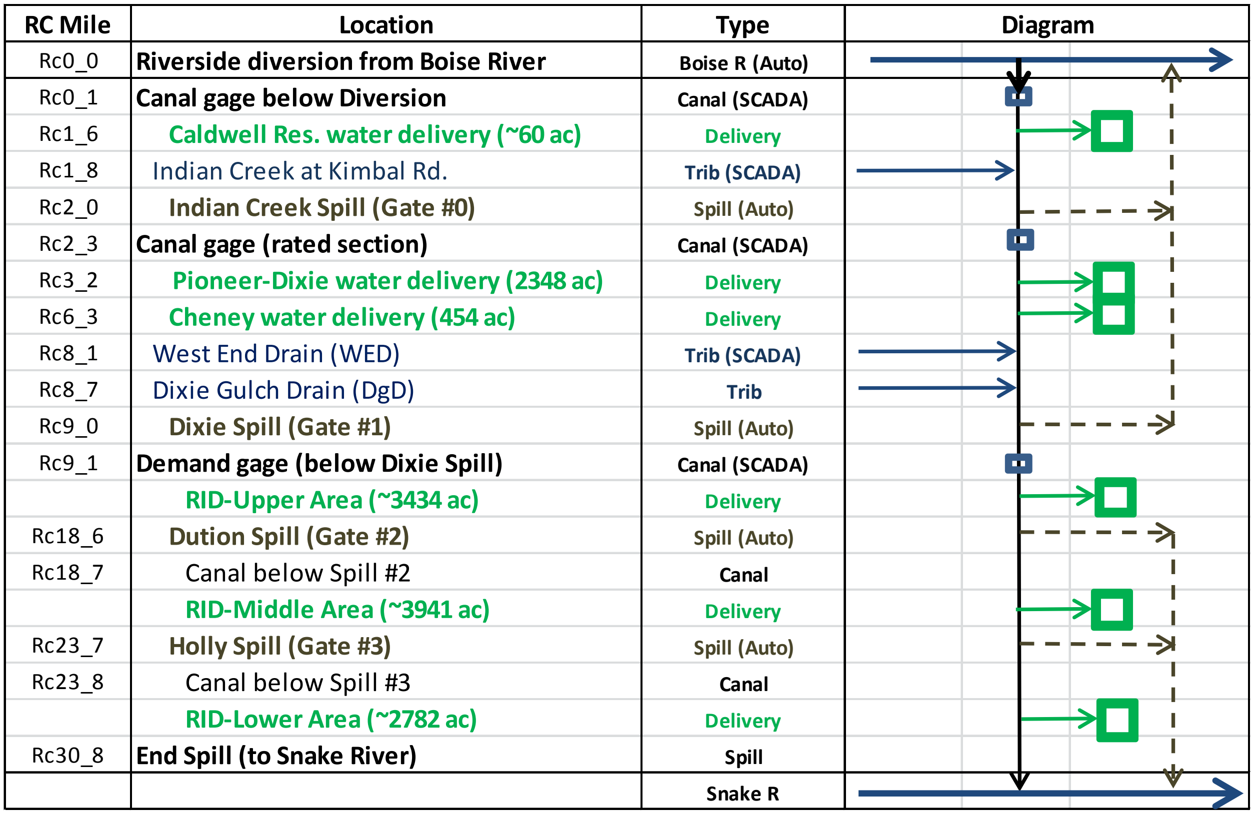
For comparison, the estimated potential load reduction for 2013 was 164 pounds per day with delivered flow of 215 cfs and change in concentration of 0.14 mg/L. The 2013 load reduction is termed a "potential load reduction" because in 2013 the canal operations were not directed toward "full time" water quality improvements, while in 2014 water quality was the focused over the entire irrigation season.

While not shown in Table 1, runoff (e.g., field losses and system spills was included in the daily mass balance load model and reduced the delivery load for Year 2014 operations compared to Baseline operations. This reflects the higher level of control under the automated canal operations fully implemented in 2014, as discussed in more detail below.

2014 and Baseline Flows

As stated above, the 2014 water-quality-focused canal operations were designed to maximize the use of high phosphorus tributary drainage water on the RID agricultural lands. The Boise River diversion and major spills are automated and controlled by a SCADA system designed for real time monitoring of primary inflows and subsequent adjustment of the Boise River diversions.

To model daily phosphorous load reductions under 2014 operations, flow data collected and recorded in the SCADA system at the Boise River diversion and other inflows locations (Figure 3) are used to model the flow (and phosphorus concentrations) along the canal. Next, Baseline operations flows were modeled with the Boise River diversion based on Riverside's legally established water right of 271.5 cfs. Finally, the load reduction was calculated by difference (Table 1).



RC Mile	Location	Type	Diagram
Rc0_0	**Riverside diversion from Boise River**	**Boise R (Auto)**	
Rc0_1	**Canal gage below Diversion**	**Canal (SCADA)**	
Rc1_6	**Caldwell Res. water delivery (~60 ac)**	**Delivery**	
Rc1_8	Indian Creek at Kimbal Rd.	**Trib (SCADA)**	
Rc2_0	**Indian Creek Spill (Gate #0)**	**Spill (Auto)**	
Rc2_3	**Canal gage (rated section)**	**Canal (SCADA)**	
Rc3_2	**Pioneer-Dixie water delivery (2348 ac)**	**Delivery**	
Rc6_3	**Cheney water delivery (454 ac)**	**Delivery**	
Rc8_1	West End Drain (WED)	**Trib (SCADA)**	
Rc8_7	Dixie Gulch Drain (DgD)	**Trib**	
Rc9_0	**Dixie Spill (Gate #1)**	**Spill (Auto)**	
Rc9_1	**Demand gage (below Dixie Spill)**	**Canal (SCADA)**	
	RID-Upper Area (~3434 ac)	**Delivery**	
Rc18_6	**Dution Spill (Gate #2)**	**Spill (Auto)**	
Rc18_7	Canal below Spill #2	**Canal**	
	RID-Middle Area (~3941 ac)	**Delivery**	
Rc23_7	**Holly Spill (Gate #3)**	**Spill (Auto)**	
Rc23_8	Canal below Spill #3	**Canal**	
	RID-Lower Area (~2782 ac)	**Delivery**	
Rc30_8	**End Spill (to Snake River)**	**Spill**	
		Snake R	

Figure 3. Diagram of Riverside Canal showing RC mile, location (with sampling ID or estimated irrigated acreage in parentheses), and type (i.e., source and receiving waters, delivery in green, tributary (trib) creek or drain in blue, and spill in dashed line to receiving water). Also shown are automated gates (Auto) and gages linked into the SCADA system.

The raw 15-minute flow data were converted to average daily data and corrected to model the flows and concentrations, as shown in the graphs below (Figure 4a through 4d). During the irrigation season, preliminary 15-minute discharge data from water-level measuring devices were recorded in the SCADA system. Additionally, flows were measured manually (e.g. using an acoustic Doppler device) or estimated at various locations to verify accuracy or make preliminary flow adjustments. After the irrigation season ended, the discharge measurements and RID flow estimates were used to correct the raw SCADA records for the major inflows (i.e., Boise River diversion and Indian Creek, Rc0.0 and Rc1_8, respectively) to reduce errors (Appendix A). Once corrected, the flow data were then used to model phosphorus concentrations in the Riverside Canal for both 2014 and Baseline loads. However, it should be noted, that while corrected flows are used to model concentrations, the delivery loads and the load reductions are based on uncorrected flow data.

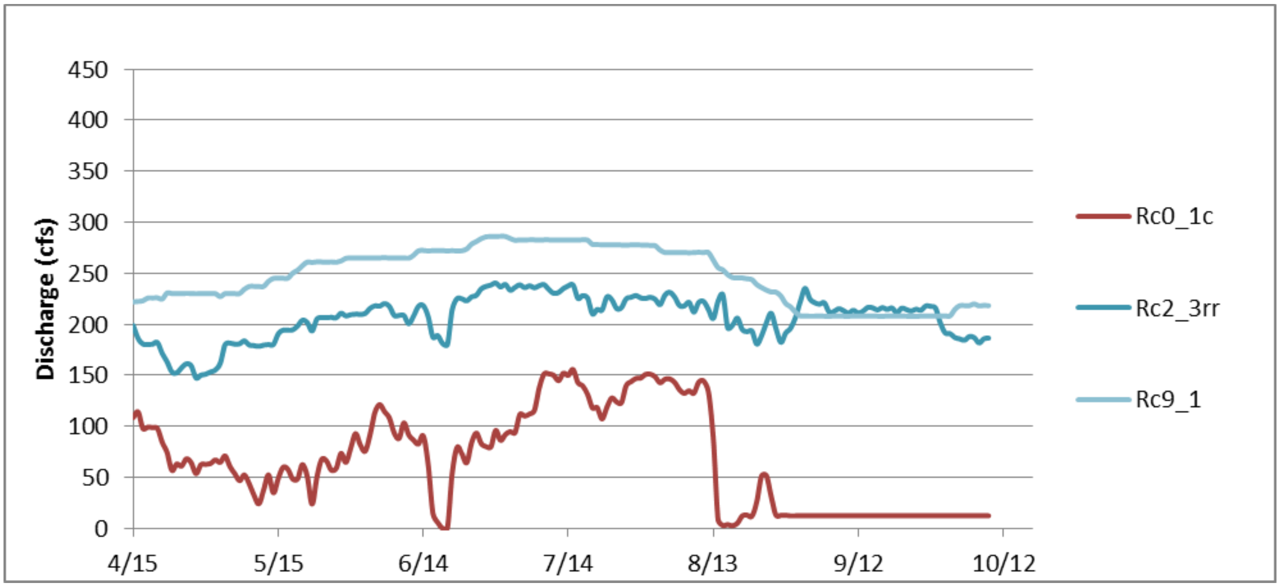


Figure 4a. Daily average flow data for Boise River diversion (Rc0_1c), Riverside gage (Rc2_3rr) and Demand (Rc9_1).

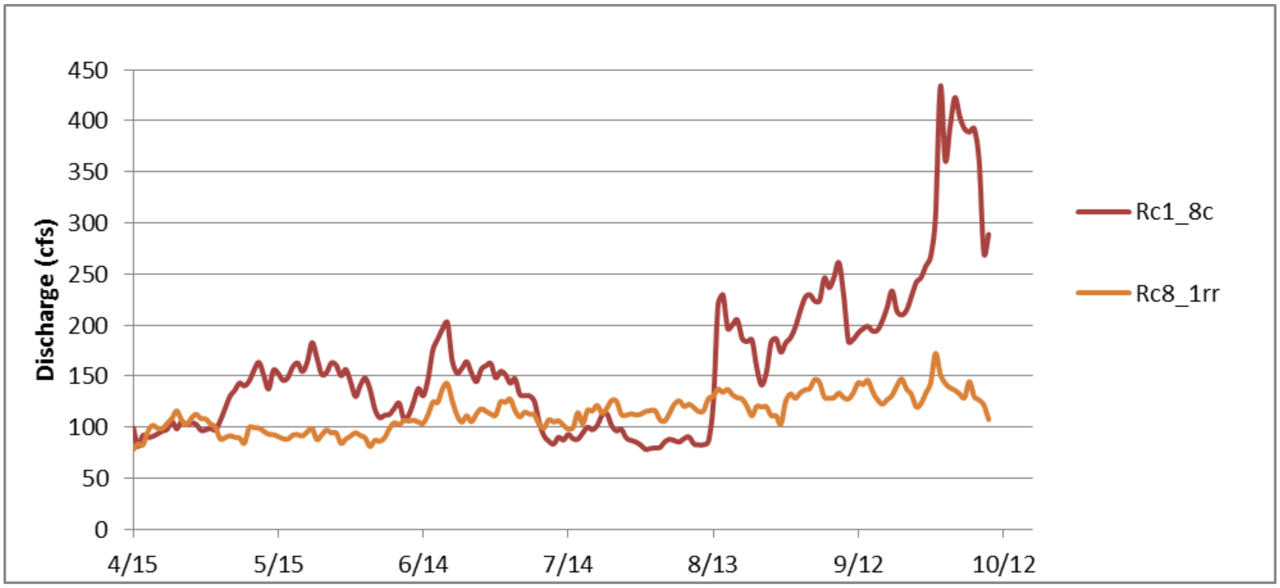


Figure 4b. Daily average Inflow data for Indian Creek at Kimball (Rc1_8c) and West End Drain (Rc8_1).

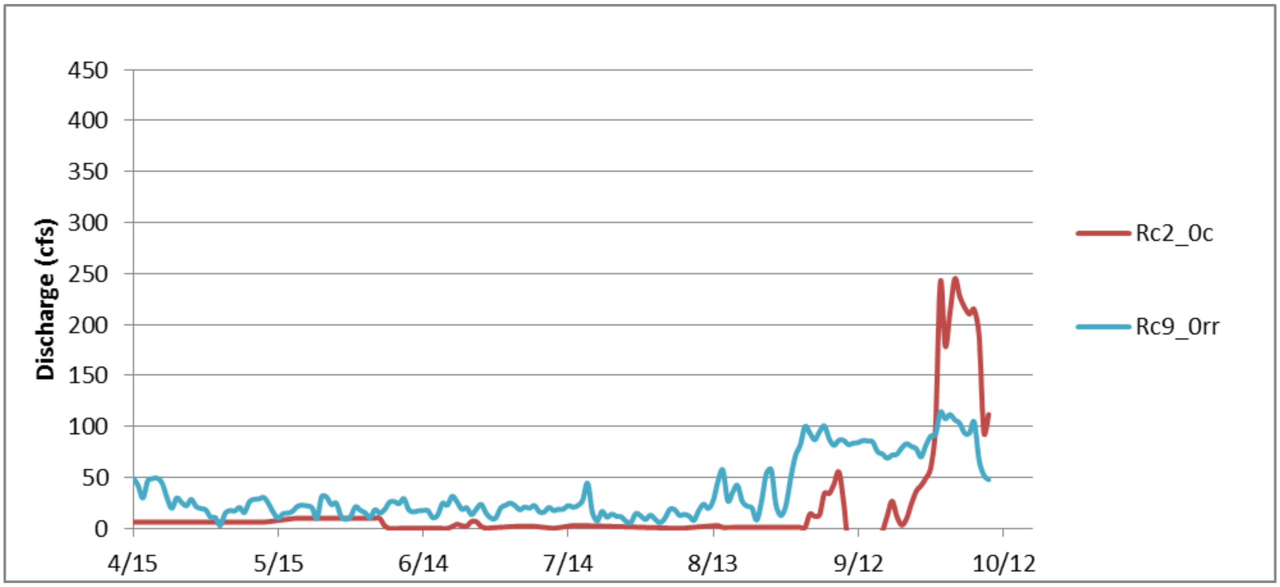


Figure 4c. Daily average Upper Spill data for Indian Creek (Rc2_0c) and Dixie Spill (Rc9_0).

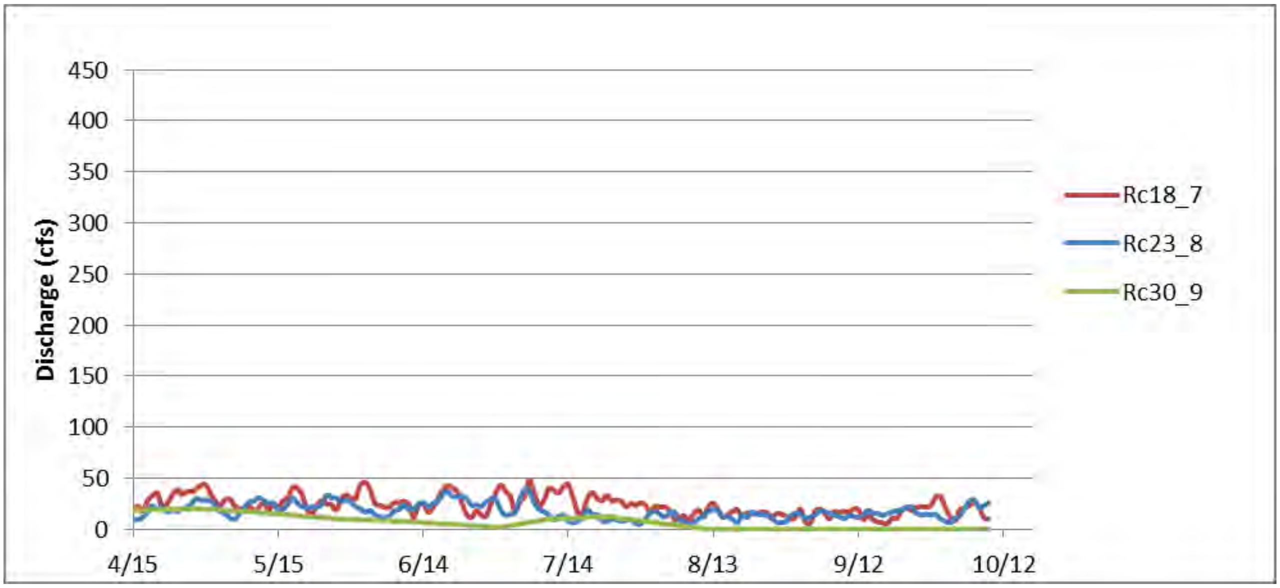


Figure 4d. Daily average lower spills for Dutton spill (Rc18_7), Holly spill (Rc23_8) and End spill (Rc30_9).

Delivered Flow

The daily delivery to RID irrigators is modeled using Riverside Canal demand after subtraction of the lower canal spills (Figure 3). The demand is measured in the canal upstream of RID deliveries (Rc9_1), which is just below the Dixie Spill (Rc9_0). The lower spill locations used to calculate the RID delivery are the Dutton, Holly and End Spills (Figure 3). The delivery calculated for 2014 operations is also used to model daily Baseline delivery loads, under the assumption that water delivery for either operation is the same. Total deliveries (Figure 5) are the sum of the RID and upper deliveries, which include deliveries to the Caldwell area, the Pioneer-Dixie and Cheney (Figure 3). The upper delivery loads are calculated using the measured diversion rates.

Figure 5. Daily modeled total delivery and upper tributaries (tribs) inflows as modeled for 2014.

Also shown in Figure 5 is the sum of the tributary inflows to the upper reaches of canal (Figure 4b). This is the sum of Indian Creek, West End Drain and Dixie Gulch. When the deliveries exceed the inflow from the upper tributaries, the SCADA system diverts water from Boise River (e.g., July through mid-August) to meet irrigation demands. When the upper tributary inflows exceed delivery, then the Boise River diversion is reduced, and upper spills (Indian Creek and Dixie Slough) will tend to increase (Figure 4c). During most of the 2014 irrigation season, the Boise River diversion gate was operated by the SCADA system, which was programed to minimize diversions from the Boise River (Figure 4a).

Baseline Diversion

Defining Baseline operations is necessary to determine the amount of phosphorus load reduction resulting from the ROWQIP. A definition of the baseline diversion is the critical parameter because it determines the flow along the canal, which will then be used to determine phosphorus concentration in the canal and delivery load for the Baseline operations. The ROWQIP is specifically designed to modify canal operations in a way that reduces phosphorus loading to the Snake and Boise rivers. However, the program does not include any actions to modify or redefine Riverside's overall irrigation requirements or the volume of water diverted as currently specified by adjudicated water rights. Therefore, the baseline relative to water diverted from the Boise River is 271.5 cfs as legally established by Riverside's water rights.

Lower Spills and Runoff

In addition to changing Boise River diversion rates for the baseline model, the lower spills (i.e., Dutton, Holly and End Spill) used to model Baseline operations were the average of the spills measured during the 2010 through 2013 irrigations season (Harrison et al 2014). This baseline condition (Table 2) is used to model the benefits of reducing the lower spills and thereby offsetting any potential changes in runoff loads that could be caused by the slightly higher phosphorus concentration in the canal (Table 1).

Table 2. Lower canal spills as measured in 2014 (average) and for Baseline Operations.

Flows (cfs)	Rc18_7	Rc23_8	Rc31_1
2014 (average)	26	19	9
Baseline	36	29	28
2014-BL	-10	-10	-19

Corrected Flow and Quality Control

The RID demand (i.e., the flow at Rc9_1) was measured and calculated using a water balance (Figure 6). The Delta is the difference between measured and calculated, which represents the model flow error. The causes of the error vary by measured location, canal reach and season, and can include errors related to instruments, calculations, calibrations, channel conditions (i.e., weed growth and silting), unknown inflow or outflow (i.e., discharges, unmeasured agricultural and stormwater drains, seepage to groundwater, groundwater inflows).

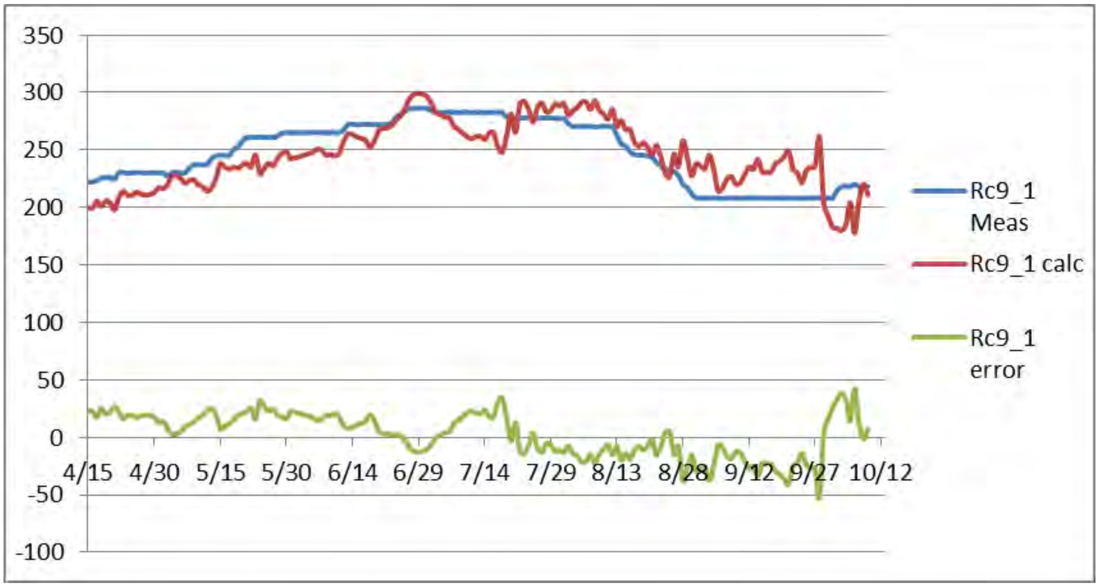


Figure 6. Yr 2014 Measured (Meas) and calculated (calc) demand flows, and the error.

During the irrigation season, preliminary raw discharge data from water-level measuring devices were recorded in the SCADA system and used to operate the canal diversion and spills in real time. Additionally, flows were measured manually (e.g. using acoustic Doppler and/or current meter devices) or estimated at various locations to verify accuracy or make preliminary flow adjustments.

After the irrigation season ended, the discharge measurements and RID flow estimates were used to correct the raw SCADA records for the major inflows (i.e., Boise River diversion and Indian Creek, Rc0.0

and Rc1_8, respectively) to reduce errors (Appendix A). Once corrected, the flow data are then used to model phosphorus concentrations in the Riverside Canal for both 2014 and Baseline loads. However, it should be noted, that while corrected flows are used to model concentrations, the delivery loads and the load reductions are based on the measured flow data that have not been corrected. This is done to link the calculated load reductions more directly to measured data and thereby limit possible errors introduced during the correction process.

Water Quality

The total phosphorus concentration data used in the mass balance model (Table 3) were collected bi-monthly at Boise River diversion (Rc0_0), Indian Creek (Rc1_8) and West End Drain (Rc8_1). The water quality data were collected as part of a Riverside Canal monitoring program, and the monitoring procedures for collection of the data are presented in Harrison et al 2014. The other laboratory data reported for the 2014 irrigation season are summarized in Appendix B.

Table 3. Total Phosphorus (mg/L) concentrations for inflow locations used in RC mass balance model.

Sample Date	Rc0_0	Rc1_8	Rc8_1
4/9/2014	0.144	2.170	0.164
4/29/2014	0.129	1.320	0.259
5/7/2014	0.207	1.100	0.296
5/28/2014	0.241	0.741	0.662
6/11/2014	0.248	0.895	0.391
6/30/2014	0.170	0.698	0.481
7/10/2014	0.209	0.848	0.556
7/22/2014	0.242	0.941	0.430
8/12/2014	0.226	0.989	0.481
8/19/2014	0.209	0.752	0.316
9/2/2014	0.204	0.547	0.28
9/17/2014	0.191	0.665	0.222
10/6/2014	0.201	0.441	0.189

As evident in Figure 57, the bi-monthly water quality data phosphorus concentration for the canal tributary inflows (Rc1_8 and Rc8_1) are consistently higher compared to the Boise River Diversion (Rc0_0). By optimizing the use of these higher phosphorus tributary waters, the concentration of phosphorus (and other pollutants) in the water delivered to the irrigators is higher (Table 2 and Figure 68). Coupled with reduced spills achieved through SCADA-controlled automation, therefore, lower levels and loads of phosphorus (and other pollutants) were allowed to discharge to the Boise and Snake Rivers.

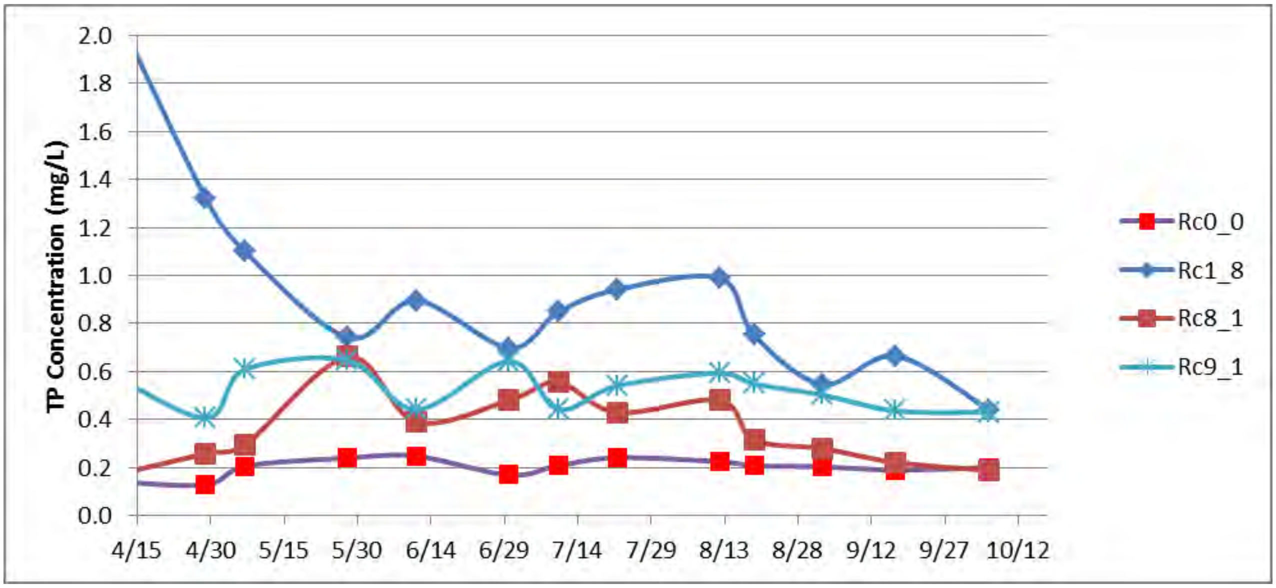


Figure 7. Graph of total phosphorus concentrations (TP) at modeled inflow locations and Riverside Canal at Dixie Spill (Rc9_1).

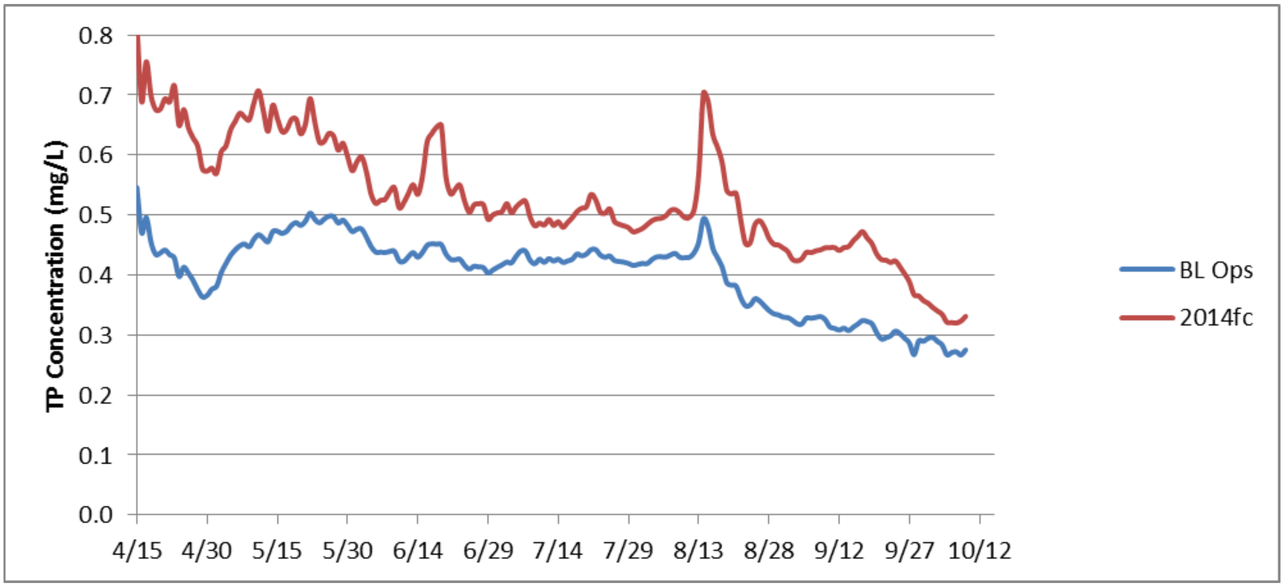


Figure 8. Modeled daily TP concentration of canal water delivered to RID irrigators for baseline and 2014 operations.

As discussed below, the mass balance approach is used to calculate total phosphorus loads delivered to irrigators on a daily basis. To calculate the loads in the canal on a given day, total phosphorus concentration data reported by the laboratory for the three primary inflows were first interpolated.

These interpolated daily concentrations are then used with the modeled flows to calculate daily loads along the canal using a simple mass balance equation as often used by others (Etheridge, 2014).

Modeled 2014 Load Reduction

During the 2014 irrigation season, RID operated the Riverside Canal with the intent of reducing the discharge of phosphorus loads to the Boise and Snake Rivers. Using a mass balance water quality model of Riverside canal (Harrison et al 2014), the daily TP reduction for the irrigation season (Figure 9) was calculated using bi-monthly water quality data, and corrected flow data.

The daily TP loads delivered to RID irrigators for 2014 water-quality focused operations were modeled using corrected 2014 daily average flow and interpolated water quality data (Figure 9 – 2014fd). The Baseline canal operations was also modeled (Figure 9 – BL Operations) using the same inflow data and assuming Boise River diversions are at the permitted rate. The TP Load Reduction was calculated as the difference between 2014 and BL Operations. This curve represents the daily load reduction in the Boise and Snake Rivers for the irrigation season.

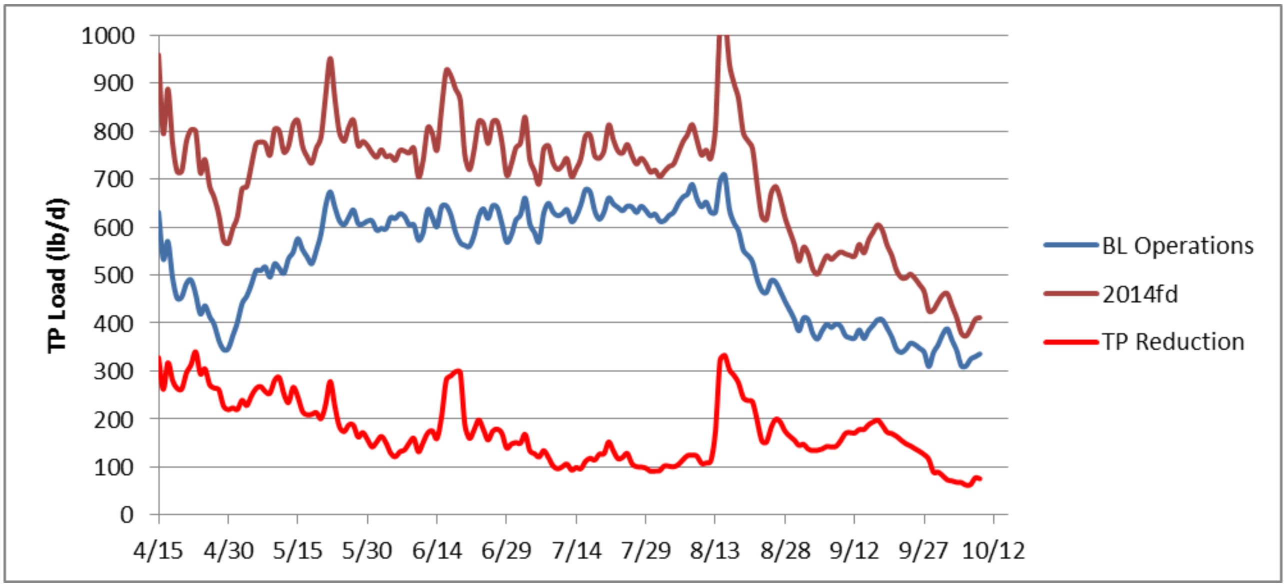


Figure 9. Preliminary daily average load reductions with lower spills set at Baseline (BL) rates (v6 w/adj.).

Based on these model results the 2014 annual TP load reduction exceeded 30,000 lbs (Table 4). This annual phosphorus load reduction represent the change in phosphorus load in the Boise and Snake Rivers (e.g., Figure 2) that would occur over a 183-day irrigation season under the water-quality focus operations of the ROWQIP.

Table 4. Preliminary total phosphorus load reductions for 2014.

TP Load Reduction (2014 - BL)		
(lb/d)	Days	lb/yr
174	183	31920

Conclusions

During the 2014 irrigation season, RID operated the Riverside Canal with the intent of reducing the discharge of phosphorus loads to the Boise and Snake Rivers. The phosphorus originated from upstream urban and agricultural sources, and previously discharged into the canal as tributary drains and discharged from the canal as canal “spills”, which then discharge into downstream receiving waters. The canal spills and Boise River diversion were controlled with a SCADA system designed to automatically reduce the Boise River diversion as drainage inflows increased while meeting irrigation deliveries.

The flow and water quality data were collected in 2014 to model the phosphorus load reduction of the ROWQIP for the irrigation season. The modeling results show that with current implementation, the ROWQIP phosphorus load reduction can exceed 30,000 lb/year. The 2014 load reduction was comparable to the potential load reduction calculated for 2013 (Harrison et. al., 2015).

The load reduction represents phosphorus from upstream sources that was applied to RID and other farm land via the Riverside Canal, and is thereby removed from the Snake River. The modeled load reductions occurring over the 183-day irrigation season exceeds the equivalent phosphorus load reduction of 15,000 lb/yr, which is comparable to the SR-HC TMDL dissolved oxygen allocation.

The information provided in this report documents the methods used to ensure the project performance is transparent, reliable, and verifiable. Laboratory data reports, raw flow measurement data, and other data are available upon request.

References

Etheridge, A. 2013. Evaluation of Total Phosphorus Mass Balance in the Lower Boise River, Southwestern Idaho. USGS SIR 2013-5220.Appendices

Harrison, J. S. King and S. Mooney, 2014. Riverside Operational Water Quality Improvement Project Development Report. Prepared for Idaho Power Company. May, 2014.

IDEQ, and ODEQ, 2004. Snake River–Hells Canyon total maximum daily load (TMDL). IDEQ, Boise Regional Office, Boise, ID, and ODEQ, Pendleton Office, Pendleton, OR.

Appendix A – Corrected 2014 Flow Data

Date	Rc0_1c	Rc1_6	Rc1_8c	Rc2_0c	Rc2_3rr	Rc3_2rr	Rc6_3rr	Rc8_1rr	Rc8_7rr	Rc9_0rr	Rc9_1	Rc18_	Rc23_8	Rc30_9
15-Apr	108	3	100	6	199	23	7	78	2	49	222	19	9	19
16-Apr	114	3	81	6	186	23	7	84	2	42	222	23	10	19
17-Apr	98	3	92	6	181	23	7	83	2	30	223	18	12	19
18-Apr	99	3	90	6	180	23	7	96	2	47	226	28	18	19
19-Apr	99	3	91	6	181	23	7	102	2	49	226	33	23	19
20-Apr	98	3	93	6	182	23	7	99	2	49	226	35	19	19
21-Apr	84	3	96	6	171	23	7	99	2	44	225	21	21	19
22-Apr	75	3	98	6	163	23	7	104	2	30	231	25	17	19
23-Apr	57	3	106	6	153	23	7	109	2	20	230	33	20	19
24-Apr	63	3	98	6	152	23	7	116	2	30	230	39	17	19
25-Apr	61	3	106	6	157	23	7	107	2	26	230	34	20	20
26-Apr	68	3	102	6	161	23	7	102	2	22	230	38	21	20
27-Apr	64	3	104	6	159	23	7	109	2	28	230	36	25	20
28-Apr	54	3	103	6	147	23	7	113	2	22	230	39	30	20
29-Apr	62	3	97	6	150	23	7	108	2	19	230	43	28	20
30-Apr	63	3	97	6	151	23	7	108	2	18	230	43	29	20
1-May	64	3	99	6	153	23	7	103	2	11	230	35	28	20
2-May	67	3	97	6	155	23	7	100	1	11	230	27	23	19
3-May	65	3	106	6	162	23	7	89	1	3	227	23	17	19
4-May	71	3	118	6	180	23	6	90	1	15	230	29	16	19
5-May	61	3	130	6	182	23	6	92	1	17	230	29	11	19
6-May	54	3	136	6	181	23	6	90	1	17	230	23	10	18
7-May	47	3	143	6	181	23	6	89	1	20	230	20	16	18
8-May	52	3	141	6	184	23	6	84	1	16	234	17	22	18
9-May	44	3	145	6	180	23	7	100	1	26	237	23	27	17
10-May	32	3	156	6	179	23	7	100	1	29	237	17	28	17
11-May	24	3	163	6	178	24	8	99	1	29	237	22	31	16
12-May	38	3	151	6	180	24	8	96	1	30	237	26	28	16
13-May	52	3	137	7	180	24	9	93	1	24	242	19	25	16
14-May	35	3	156	7	180	24	9	93	1	16	245	24	26	15

HyQual

Date	Rc0_1c	Rc1_6	Rc1_8c	Rc2_0c	Rc2_3rr	Rc3_2rr	Rc6_3rr	Rc8_1rr	Rc8_7rr	Rc9_0rr	Rc9_1	Rc18_	Rc23_8	Rc30_9
15-May	49	3	153	8	191	24	9	91	1	10	245	21	19	15
16-May	60	3	146	8	194	24	10	89	1	14	245	28	20	15
17-May	58	3	149	9	194	24	10	88	1	15	245	31	25	14
18-May	48	3	159	10	195	25	11	92	1	17	250	41	30	14
19-May	48	3	163	10	198	25	11	93	1	22	253	40	26	13
20-May	62	3	155	10	204	25	12	91	1	23	257	33	22	13
21-May	51	3	164	10	202	25	12	95	1	22	261	20	21	13
22-May	24	3	183	10	194	25	12	99	1	20	261	15	22	12
23-May	50	3	168	10	205	25	13	88	1	10	261	23	22	12
24-May	68	3	152	10	207	25	13	92	1	31	261	28	24	12
25-May	66	3	154	10	207	26	14	97	1	31	261	25	34	11
26-May	57	3	163	10	207	26	14	94	1	23	261	24	31	11
27-May	59	3	161	10	206	26	15	94	1	25	261	19	31	10
28-May	74	3	150	10	211	26	15	84	1	12	262	30	27	10
29-May	65	3	157	10	208	26	15	88	1	9	265	34	29	10
30-May	79	3	144	10	210	26	15	91	1	12	265	31	26	10
31-May	93	3	130	10	210	26	15	94	1	21	265	30	22	9
1-Jun	82	3	141	10	210	27	15	92	1	18	265	43	20	9
2-Jun	76	3	148	10	211	27	15	89	1	15	265	46	17	9
3-Jun	92	3	137	10	216	27	15	81	1	10	265	39	18	9
4-Jun	114	3	118	10	218	27	15	87	1	18	265	25	14	9
5-Jun	121	3	109	10	218	27	14	86	1	15	265	24	12	9
6-Jun	114	3	112	3	220	27	14	90	1	18	265	21	11	8
7-Jun	108	3	113	0	218	27	14	99	1	26	265	22	13	8
8-Jun	93	3	118	0	209	28	14	104	1	26	265	26	18	8
9-Jun	88	3	124	0	209	28	14	102	1	24	265	26	20	8
10-Jun	103	3	108	0	209	28	14	106	1	29	265	27	23	8
11-Jun	92	3	112	0	201	28	14	106	1	18	265	25	20	7
12-Jun	86	3	125	0	208	28	14	107	1	16	268	12	20	7
13-Jun	83	3	138	0	218	28	14	105	1	17	272	23	25	7
14-Jun	91	3	131	0	218	28	15	104	1	18	272	25	26	7
15-Jun	63	3	147	0	208	28	15	112	2	17	272	17	22	6

HyQual

Date	Rc0_1c	Rc1_6	Rc1_8c	Rc2_0c	Rc2_3rr	Rc3_2rr	Rc6_3rr	Rc8_1rr	Rc8_7rr	Rc9_0rr	Rc9_1	Rc18_	Rc23_8	Rc30_9
16-Jun	15	3	176	0	187	28	15	125	2	10	272	21	25	6
17-Jun	6	3	186	0	189	28	15	124	2	13	272	30	27	6
18-Jun	-12	3	196	0	181	28	15	138	2	25	272	38	34	5
19-Jun	-19	3	202	0	180	28	16	143	2	23	272	43	37	5
20-Jun	54	3	165	2	215	28	16	126	2	32	272	41	33	5
21-Jun	79	3	153	4	225	29	16	112	3	26	272	37	32	5
22-Jun	73	3	158	3	225	29	16	105	3	19	272	26	33	4
23-Jun	64	3	164	2	223	29	17	111	3	20	274	14	30	4
24-Jun	84	3	153	7	227	29	17	105	3	14	279	12	24	4
25-Jun	93	3	145	7	229	29	17	113	3	19	281	18	24	3
26-Jun	83	3	157	2	235	29	17	118	3	24	284	14	23	3
27-Jun	80	3	160	0	237	29	17	116	4	15	286	13	27	3
28-Jun	80	3	162	1	238	29	18	113	4	10	286	25	30	3
29-Jun	96	3	148	1	241	29	18	112	4	10	286	35	30	2
30-Jun	86	3	155	1	237	29	18	125	4	20	286	43	19	2
1-Jul	92	3	152	1	239	29	19	124	4	23	286	37	14	3
2-Jul	95	3	143	2	233	29	20	128	3	25	284	32	15	4
3-Jul	94	3	147	2	236	29	22	116	3	22	282	18	16	4
4-Jul	112	3	132	2	239	29	23	110	3	18	283	27	30	5
5-Jul	110	3	131	2	236	29	24	115	2	21	283	32	39	6
6-Jul	112	3	131	2	238	30	25	113	2	20	283	48	37	7
7-Jul	115	3	125	2	236	30	26	112	2	22	283	35	26	8
8-Jul	138	3	105	2	238	30	28	103	1	16	283	23	19	8
9-Jul	151	3	92	1	239	30	29	99	1	16	283	29	17	9
10-Jul	151	3	86	1	234	30	30	107	1	21	283	40	14	10
11-Jul	150	3	84	0	230	30	29	105	1	18	283	38	9	10
12-Jul	145	3	90	1	231	30	28	106	1	19	283	36	12	10
13-Jul	152	3	87	1	235	30	26	102	1	19	283	42	14	11
14-Jul	150	3	93	2	238	30	25	98	1	22	283	44	9	11
15-Jul	156	3	89	3	239	30	24	100	1	21	283	31	6	11
16-Jul	143	3	88	3	226	30	23	114	1	22	283	16	8	11
17-Jul	140	3	94	3	228	30	21	103	1	28	283	16	12	11

HyQual

Date	Rc0_1c	Rc1_6	Rc1_8c	Rc2_0c	Rc2_3rr	Rc3_2rr	Rc6_3rr	Rc8_1rr	Rc8_7rr	Rc9_0rr	Rc9_1	Rc18_	Rc23_8	Rc30_9
18-Jul	131	3	100	3	226	30	20	116	1	44	283	31	19	12
19-Jul	118	3	98	2	210	30	19	116	1	16	278	36	14	12
20-Jul	118	3	102	2	215	30	18	121	1	7	278	30	14	12
21-Jul	107	3	112	2	214	30	16	114	1	17	278	28	8	12
22-Jul	119	3	113	2	227	30	15	119	1	11	278	33	8	12
23-Jul	128	3	101	2	224	30	15	126	1	14	278	28	10	12
24-Jul	124	3	96	2	216	30	15	125	1	12	278	29	10	11
25-Jul	123	3	98	2	216	30	14	113	1	11	278	27	8	11
26-Jul	140	3	90	2	225	29	14	112	1	7	278	22	9	10
27-Jul	144	3	87	1	227	29	14	113	1	6	278	25	10	9
28-Jul	147	3	86	1	228	29	14	112	1	15	278	24	6	9
29-Jul	147	3	83	1	226	29	14	113	1	12	278	26	5	8
30-Jul	151	3	78	1	225	29	13	115	1	9	278	23	10	8
31-Jul	151	3	79	1	227	29	13	116	1	13	277	17	17	7
1-Aug	148	3	80	1	225	29	13	116	1	9	277	23	18	7
2-Aug	143	3	80	1	219	28	13	107	1	6	273	22	14	6
3-Aug	146	3	86	0	229	28	13	106	1	10	270	22	12	5
4-Aug	147	3	88	0	231	28	13	114	1	19	271	18	16	5
5-Aug	143	3	87	0	227	28	12	123	1	19	270	9	17	4
6-Aug	136	3	86	0	219	28	12	126	1	13	271	11	9	4
7-Aug	132	3	89	0	218	28	12	120	1	14	271	13	7	3
8-Aug	135	3	90	1	222	28	12	122	1	12	270	9	4	2
9-Aug	133	3	84	1	212	27	12	119	1	8	270	15	7	2
10-Aug	143	3	83	1	221	27	11	115	1	17	271	19	10	1
11-Aug	144	3	83	2	222	27	11	116	1	24	270	12	13	1
12-Aug	134	3	86	2	215	27	11	128	1	20	270	22	17	0
13-Aug	89	3	122	3	206	27	11	130	1	28	263	26	19	0
14-Aug	8	3	220	3	223	28	11	137	1	46	256	19	18	0
15-Aug	3	3	230	1	229	28	11	134	1	57	253	12	12	0
16-Aug	4	3	197	1	196	29	10	137	1	27	249	14	12	0
17-Aug	3	3	200	1	199	29	10	132	1	35	246	17	10	0
18-Aug	5	3	205	1	206	30	10	129	1	42	246	19	6	0

HyQual

Date	Rc0_1c	Rc1_6	Rc1_8c	Rc2_0c	Rc2_3rr	Rc3_2rr	Rc6_3rr	Rc8_1rr	Rc8_7rr	Rc9_0rr	Rc9_1	Rc18_	Rc23_8	Rc30_9
19-Aug	12	3	187	1	195	30	10	128	1	27	246	13	14	0
20-Aug	13	3	184	1	193	30	10	120	1	22	245	16	12	0
21-Aug	12	3	186	1	193	29	10	111	1	20	244	15	17	0
22-Aug	26	3	159	1	181	29	10	120	1	8	239	16	15	0
23-Aug	51	3	141	1	189	28	11	120	1	26	236	17	14	0
24-Aug	52	3	154	1	202	28	11	120	1	54	234	16	14	0
25-Aug	31	3	184	1	211	27	11	111	1	58	232	11	13	0
26-Aug	13	3	187	1	196	27	11	111	1	23	232	15	7	0
27-Aug	13	3	173	1	182	27	11	103	1	13	228	15	7	0
28-Aug	13	3	183	1	191	26	11	125	1	22	220	13	7	0
29-Aug	12	3	188	1	196	26	11	133	1	49	217	10	13	0
30-Aug	12	3	198	1	206	25	12	128	1	71	212	12	16	0
31-Aug	12	3	214	1	222	25	12	134	1	82	208	20	15	0
1-Sep	12	3	227	1	235	24	12	137	1	100	208	8	11	0
2-Sep	12	3	230	14	225	24	12	138	1	94	208	6	12	0
3-Sep	12	3	224	12	221	24	12	147	1	87	208	17	14	0
4-Sep	12	3	224	13	220	24	12	144	1	95	208	20	17	0
5-Sep	12	3	246	34	221	24	12	129	1	101	208	16	18	0
6-Sep	12	3	237	34	212	25	11	128	1	88	208	10	16	0
7-Sep	12	3	247	44	213	25	11	129	1	82	208	17	14	0
8-Sep	12	3	261	55	215	25	11	133	1	87	208	17	12	0
9-Sep	12	3	229	25	213	25	11	129	1	86	208	18	10	0
10-Sep	12	3	184	-18	211	25	11	128	1	82	208	17	13	0
11-Sep	12	3	186	-18	214	25	11	134	1	84	208	20	13	0
12-Sep	12	3	192	-9	211	25	11	144	1	84	208	20	12	0
13-Sep	12	3	196	-7	213	25	11	142	1	86	208	10	14	0
14-Sep	12	3	199	-8	217	26	10	146	1	86	208	14	19	0
15-Sep	12	3	194	-13	216	26	10	135	1	85	208	10	16	0
16-Sep	12	3	195	-10	214	26	10	127	1	75	208	7	16	0
17-Sep	12	3	204	-3	216	26	10	123	1	73	208	7	14	0
18-Sep	12	3	218	12	215	26	10	127	1	69	208	5	15	0
19-Sep	12	3	233	27	216	26	10	131	1	72	208	11	17	0

HyQual

Date	Rc0_1c	Rc1_6	Rc1_8c	Rc2_0c	Rc2_3rr	Rc3_2rr	Rc6_3rr	Rc8_1rr	Rc8_7rr	Rc9_0rr	Rc9_1	Rc18_	Rc23_8	Rc30_9
20-Sep	12	3	214	12	211	26	10	140	1	73	208	10	18	0
21-Sep	12	3	210	3	216	26	10	147	1	79	208	19	19	0
22-Sep	12	3	215	10	214	26	10	137	1	83	208	22	21	0
23-Sep	12	3	228	24	213	26	10	132	1	80	208	19	22	0
24-Sep	12	3	242	36	215	26	10	120	1	78	208	21	16	0
25-Sep	12	3	247	42	214	26	10	123	1	70	208	22	14	0
26-Sep	12	3	258	49	218	26	10	133	1	82	208	22	15	0
27-Sep	12	3	267	59	218	26	10	144	1	91	208	23	14	0
28-Sep	12	3	306	99	216	26	10	172	1	92	208	31	15	0
29-Sep	12	3	434	242	201	26	10	152	1	114	208	32	10	0
30-Sep	12	3	361	179	192	26	10	143	1	108	208	22	8	0
1-Oct	12	3	394	212	191	26	10	139	1	112	208	12	6	0
2-Oct	12	3	423	245	187	26	10	136	1	106	215	8	10	0
3-Oct	12	3	404	228	186	26	10	132	1	103	218	19	13	0
4-Oct	12	3	392	217	184	26	10	129	1	94	218	21	20	0
5-Oct	12	3	389	210	188	26	10	145	1	93	218	23	28	0
6-Oct	12	3	393	215	187	26	10	130	1	104	220	26	29	0
7-Oct	12	3	362	189	182	26	10	127	1	67	218	22	21	0
8-Oct	12	3	271	94	186	26	10	122	1	52	219	11	23	0
9-Oct	12	3	289	112	186	26	10	107	1	48	218	10	26	0

Note: C = corrected; rr= rerated

Flow Correction Summary

Using the re-rated flow data, a daily water balance was calculated to assess errors in the upper reach of the canal (Figures B1 and B2).

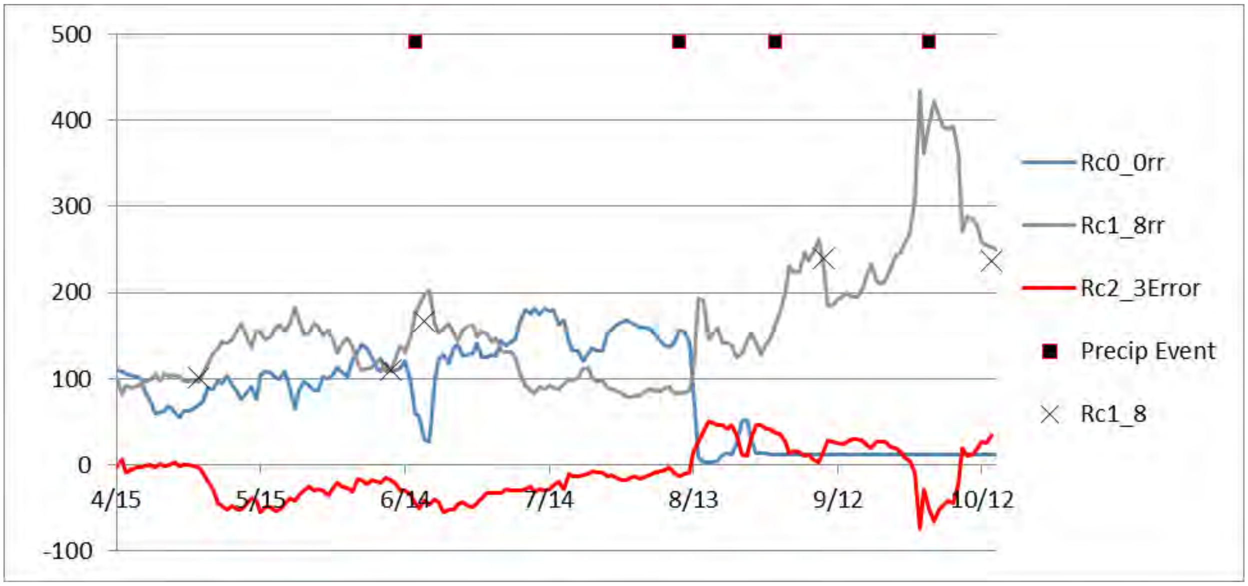


Figure B1. Corrected upper canal flows, error as calculated using a water balance at Rc2_3 (Rated Section), and precipitation events.

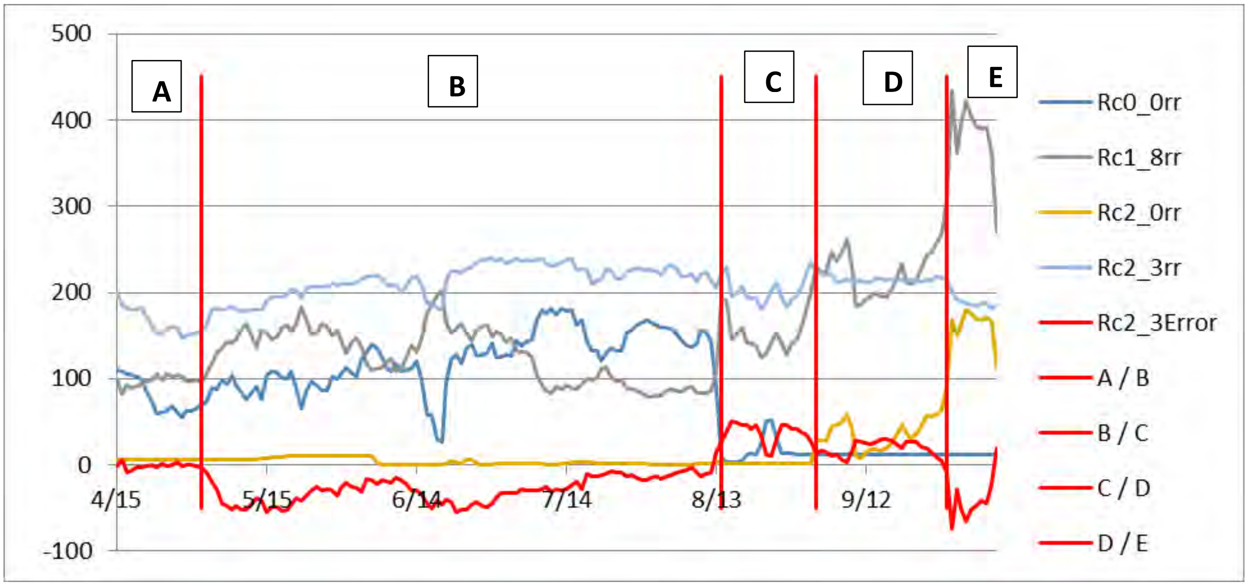


Figure B2. Corrected upper canal flows, error as calculated using a water balance at Rc2_3 (Rated Section), and operational periods.

The flows error was divided by operational periods to assess potential causes and contributing factors. The periods include: (A) Beginning of irrigation season: Low error, Boise River flow was dropping; (B) Irrigation season with relatively dry weather: High negative error (inflow>>outflow), possibly related to canal leakage in upper reach of canal; (C) Mid-August Post-Precipitation: High positive error (inflow<<outflow), note Boise River diversion is near zero, and possibly related to increased inflow related to precipitation event; (D) September Post-Precipitation: Small positive error; and (E) October Post-Precipitation: high negative error (inflow>>outflow); possibly due to increased runoff related to precipitation event and measured flow at Indian Creek spill (Rc2_0).

The procedure used to correct the flow data includes the following steps:

1. Revise Rating Curves: use data collected during irrigation season to review and revise rating curves
2. Recalculate SCADA Flows: using revised rating curves and raw water level records, recalculate flow records
3. Replace SCADA data: where accuracy is higher based on Best Professional Judgment (BPJ), replace SCADA data with RID flow observations (note that these were generally near zero flow levels)
4. Adjust Flows: for selected inflows, data records were adjusted based on observed errors and BPJ; this was needed to reduce overall flow error for baseline modeling TP load reductions…

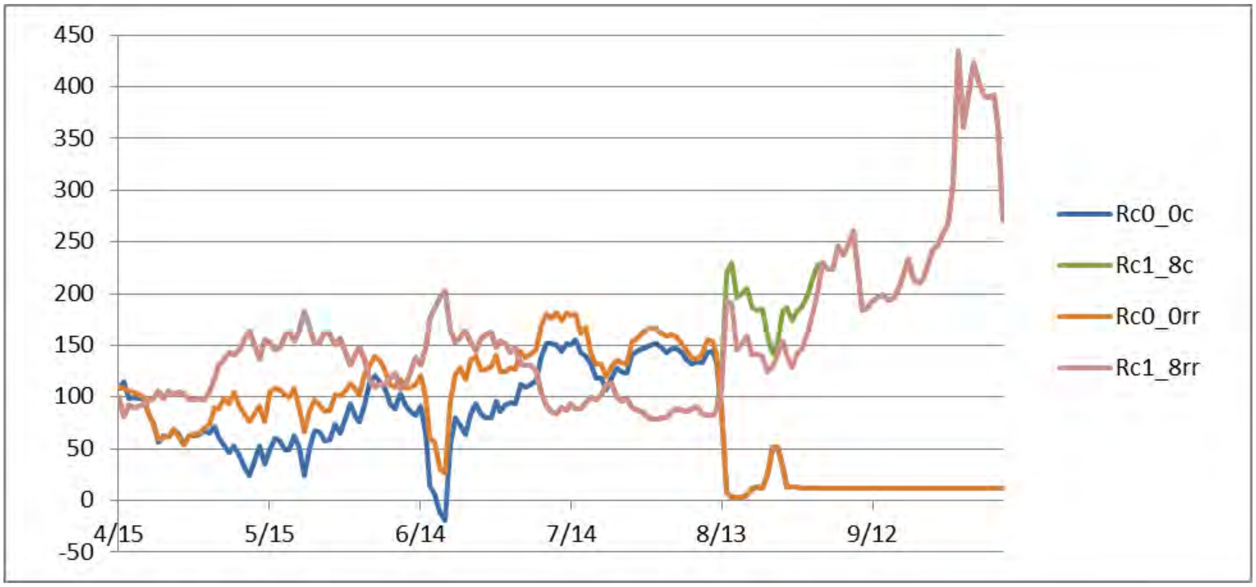


Figure B3. Corrected (c) and rerated (rr) SCADA records for the major inflows (i.e., Boise River diversion and Indian Creek, Rc0.0 and Rc1_8, respectively).

Appendix B – Water Quality Data and QC

Water Quality Data

Boise River and Diversion (Rc0_1)				
		Laboratory Analysis		
Date	Discharge (cfs)	Ortho P (mg/L)	Total (mg/L)	TSS (mg/L)
4/9/2014	115	0.069	0.144	18
4/29/2014	70	0.081	0.129	20
5/7/2014	82	0.127	0.207	33
5/28/2014	77	0.155	0.241	39
6/11/2014	93	0.137	0.248	60
6/11/2014	--	0.138	0.251	53
6/30/2014	109	0.114	0.170	50
7/10/2014	155	0.124	0.209	36
7/22/2014	114	0.157	0.242	50
8/12/2014	137	0.162	0.226	38
8/19/2014	42	0.175	0.209	25
8/24/2014	--	0.180	0.213	23
9/2/2014	43	0.158	0.204	13
9/17/2014	47	0.148	0.191	15
10/6/2014	50	0.155	0.201	16

Indian Creek at Kimbal (Rc1_8)				
		Laboratory Analysis		
Date	Discharge (cfs)	Ortho P (mg/L)	Total (mg/L)	TSS (mg/L)
4/9/2014	150	0.945	2.170	36
4/29/2014	130	0.786	1.320	17
5/7/2014	173	0.823	1.100	29
5/28/2014	180	0.511	0.741	40
6/11/2014	111	0.778	0.895	26
6/30/2014	147	0.622	0.698	41
6/30/2014	--	0.631	0.734	46
7/10/2014	93	0.766	0.848	45
7/22/2014	116	0.791	0.941	65
8/12/2014	84	0.891	0.989	47
8/19/2014	138	0.688	0.752	42
9/2/2014	205	0.469	0.547	36
9/17/2014	187	0.559	0.665	18
10/6/2014	301	0.413	0.441	23
10/6/2014	--	0.406	0.453	17

West End Drain at Greenleaf (Rc8_1)				
		Laboratory Analysis		
Date	Discharge (cfs)	Ortho P (mg/L)	Total (mg/L)	TSS (mg/L)
4/9/2014	69	0.055	0.164	72
4/29/2014	124	0.113	0.259	79
4/29/2014	--	0.115	0.258	91
5/7/2014	110	0.111	0.296	11
5/28/2014	111	0.125	0.662	313
6/11/2014	127	0.108	0.391	177
6/30/2014	148	0.113	0.481	257
7/10/2013	133	0.126	0.556	224
7/22/2014	134	0.122	0.430	389
8/12/2014	132	0.117	0.411	289
8/19/2014	147	0.137	0.316	121
9/2/2014	154	0.140	0.280	97
9/17/2014	145	0.104	0.222	65
10/6/2014	126	0.132	0.189	43

Riverside Canal at Dixie Spill (Rc9_0)					
	Discharge		Laboratory Analysis		
Date	Spill (cfs)	Canal (cfs)	Ortho P (mg/L)	Total (mg/L)	TSS (mg/L)
4/9/2014	37	200	0.421	0.595	37
4/29/2014	22	229	0.311	0.408	62
5/7/2014	26	230	0.352	0.609	42
5/28/2014	27	261	0.300	0.646	148
5/28/2014	--	--	0.308	0.644	138
6/11/2014	23	264	0.326	0.443	67
6/30/2014	24	286	0.284	0.541	136
7/10/2014	29	280	0.262	0.542	171
7/22/2014	20	274	0.395	0.685	171
7/22/2014	--	--	0.396	0.700	171
8/12/2014	24	270	0.375	0.594	97
8/19/2014	26	243	0.399	0.549	76
9/2/2014	97	208	0.377	0.503	50
9/17/2014	79	207	0.348	0.437	44
10/6/2014	89	217	0.321	0.431	28

Riverside Canal at Dutton Spill (Rc18_7)					
	Discharge		Laboratory Analysis		
Date	Spill (cfs)	Canal (cfs)	Ortho P (mg/L)	Total (mg/L)	TSS (mg/L)
4/9/2014	32	--	0.334	0.498	50
4/29/2014	39	--	0.285	0.433	74
5/7/2014	23	--	0.285	0.567	89
5/28/2014	31	--	0.272	0.670	179
6/11/2014	30	--	0.263	0.467	128
6/30/2014	43	--	0.256	0.476	136
7/10/2014	33	--	0.226	0.494	62
7/10/2014		--	0.229	0.501	174
7/22/2014	38	--	0.309	0.595	150
8/12/2014	14	--	0.273	0.464	107
8/19/2014	12	--	0.324	0.433	75
9/2/2014	0.66	--	0.284	0.373	44
9/17/2014	10	--	0.277	0.378	30
10/6/2014	25	--	0.228	0.285	16

Riverside Canal at Holly Spill (Rc23_8)					
	Discharge		Laboratory Analysis		
Date	Spill (cfs)	Canal (cfs)	Ortho P (mg/L)	Total (mg/L)	TSS (mg/L)
4/9/2014	12.7	--	0.301	0.527	53
4/9/2014	--	--	0.297	0.489	66
4/29/2014	29	--	0.233	0.406	83
5/7/2014	16	--	0.252	0.425	<3
5/28/2014	33	--	0.222	0.413	119
6/11/2014	23	--	0.240	0.411	85
6/30/2014	12	--	0.222	0.389	120
7/10/2014	20	--	0.210	0.395	101
7/22/2014	7.85	--	0.289	0.533	143
8/12/2014	16	--	0.269	0.423	97
8/19/2014	15	--	0.312	0.409	67
9/2/2014	12	--	0.307	0.397	35
9/2/2014	--	--	0.307	0.383	38
9/17/2014	12	--	0.282	0.370	31
9/17/2014	--	--	0.284	0.355	32
10/6/2014	32	--	0.231	0.309	29

Riverside Canal End Spill (Rc31_3)					
	Discharge		Laboratory Analysis		
Date	Spill (cfs)	Canal (cfs)	Ortho P (mg/L)	Total (mg/L)	TSS (mg/L)
4/9/2014	--	18	0.315	0.471	16
4/29/2014	--	20	0.251	0.324	32
5/7/2014	--	18	0.234	0.327	11
5/28/2014	--	10	0.165	0.205	11
5/28/2014	--	--	0.168	0.202	5
6/11/2014	--	7.5	0.120	0.181	10
6/30/2014	--	2	0.160	0.200	<3
7/10/2014	--	10	0.167	0.223	7
7/22/2014	--	12.4	0.269	0.327	25
8/12/2014	--	0.1	0.267	0.336	14
8/19/2014	--	0.1	0.328	0.371	15
8/19/2014	--	--	0.332	0.339	13
9/2/2014	--	0.1	0.310	0.352	15
9/17/2014	--	2.5	0.237	0.262	<3
10/6/2014	--	0.1	0.229	0.274	6

Water Quality QC

Riverside Canal and Diversion (Rc0_1)							
		Laboratory Analysis			Difference (Duplicate-Original) / Original		
Date	Status	Ortho P (mg/L)	Total (mg/L)	TSS (mg/L)	Ortho P (mg/L)	Total (mg/L)	TSS (mg/L)
6/11/2014	Original	0.137	0.248	60			
6/11/2014	Duplicate	0.138	0.251	53	1%	1%	-12%
8/19/2014	Original	0.175	0.209	25			
8/19/2014	Duplicate	0.180	0.213	23	3%	2%	-8%

Indian Creek at Kimball (Rc1_8)							
		Laboratory Analysis			Difference (Duplicate-Original) / Original		
Date	Status	Ortho P (mg/L)	Total (mg/L)	TSS (mg/L)	Ortho P (mg/L)	Total (mg/L)	TSS (mg/L)
6/30/2014	Original	0.622	0.698	41			
6/30/2014	Duplicate	0.631	0.734	46	1%	5%	12%
10/6/2014	Original	0.413	0.441	23			
10/6/2014	Duplicate	0.406	0.453	17	-2%	3%	-26%

West End Drain at Greenleaf (Rc8_1)							
		Laboratory Analysis			Difference (Duplicate-Original) / Original		
Date	Status	Ortho P (mg/L)	Total (mg/L)	TSS (mg/L)	Ortho P (mg/L)	Total (mg/L)	TSS (mg/L)
4/29/2014	Original	0.113	0.259	79			
4/29/2014	Duplicate	0.115	0.258	91	2%	0%	15%

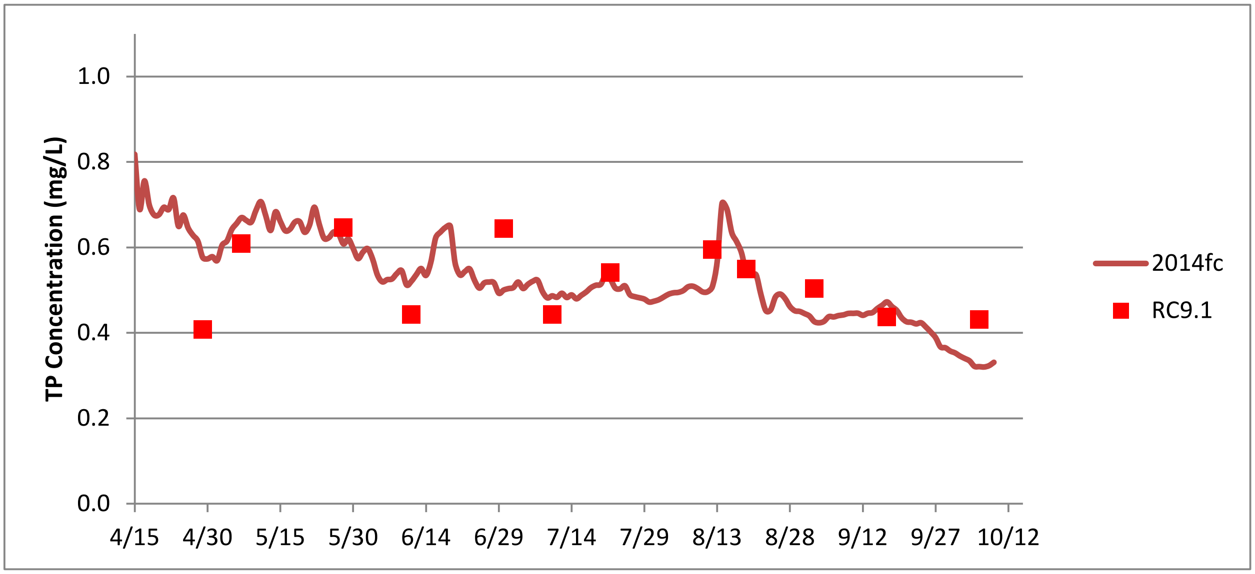
Riverside Canal at Dixie Spill (Rc9_0)

Date	Status	Laboratory Analysis Ortho P (mg/L)	Total (mg/L)	TSS (mg/L)	Difference (Duplicate-Original) / Original Ortho P (mg/L)	Total (mg/L)	TSS (mg/L)
5/28/2014	Original	0.300	0.646	148			
5/28/2014	Duplicate	0.308	0.644	138	3%	0%	-7%
7/22/2014	Original	0.395	0.685	171			
7/22/2014	Duplicate	0.396	0.700	171	0%	2%	0%

Riverside Canal End Spill (Rc31_3)

Date	Status	Laboratory Analysis Ortho P (mg/L)	Total (mg/L)	TSS (mg/L)	Difference (Duplicate-Original) / Original Ortho P (mg/L)	Total (mg/L)	TSS (mg/L)
5/28/2014	Original	0.165	0.205	11			
5/28/2014	Duplicate	0.168	0.202	5	2%	-1%	-55%
8/19/2014	Original	0.328	0.371	15			
8/19/2014	Duplicate	0.332	0.339	13	1%	-9%	-13%

TP Concentration Error



	Mean Error	
	Arithmetic	Absolute
4/29/2014	0.168	0.168
5/7/2014	0.061	0.061
5/28/2014	-0.038	0.038
6/11/2014	0.078	0.078
6/30/2014	-0.144	0.144
7/10/2014	0.044	0.044
7/22/2014	-0.016	0.016
8/12/2014	-0.086	0.086
8/19/2014	-0.008	0.008
9/2/2014	-0.077	0.077
9/17/2014	0.036	0.036
10/6/2014	-0.110	0.110
Average	-0.0076	0.0720

Exhibit 7.2-2

Riverside Operational Water Quality Improvement Project Development Report

HyQual
Hydraulics
Hydrology
Water Quality

Riverside Operational Water Quality Improvement Project

Development Report

Report to:	Idaho Power Company
	Riverside Irrigation District
Prepared by:	Jack Harrison, PhD, P.E, HyQual, P.A.
	Scott King, P.E., SPF Water Engineering, LLC
	Scott Mooney, Control Engineers
Date:	May 2014

HyQual

Hydraulics
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Date: May 2014

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JACK R. HARRISON

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Appendix 3	Phosphorus Load Reduction Calculation Methodology
Appendix 4	Riverside Canal Water Quality Monitoring Status Report for 2011, 2012, and 2013
Appendix 5	ROWQIP Flow Measurement Methodology

Note: This report is a summary of the project development occurring from 2010 through 2013. It was originally published as a part of the Section 401 Water-Quality Certification Application for Hells Canyon Complex (FERC Project No. 1971), which was submitted to Idaho and Oregon DEQs on May 23, 2014.

Cover Photo: Riverside Canal "spill gates" at Indian Creek shown during SCADA system testing

Executive Summary

Idaho Power Company (IPC) is proposing to address its dissolved oxygen (DO) load allocation assigned to the transition zone and metalimnion of Brownlee Reservoir in the Snake River – Hells Canyon Total Maximum Daily Load (SR–HC TMDL) (IDEQ and ODEQ 2004) by implementing the Riverside Operational Water-Quality Improvement Project (ROWQIP). The SR–HC TMDL identified the Hells Canyon Complex Clean Water Act Section 401 (HCC CWA § 401) certification as the process for detailing IPC's implementation plan for the required DO improvements. Following is a description of the proposed project and provides the supporting documentation to ensure the project is transparent, reliable, and verifiable.

To meet the SR–HC TMDL allocation, IPC developed the ROWQIP with the intent that the Riverside Irrigation District (Riverside) will operate its primary delivery facility (Riverside Canal) in a way that reduces the loads of phosphorus and other pollutants discharged from the Riverside Canal to the Boise and Snake rivers. The studies and analyses conducted from 2010 through 2013 show that when the ROWQIP is fully implemented by Riverside, phosphorus load reductions can exceed 30,000 lb/yr. This exceeds the equivalent load reduction of phosphorus necessary to meet IPC's DO requirements identified in the SR–HC TMDL estimated to be 15,000 lb P/yr.

IPC initiated support for this program in 2010, prior to acceptance of this program in the HCC CWA § 401 certification or FERC license. This early implementation, relative to IPC's regulatory requirements, was justified by the opportunity to begin improving water quality. By initiating implementation of the program, including constructing control systems, establishing flow monitoring stations, and testing operations prior to program approval by the regulatory agencies, IPC has collected and analyzed data to ensure the value of the program toward meeting its SR–HC TMDL responsibility for DO in Brownlee Reservoir. Data collected and analyzed conducted between 2010 and 2013 supports a high level of certainty that the expected benefits in phosphorus load reductions to the Snake and Boise rivers will occur.

Project Description

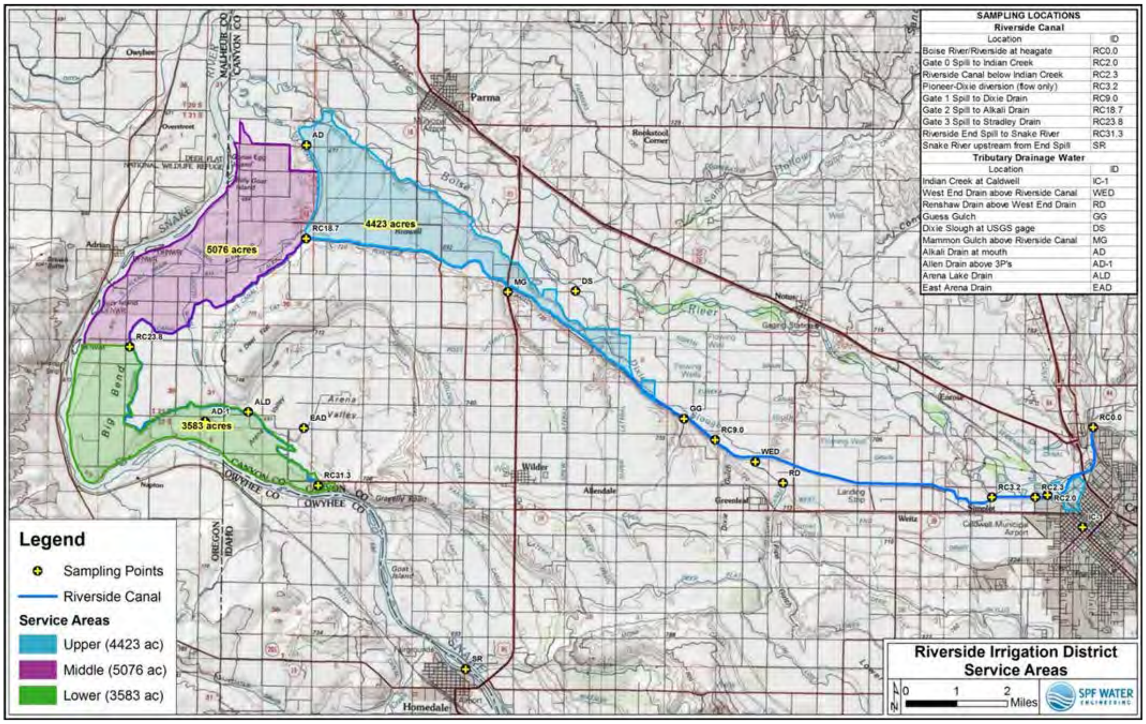
Riverside operates the Riverside Canal, located at the western end of the Boise River valley near the confluence of the Boise and Snake rivers, as its primary conveyance for delivery of irrigation water (Figure 1). Riverside delivers water to approximately 230 water users for agricultural purposes, with principal crops of onions, sugar beets, wheat, potatoes, alfalfa, beans, and hops. According to Idaho Department of Water Resources (IDWR) records, Riverside has water rights authorizing the irrigation of 10,158 acres within a district boundary (IDWR 2013). The primary diversion to the Riverside Canal is from the south bank of the Boise River near Caldwell (Figure 1). Additionally, a number of tributary creeks and drains discharge into the canal along its length. Excess canal inflows are discharged (i.e., spilled) to the lower Boise and Snake rivers upstream of Brownlee Reservoir.

When fully implemented, the ROWQIP is designed to implement the automatic operation of the Riverside Canal in a manner that reduces phosphorus loading to the Boise and Snake rivers.
The phosphorous load reductions from these water-quality-focused canal operations will be

accomplished by prioritizing the use of high-nutrient agricultural and municipal drainage water for delivery to irrigators and thereby reducing agricultural return flows to the Boise and Snake rivers. Specific actions are described and defined in the operating guidelines (Appendix 1 – Canal Automation System). In addition, the project was designed and will be implemented consistent with generally accepted quality standards and guidelines.

Under historical operations, water in Indian Creek and the West End Drain entered the Riverside Canal, along with Riverside's water-right diversion from the Boise River. Because of the configuration of the canal system, Riverside has no operational option other than to accept all of the water from Indian Creek and the West End Drain into its canal. Flows entering the Riverside Canal from Indian Creek and the West End Drain are variable and unreliable. Consequently, under baseline conditions, Riverside's necessary operation was to divert up to its full water right from the Boise River. This ensured sufficient water for irrigation demand. If the total flow into the Riverside Canal exceeded irrigation demand, excess water was spilled back into the Boise and Snake through four manually-operated spill gates along the canal and a spill at the end of the canal. The lack of system automation precluded operations capable of efficiently dealing with the variability of inflows from Indian Creek, West End Drain, and other minor tributary inflows. Consequently, significantly more water was typically diverted from the Boise River than would be necessary under improved, more efficient operations proposed under the ROWQIP. Baseline diversion from the Boise River was consistent with the decreed water rights and was a practical necessity to meet irrigation demand because of the lack of operational flexibility and efficiency under the pre-ROWQIP system design.

The proposed operations, made possible by the ROWQIP, will allow Riverside to fully use water from tributaries with relatively high phosphorus levels for irrigation purposes, rather than spilling it into the Boise or Snake rivers. Diversion of Boise River water with low phosphorus levels is correspondingly reduced. The result will be reductions in phosphorus loading to the Boise and Snake rivers. The reduced phosphorus loading to the rivers will result in corresponding reductions in phosphorus and organic matter loading to Brownlee Reservoir. IPC is proposing to use the reduction in oxygen demand in Brownlee Reservoir resulting from the reduction of phosphorus and organic matter loading to Brownlee Reservoir to meet its DO load allocation defined in the SR–HC TMDL.



SAMPLING LOCATIONS	
Riverside Canal	
Location	ID
Boise River/Riverside at heagate	RC0.0
Gate 0 Spill to Indian Creek	RC2.0
Riverside Canal below Indian Creek	RC2.3
Pioneer-Dixie diversion (flow only)	RC3.2
Gate 1 Spill to Dixie Drain	RC9.0
Gate 2 Spill to Alkali Drain	RC18.7
Gate 3 Spill to Stradley Drain	RC23.8
Riverside End Spill to Snake River	RC31.3
Snake River upstream from End Spill	SR
Tributary Drainage Water	
Location	ID
Indian Creek at Caldwell	IC-1
West End Drain above Riverside Canal	WED
Renshaw Drain above West End Drain	RD
Guess Gulch	GG
Dixie Slough at USGS gage	DS
Mammon Gulch above Riverside Canal	MG
Alkali Drain at mouth	AD
Allen Drain above 3P's	AD-1
Arena Lake Drain	ALD
East Arena Drain	EAD

Figure 1. Riverside Irrigation District, approximate irrigated acreages, and sampling locations including spill gates.

Equivalent Phosphorus Load

To address DO concerns in Brownlee Reservoir, the SR–HC TMDL allocated an annual DO supplementation of 1,125 tons to IPC. The SR–HC TMDL specifically allows IPC to use upstream nutrient reduction to satisfy this requirement to improve DO levels in the transition zone and metalimnion of Brownlee Reservoir.

Based on typical stoichiometry, an equivalent seasonal phosphorus load reduction to IPC's 1,125 tons of oxygen requirement is 15,000 pounds of phosphorus (Appendix 2 - Equivalent Seasonal Load Reduction). This equates to an average phosphorus load reduction of 82 pounds per day over a 183-day irrigation season, the period the Riverside Canal is typically operated. This time period is appropriate considering the overall benefits of the inflow load reductions related to long-term storage and cycling of phosphorus within the reservoir. Given the dynamic nature of phosphorus spiraling in a phosphorus-rich riverine system, such as the Snake River and Brownlee Reservoir (ODEQ and IDEQ 2004), it is justifiable to assume all phosphorus released into the rivers through Riverside's system has practical implications for the DO dynamics in Brownlee Reservoir. Further, the phosphorus reductions upstream of Brownlee Reservoir provide additional water-quality benefits for the lower Boise River and the Snake River immediately upstream of Brownlee Reservoir.

As stated previously, the SR–HC TMDL DO load allocation is 1,125 tons as an annual load. In the TMDL, the assumed approach to meet this allocation was reservoir aeration over a low-DO critical period from July 1 through September 7. While this was the time period of potentially lower DO conditions in

Brownlee Reservoir, the TMDL states, “this time frame should not be interpreted as an absolute requirement” (IDEQ and ODEQ 2004). The relatively short 65-day time period was based on the understanding that potential DO additions that were assumed possible through reservoir aeration would have no benefits outside of the actual time period when aeration was occurring. Conversely, reductions in phosphorus and organic matter loading address the underlying problem of excessively high oxygen demand. Therefore, phosphorus load reductions outside of the specific critical DO time period will still affect the actual DO levels within the critical period, plus will provide benefits outside of the critical period.

The typical time period that phosphorus loading will be reduced to the Boise and Snake rivers under this proposal is 183 days beginning April 15 and extending to October 15 (Appendix 2 - Equivalent Seasonal Load Reduction). Under current phosphorus levels, the project is anticipated to reduce seasonal phosphorus loads by levels that exceed the calculated equivalent to the DO allocation. The TP reductions provided by the ROWQIP address the underlining causes of low DO and will have cumulative benefits that occur throughout the year, as well as across many years. For this reason, it is appropriate to calculate the load reductions resulting from the implementation of the ROWQIP over the irrigation season.

Phosphorus-Reduction Calculation Methodology

The phosphorus-load-reduction calculation methodology (Appendix 3 - Phosphorus Load Reduction Calculation Methodology) relies on a mass balance analysis to determine the TP load (pounds per day) delivered to areas irrigated with Riverside Canal water. By changing the canal operations, such as diverting less Boise River water, more water from other sources, such as Indian Creek, is used for irrigation rather than spilled. Consequently, less of the water that is higher in phosphorus levels is discharged to the Boise and Snake rivers.

A Riverside Canal model was developed to estimate the TP loads that would be delivered in irrigation water under different canal operations. A simplified schematic diagram (Figure 2) shows conceptually how the canal is structured with water diverted from the Boise River and a tributary containing drainage water discharging into the canal. Any excess drain water then “spills” back to the river downstream of the diversion along with agricultural runoff. The change in TP load in the river is calculated using delivered and runoff loads because it reduces uncertainty by relying on the same measurements for canal inflows and agricultural water delivery when modeling loads for differing canal operations.

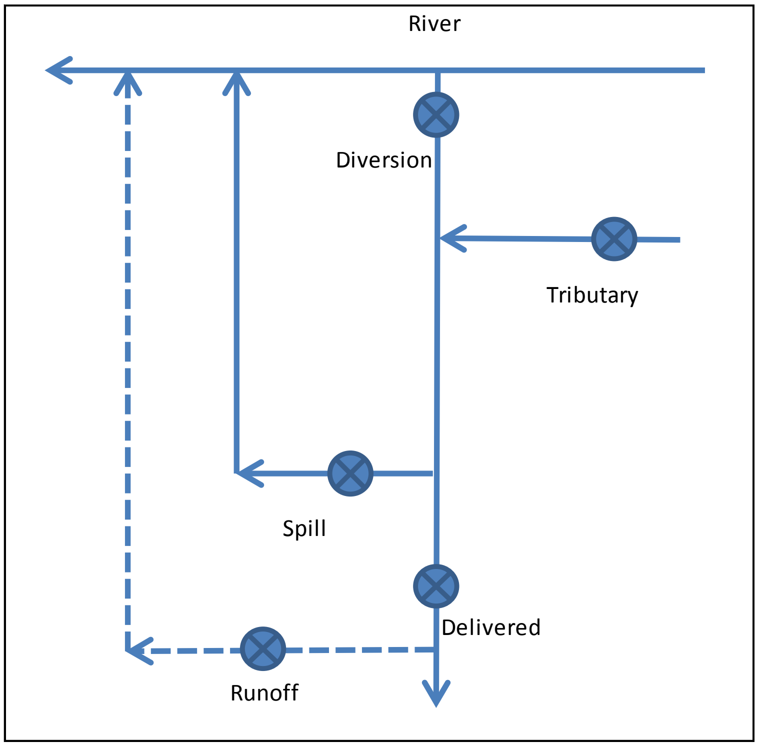


Figure 2. Simplified schematic of ROWQIP showing main components of the phosphorus-reduction calculation methodology.

Using a mass balance approach, the TP load delivered to farm land (L Delivery) under various canal operations is calculated as follows:

$$\textbf{Equation 1}\text{: } L_{Delivery} = L_{Diversion} + L_{Tributary} - L_{Spill}$$

Where:

$L_{Diversion} =$ the load delivered to agricultural areas

$L_{Tributary}$ = the tributary inflow load

L_{Spill} = the load spilled back to the river

A change in the canal operations, such as diverting less Boise River water, will change the load in the canal because the various sources of water to the canal have differing water quality. Consequently, this changes the load delivered to the farm land. The automated operations of the canal under the proposed ROWQIP are designed to reduce phosphorus loading to the Boise and Snake rivers and are referred to as water-quality (WQ) operations. Phosphorus loads delivered to the irrigated lands in the absence of the ROWQIP are referred to as baseline (BL) operations. The load (L) reduction produced by the change in canal operations is calculated by subtraction:

$$\textbf{Equation 2}\text{: } L\ Reduction_{\ in\ rivers} = (L_{Delivered} - L_{Runoff})WQ - (L_{Delivered} - L_{Runoff})BL$$

The RC model uses a water-balance approach similar to the load balance (Equation 1), applied over the 31-mile long canal (Appendix 3 - Phosphorus Load Reduction Calculation Methodology). Because the phosphorus load is calculated from the flow rate and phosphorus concentration, defining both flow and concentration are key considerations for load reduction calculations. The model assumes both tributary flow and water quality remain the same under WQ and BL operations. Therefore, the load reductions are derived from changes in Boise River diversion rates.

Water-Quality Operations Flows

As stated previously, the load reductions for water-quality-focused canal operations will be accomplished by prioritizing the use of high-nutrient agricultural and municipal drainage water. This is accomplished by minimizing diversion of the comparatively higher-quality Boise River. To estimate potential water-quality improvement under WQ operations prior to full implementation, the Boise River diversion is “back-calculated” from the measured irrigation water delivered using the mass balance flow model. After implementation, flow data collected at the Boise River diversion will be used to model the flows along the canal.

Baseline Operations Flows

As shown by Equation 2, defining BL operations is necessary to determine the amount of phosphorus load reduction resulting from the ROWQIP. A definition of the baseline diversion is the critical parameter because it determines the flow along the canal, which will then be used to determine phosphorus loads for the BL operations.

The ROWQIP is specifically designed to modify canal operations in a way that reduces phosphorus loading to the Snake and Boise rivers. However, the program does not include any actions to modify or redefine Riverside’s overall irrigation requirements or the volume of water diverted as currently specified by adjudicated water rights. Therefore, it is appropriate that the baseline relative to water diverted from the Boise River be Riverside’s legally established Boise River water rights, which total 271.5 cfs (IDWR 2013). Under Idaho law, the adjudication of these rights constitutes a judicial determination that the decreed amount of water was put to use and that the users have the right to continue to put those decreed rates to use. While actual diversion may vary among years and specific times within a given year from the water-right diversion rate, it is the rate allowed under law and therefore the most logical and legally defensible flow estimate for use in baseline calculations. Furthermore, the 271.5 cfs Boise River water right is available (i.e., in priority) for diversion by Riverside throughout the irrigation season at the Riverside diversion point, even in low water years.

Water Quality

The phosphorus concentrations used to determine loads for both WQ and BL operations are the concentrations measured in water sources flowing into the Riverside Canal. These concentrations will be measured for all sources during project operations. At this point in the development of the project, the primary sources include the Boise River, Indian Creek, and West End Drain. Because this project deals mainly with changes in the operation of the water delivery system, rather than on-farm or upstream practices that improve water quality, it is appropriate to incorporate any changes in phosphorus concentrations of inflowing water into the quantification of baseline conditions.

Agricultural Runoff

For purposes of estimating load reductions to the Boise and Snake rivers, the runoff load from agricultural land is assumed to remain unchanged. This assumption is considered conservative for a number of reasons detailed in Appendix 3 - Phosphorus Load Reduction Calculation Methodology and includes the following:

1. Typically, more than 90% of phosphorus runoff from "clean-tilled row-crop" fields is in particulate form.
2. Soils typically have the capacity to retain a large percentage of the phosphorus applied.
3. The change in canal water quality anticipated for the canal is relatively small and represents less than 3% of the phosphorus needed to produce crops.
4. On-farm water quality and nutrient management has increased over last 10 years (i.e., since the SR–HC TMDL was established) and will be an ongoing focus of future load reduction efforts.

Riverside Canal Modeled Load Reductions

To estimate the potential for load reductions under WQ operations, the RC model was developed and applied using data collected from 2011 through 2013. The 2013 average modeled flows, concentrations, and loads for the parameters shown in Figure 2 and Equation 1 are given first to illustrate how data are used to calculate the TP load reductions. This is followed by a summary of total reductions for each of the 3 years IPC has been monitoring the canal water quality (Appendix 4 - Riverside Canal Water Quality Monitoring Status Report) and flows (Appendix 5 - ROWQIP Flow Measurement Methodology). More detailed information on modeling the daily average loads is presented in (Appendix 3 - Phosphorus Load Reduction Calculation Methodology).

Simplified Average Load Reduction Calculations for Year 2013

A simplified presentation of the Riverside Canal model, which is based on the schematic diagram (Figure 2), is used to show how the TP load reduction under BL and WQ in 2013 would differ (Table 1). The tributary and delivered flows, which are based on data measured in 2013, are the same for both operations, while the flow diverted from the Boise River varies. For the WQ operations, the diversion from the Boise River is then minimized, while for the BL, the diversion flow is the adjudicated water right of 272 cfs. Because Boise River inflows vary, the calculated spills back to the Boise and Snake rivers also vary. The change in proportions of canal-source water produces the different TP concentrations for the water delivered. The concentrations of TP in source water (diversion and tributary) are assumed to remain constant under both operations. In the 2013 example, there is a slight (0.02 mg/L) difference in estimated diversion concentrations attributable to use of average flows and loads to calculate the concentration under each of the scenarios.

Table 1. Example of load reduction calculations based on 2013 average model results.

Year 2013	Flow (cfs)	TP (mg/L)	Load (lb/d)
Water Quality			
Diversion	73	0.28	109
Tributary	234	0.65	819
Spill	92	0.55	270
Delivered	215	0.57	658
Baseline			
Diversion	272	0.26	378
Tributary	234	0.65	819
Spill	291	0.45	703
Delivered	215	0.43	494
TP Reduction		**0.14**	**164**

The Riverside Canal model is used to calculate “comparable” concentrations for the water delivered under each of the operations. The change in concentration of the water delivered to irrigators, which is the primary goal of the ROWQIP, can be use directly to calculate the TP load reduction because water delivery is the same for both operations (i.e., the change in TP load delivered can be calculated by multiplying 215 cfs by 0.14 mg/L and converting to 164 pounds per day).

Average Load Reductions for 2011, 2012, and 2013

The potential phosphorus load reductions for 3 years of available data as calculated using the Riverside Canal model total to over 30,000 pounds per year (Table 2). This represents the estimated change in phosphorus load to the Boise and Snake Rivers that could occur under full implementation of the ROWQIP over a 183-day irrigation season.

Table 2. RWQIP projected modeled load reductions for 2011 to 2013 based on a 183-day irrigation season.

Year	Phosphorus Load Reductions (pounds per year)
2013	30,098
2012	33,711
2011	36,827
Average	**33,545**

These modeled reductions are based on proposed WQ operations that assume a relatively high level of water management. Operations testing conducted during 2013 show that use of the automation control system in the upper reach of the canal can achieve TP load reductions that approach these levels, even in a relatively low runoff year (Appendix 3 - Phosphorus Load Reduction Calculation Methodology). While modeled projected water-quality improvements exceed the equivalent phosphorus load reduction of 15,000 pounds per year, testing in 2014 will help verify this range of load estimates is attainable.

Implementation

IPC began its participation with Riverside to reduce phosphorus loading to the Boise and Snake rivers in 2010. The implemented actions shows that the project can provide the levels of phosphorus load reductions needed to satisfy IPC's Brownlee Reservoir load allocation. By early implementation of the ROWQIP, including constructing control systems (Appendix 1 – Canal Automation System), collecting water-quality data (Appendix 4 - Riverside Canal Water Quality Monitoring Status Report), establishing flow monitoring stations (Appendix 5 - ROWQIP Flow Measurement Methodology), and testing operations prior to program approval by regulatory agencies (Appendix 3 - Phosphorus Load Reduction Calculation Methodology), IPC has been able to collect and analyze data to show how the program can meet its SR–HC TMDL responsibility for DO in Brownlee Reservoir (Appendix 2 - Equivalent Seasonal Load Reduction).

References

See Appendices 1 through 5.

Appendix 1 – Canal Automation System

Harrison, J., S Mooney, and P Cook. 2013. ROWIP Phased Implementation of Canal Automation System. Report to Riverside Irrigation District and Idaho Power Company. December 2, 2013.

ROWQIP Report on

Phased Implementation of Canal Automation System

Prepared for: Riverside Irrigation District
Idaho Power Company

Prepared by: Jack Harrison, PhD, P.E, HyQual
Scott Mooney, Control Engineers
Pete Cook, P.E., Control Engineers

Date: 12-2-13

ROWQIP Report on

Phased Implementation of Canal Automation System

Prepared for: Riverside Irrigation District
Idaho Power Company

Prepared by: Jack Harrison, PhD, P.E, HyQual
Scott Mooney, Control Engineers
Pete Cook, P.E., Control Engineers

Date: 12-2-13

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Attachment - Riverside SCADA Control Description, Phase 2, Upper Reach 8

Photo on cover: Newly installed local SCADA system control panel at Boise River diversion with automatic gates in background.

Introduction

The Riverside Operational Water Quality Improvement (ROWQI) Project includes installation of water control equipment and cellular communication systems for pre-programmed automated diversion of Boise River water and canal discharges (referred to as “spills”) from the Riverside Canal. The proposed water quality focused canal operations include prioritized use of nutrient-enriched, low-quality tributary irrigation water sources (i.e. creeks and drains discharging into the canal) over higher-quality water with lower nutrient levels (e.g. Boise River). Priority use of nutrient-rich water for consumptive irrigation increases use of the agricultural and urban wastewater and subsequent uptake of nutrients by crops. This reduces discharge of nonpoint source agricultural and urban runoff and point source discharges from draining to the Boise and Snake Rivers, and reduces diversion of higher-quality water from the Boise River. There are also a number of additional benefits such as the potential for increased river flows and thermal benefits, and demonstration of collaborative water quality management in the Treasure Valley.

As part of the ROWQI project, an automated canal control system is being designed and constructed that will include automatic control of spill gates and real-time flow monitoring of the canal flows, tributary inflows, and spills (Figure 1). After installation and setup of data loggers, cellular communications equipment and a centralized server, the upper reach of the Riverside Canal will be controlled by a supervisory control and data acquisition (SCADA) system. When this equipment is in place and operational, Riverside Irrigation District can prioritize use of drainage water flowing into their canal and limit the amount of canal discharge (i.e., spill) that flows unused to the Boise and Snake Rivers.

Overview of Phased Implementation of ROWQI Project

ROWQI Project is a multi-phased project (Table 1) that was initiated by Riverside Irrigation District (RID) in 2008 with technical support and partial funding from US Bureau of Reclamation (USBR). Phase 1 included “locally controlled” automation of Spill Gates #1, 2 and 3, without consideration of variable inflows. Phase 2 of the Program is focused on full automation of the upper reach of the Riverside canal and was funded by RID, Idaho Power Company (IPC), and USBR. Future phases will be directed toward increasing the water quality benefits as more experience in water quality management is gained. Each of the implementation phases are briefly discussed in the following section.

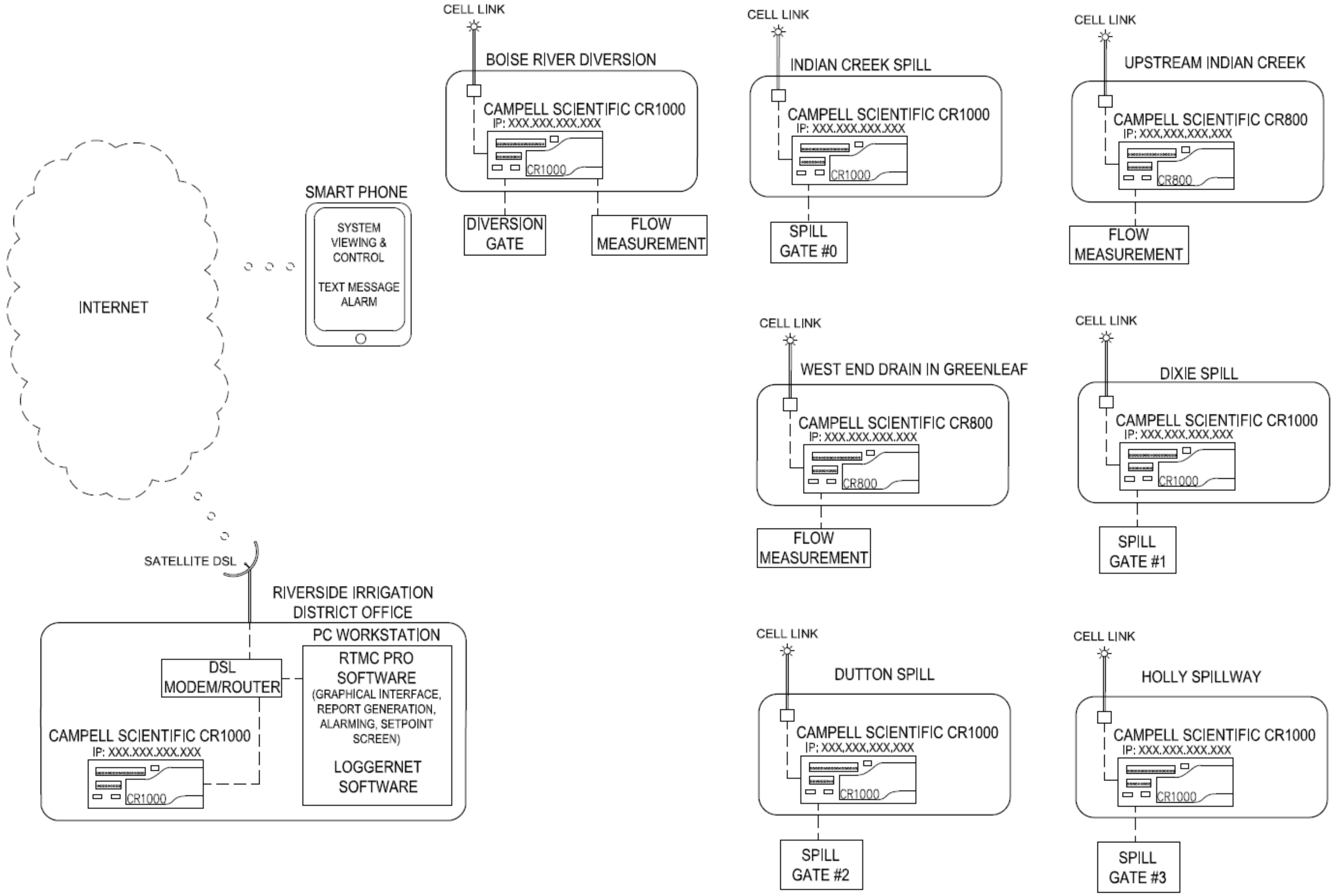


Figure 1. Automation System Configuration (Control Engineers 2012).

Table 1. ROWQI Program System Components.

Location	Phase 1	Phase 2
Riverside Canal		
Boise River Diversion	Controller, water level, diversion gate	cell, modem
Gate #0 – Indian Cr		CR800, cell, modem, and spill gate upgrade
Gate #1 – Dixie Sl	Controller, water level, spill gate	cell, modem
Gate #2 – Dutton Dn	Controller, water level, spill gate	cell, modem
Gate #3 – Holly Dn	Controller, water level, spill gate	cell, modem
Tributaries		
Indian Cr in Caldwell	Water level (upgraded Phase 2)	CR800, cell, modem
West End Drain	Water level (upgraded Phase 2)	CR800, cell, modem
RID Office -Server		
Server Computer		Dell
Internet	DSL Modem	
Master controller		CR1000
Data management software		RTMC
Program software		Loggernet

Phase 1 – Local Spill Gate Control

Phase 1 of the automation program was focused on adding motorized and localized automation for control of spill gates. A radio communication system allowed remote observation and adjustment of gate settings. This work was initiated in 2009 by RID with partial funding and support by USBR under a Water Management Grant.

Phase 2 - Automation System Implementation

In Phase 2, additional automation equipment was installed to provide automatic control of selected gates, flow measurement, and real-time data acquisition along the upper reach of the canal (Figure 1). This phase included the Riverside Canal/Indian Creek Spill Gate Project, funded by RID, IPC and USBR, which was completed in late 2012. The project, located below the inflow of Indian Creek and approximately ½ mile below the Boise River Diversion, included replacement of existing structures, installation of motorized control equipment, and improved flow measurement facilities.

Future ROWQI Program Phases

Future ROWQI Program implementation phases can include the following:

- Add additional main canal automation and gate control equipment to improve canal operations
- Increased RID reuse of minor tributaries through improved operations or automation
- Automatic control of Pioneer Dixie diversion

- Develop short term storage to offset flow fluctuations
- Improved management of lower canal and diversions to irrigated lands
- Support RID on-farm water quality management efforts

Phase 2 Automation System Implementation

The Riverside Canal automation (i.e., SCADA) system intends to provide full automation and control of the upper reach of the canal from the Riverside Irrigation District office. This will be accomplished via flow measurements, diversion and spill gates monitoring and real-time data acquisition along the upper reach of main canal from the Boise River Diversion (RC0.0) to Spill Gate #1 at Dixie Slough (RC9.0) (Figure 2). A major component of Phase 2 implementation was completed in the fall of 2012 with the installation of water control equipment on Indian Creek at the Spill Gate #0 (Table 1). In early 2013 the SCADA system equipment was installed on upper reach of the canal (i.e., Boise River to Dixie Slough). System startup and testing continued throughout the 2013 irrigation season.

Water Control

Water control projects (Phase 1), partially funded by USBR, have been completed over the past few years including the upgraded water control of three motorized spill gates referred to as Spill Gates 1, 2, and 3 (Table 1). These were set up for local automatic control with remote access for monitoring and set point adjustments.

In the fall of 2012, RID completed the Phase 2 upgrade of water control equipment at the Spill Gate #0 on Indian Creek. This major structural component of the project included replacement of existing concrete stoplog structures with new overshot gates at the Indian Creek Diversion location, and motorized control gates. These gates will provide improved water control and measurement of spill back to Indian Creek, which then discharges to the Boise River.

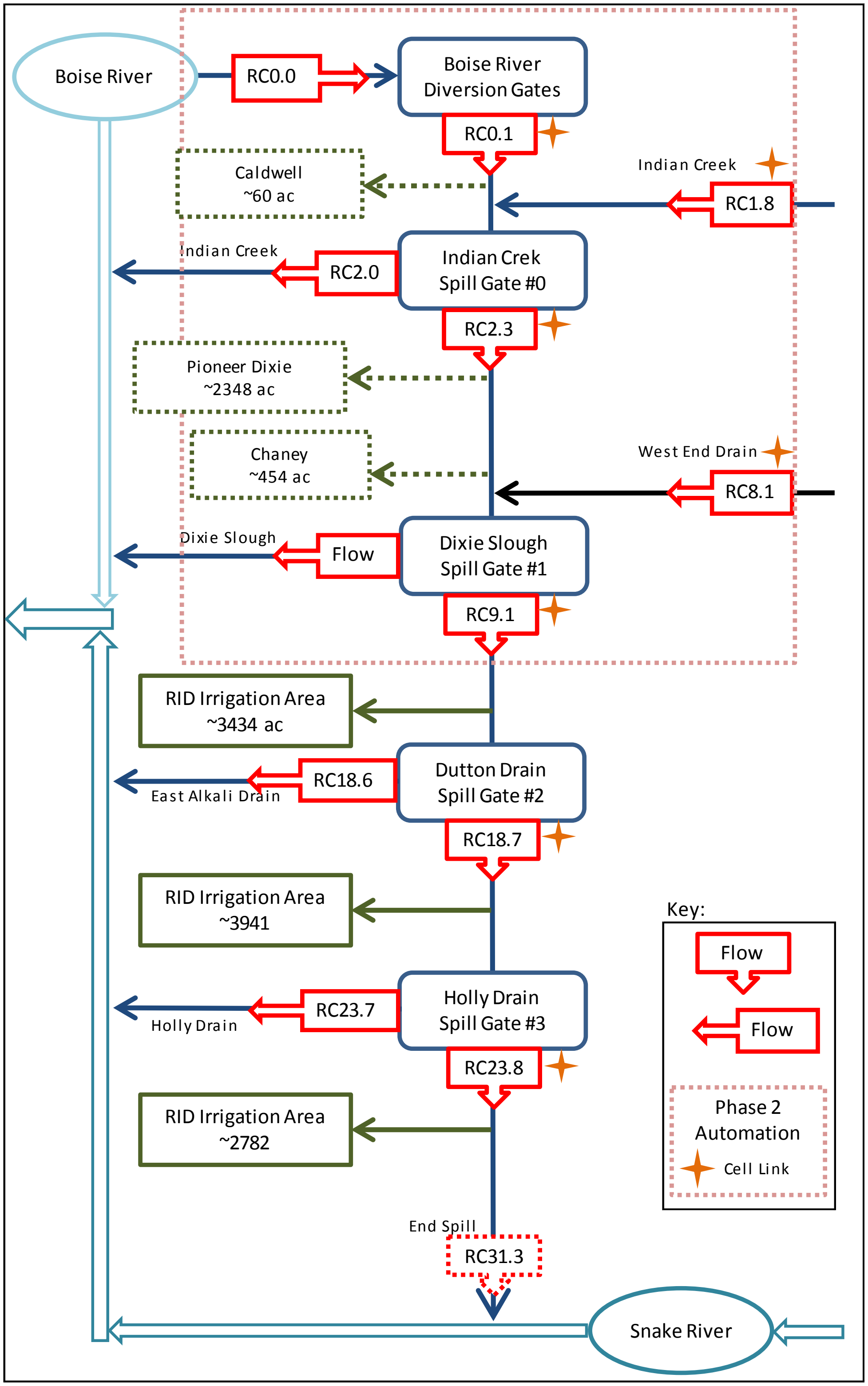
Supervisory Control and Data Acquisition System

Phase 2 includes the installation of dataloggers, cellular communications equipment and a centralized server to set up a supervisory control and data acquisition (SCADA) system for the upper reach of the Riverside Canal (Figure 2).

Dataloggers: The CR1000 dataloggers from Campbell Scientific were installed for data storage and control functions, and serve as the core component for the SCADA system. These data loggers allow:

- Data storage for continuous storage of water level/stage, flow and water quality (ie. temperature)
- Control of peripherals program using LoggerNet software
- Serial communications with serial sensors and devices supported via I/O port pairs
- Communication via various options: TCP/IP, email, FTP, web server.
- Battery-backed SRAM and clock that ensure data, programs, and accurate time are maintained while the datalogger is disconnected from the main power source

Cellular Communications Equipment: Raven XT modems are designed to maintain a reliable, consistent network connection and are a key component of the SCADA system.



Figures 2. Phase 2 automatically controlled diversion and spill gates and water level (flow) control points in Riverside Canal; also shows Phase 2 Automation above Dixie Slough Spill Gate #1.

Server: Centralized control of the Riverside Canal automation system has been set up and will be located at the Riverside Irrigation District office located near the canal west of Hwy 95. The equipment includes a “stand alone” Dell Precision Desktop computer (no other internet connections) running Campbell Scientific RTMC Pro and Logger Net Software. It will act as the human machine interface (HMI) between the operator and the SCADA system. The computer will allow the operator to track water levels at all locations on a real time basis, operate the canal diversion and spill gates, and allow the operator to make manual adjustments. The system will also include dual hard drives in RAID 1 configuration (for backup purposes) and a backup power supply.

A CR1000 datalogger is used as the Master Controller (Figure 1) and will also be located at the RID Office. It will act as the “brains” of the SCADA system. It will be setup and programed to monitor flows at each remote site and manage gate openings based on optimal flow set points to allow for minimal water spill.

System Programing, Startup and Testing

After installation of the automation/cellular equipment at each remote site, the SCADA system was fully bench tested by Control Engineers. This test ensured that all level sensors reading through to SCADA were at an accurate and acceptable rate, remote operation of the spill gates was available and that the cellular connections to each remote site were adequate for automated control. The system was programmed to maintain the same functionality that it currently has (i.e., the gates at each location will respond to changes in water level at their respective locations), and has been tested for more automatic control of the upper reach of the canal.

After completion of the final testing, the Master Controller/HMI will be installed at the RID office. It will provide the operator with the ability to observe current conditions and trends of all water levels, change local set points for gate control and manually operate the spill gates. It will essentially provide the same functionality that is in place now, except the operator will have all of the information available on a single screen without having to dial-in to the remote dataloggers. The system will also be set up for remote access, allowing the system to be programmed remotely to improve automatic control and management.

The upper canal system has also been programmed for automatic operation of the gates based on real time flows upstream and downstream of each gate. It was programmed with a safety factor to ensure that all RID irrigation areas will receive an adequate amount of water. For example, during this phase target spills of approximately 10 cfs and 20 cfs could be set for the Indian Creek and Dixie Slough, respectively.

All of the above was implemented and tested in 2013 irrigation water while ensuring adequate water deliveries to the RID irrigation areas. Throughout the irrigation season, the programing was tested and modified to reduce spill by reducing diversions from the Boise River.

Operations Program

During Phase 2 implementation, the automated control of diversion and spill gates was focused on the upper reach of the Riverside Canal from Indian Creek and the West End Drain (Figure 2). In general, water demand for the Riverside Irrigation District was set by RID (i.e. Andy Bishop) based on anticipated water use for the day. Gate controllers were programed to adjust for varying canal diversions, inflows and spills (see Attachment).

Attachment - Riverside SCADA Control Description, Phase 2, Upper Reach

General Description: The RcMaster data logger continuously polls and collects data from all other data loggers based on a user defined interval (default 15 min). Refer to the tag list (Appendix A) for a summary of all collected variables. It stores all collected flow data in a table every 15 minutes. All other variables are stored once daily. The collected flow data is used to determine the water demand at Rc0_0. This demand is used to calculate a level set point at Rc0_1 and the value is then automatically sent to the Rc0_0 data logger.

Algorithm Sequence:

1. **Data Collection:** The current canal flows (shown below) and set points are collected per the user settable poll interval. Refer to tag list (Appendix A) for variable descriptions.
    a. *CfsOut_Rc1_6*
    b. *CfsIn_Rc1_8*
    c. *CfsOut_Rc2_0*
    d. *CfsOut_Rc3_2*
    e. *CfsOut_Rc6_3*
    f. *CfsIn_Rc8_1*
    g. *CfsIn_Rc8_7*
    h. *CfsOut_Rc9_0*
    i. *CfsOutSP_Rc2_0*
    j. *CfsOutSP_Rc9_0*

2. **Data Consolidation:** The total diversions, spills and inflows for the upper reach are then calculated as follows:

$$\mathit{UpperDiversions\_Rc0\_0\_to\_2\_3} = \mathit{CfsOut\_Rc1\_6}$$
$$\mathit{UpperSpills\_Rc0\_0\_to\_2\_3} = \mathit{CfsOut\_Rc2\_0}$$
$$\mathit{UpperInflows\_Rc0\_0\_to\_2\_3} = \mathit{CfsIn\_Rc1\_8}$$

$$\mathit{UpperDiversions\_Rc2\_3\_to\_9\_0} = \mathit{CfsOut\_Rc3\_2} + \mathit{CfsOut\_Rc6\_3}$$
$$\mathit{UpperSpills\_Rc2\_3\_to\_9\_0} = \mathit{CfsOut\_Rc9\_0}$$
$$\mathit{UpperInflows\_Rc2\_3\_to\_9\_0} = \mathit{CfsIn\_Rc8\_1} + \mathit{CfsIn\_Rc8\_7}$$

$$\mathit{UpperDiversions\_Tot} = \mathit{UpperDiversions\_Rc0\_0\_to\_2\_3} + \mathit{UpperDiversions\_Rc2\_3\_to\_9\_0}$$
$$\mathit{UpperSpills\_Tot} = \mathit{UpperSpills\_Rc0\_0\_to\_2\_3} + \mathit{UpperSpills\_Rc2\_3\_to\_9\_0}$$
$$\mathit{UpperInflows\_Tot} = \mathit{UpperInflows\_Rc0\_0\_to\_2\_3} + \mathit{UpperInflows\_Rc2\_3\_to\_9\_0}$$

3. **Demand Calculation:** The flow demand at the river head gates is calculated based on the following demand equation:

$$\mathit{CfsDem\_Rc0\_1} = \mathit{Cfs\_Rc9\_1} - \mathit{UpperInflows\_Tot} + \mathit{UpperDiversions\_Tot} + \mathit{CfsOutSP\_Rc2\_0} + \mathit{CfsOutSP\_Rc9\_0}$$

4. **Rc0_1 Level Set point Calculation:** A level set point for the river head gates is determined based on the inverse of the flow rating equation as shown:

   $$CanHgtSP\_Rc0\_1 = (CfsDem\_Rc0\_1/P\_Rc0\_1)^{(1/b\_Rc0\_1)} - X\_Rc0\_1 + e\_Rc0\_1$$

5. **Level Set Point Send:** The calculated demand level set point is then automatically sent to the river head gates data logger based on a user defined interval.

Control Permissives: The following is a list of control permissives which must be met before the master logger will attempt automatic control. When all permissives are met, the variable *AutoControlReady* is set equal to 1.

1. **Data Transmission Status:** The data logger must be successfully communicating, retrieving and sending variables to all other data loggers. This value is set at the end of each poll interval. If the poll is successful, it is set to 1. If it is unsuccessful, it is set to 0 and the logger will reattempt the transmission.
   a. **Permissives**: *DataRxStatus = 1, DataTxStatus = 1*

2. **Flow Alarms**: Various flow conditions must be met. Limits for each flow value (TBD) shall be determined. A flow value outside of this range would indicate a sensor error or a flow deviation far from normal. Limit values to be appended to Appendix A.
   a. **Permissive**: *FlowAlarm = 0*

3. **Gate Alarms**: Gate alarms are already built into existing data loggers. A gate alarm or warning would indicate a gate which is being commanded to move but is not responding as expected
   a. **Permissive**: *GateAlarm = 0*

4. **All Gates in local Auto:** All gates must be in “Auto” mode (set locally via switch and in the logger program) for this permissive to be met.
   a. **Permissive:** *AllGatesAuto = 1*

5. **Auto Control Command is Issued:** The auto control command must be issued via the web interface or loggernet.
   a. **Permissive:** *AutoControlCmd = 1*

Failover: In the case where *AutoControlCmd* is issued and *AutoControlReady* is equal to 0, the master logger shall start a failover timer, which when expired will send out an alarm and the system will failover to a “safe” condition. This means setting the level set points to predetermined safe operating levels (TBD).

Riverside Irrigation District Master Tag List :

Tagname	Description	Unit	Internal/ Collected	User Settable?	Alarm?
Socket_Rc0_0	TCP Socket Variable	N/A	Internal	No	No
Result_Rc0_0	TCP Transmit Result Variable	N/A	Internal	No	No
Gte1Hgt_Rc0_0	River Headgates Gate 1 Height	ft	Collected	No	No
Gte2Hgt_Rc0_0	River Headgates Gate 2 Height	ft	Collected	No	No
GteSet_Rc0_0	River Headgates Gate Height Setpoint	ft	Collected	No	No
CfsIn_Rc0_1	River Headgates Inflow	CFS	Collected	No	No
CfsDem_Rc0_1	River Headgates Inflow Calclated Demand	CFS	Internal	No	No
CanHgtSP_Rc0_1	River Headgates Canal Height Calclated Setpoint	ft	Internal	No	No
LevSet_Rc0_1	River Headgates Canal Height Actual Setpoint	ft	Collected	No	No
P_Rc0_1	River Headgates Flow Equation Variable, P	N/A	Collected	Yes	No
X_Rc0_1	River Headgates Flow Equation Variable, X	N/A	Collected	Yes	No
b_Rc0_1	River Headgates Flow Equation Variable, b	N/A	Collected	Yes	No
e_Rc0_1	River Headgates Flow Equation Variable, e	N/A	Collected	Yes	No
CfsOut_Rc1_6	Diversion to Caldwell Area Outflow	CFS	Collected	Yes	No
Socket_Rc1_8	TCP Socket Variable	N/A	Internal	No	No
Result_Rc1_8	TCP Transmit Result Variable	N/A	Internal	No	No
CfsIn_Rc1_8	Indian Creek at Kimball Inflow	CFS	Collected	No	No
CanHgt_Rc1_8	Indian Creek at Kimball Canal Height	ft	Collected	No	No
Socket_Rc2_0	TCP Socket Variable	N/A	Internal	No	No
Result_Rc2_0	TCP Transmit Result Variable	N/A	Internal	No	No
CfsOut_Rc2_0	Indian Creek Spill	CFS	Collected	No	No
CfsOutSP_Rc2_0	Indian Creek Spill Set Point	CFS	Internal	Yes	No
EastGteHgt_Rc2_0	Indian Creek East Gate Height	ft	Collected	No	No
WestGteGht_Rc2_0	Indian Creek West Gate Height	ft	Collected	No	No
GteSet_Rc2_0	Indian Creek Gate Height Setpoint	ft	Collected	No	No
CanHgt_Rc2_3	Riverside Gage Canal Height Setpoint	ft	Collected	Yes	No
CfsDem_Rc2_0	Indian Creek Canal Demand	CFS	Internal	No	No
Cfs_Rc2_3	Riverside Gage Canal Flow	CFS	Collected	No	No
LevSet_Rc2_3	Riverside Gage Height Setpoint	ft	Collected	Yes	No
CfsOut_Rc3_2	Diversion to Pioneer Dixe	CFS	Collected	Yes	No
CfsOut_Rc6_3	Diversion to Chaney	CFS	Collected	Yes	No
Socket_Rc8_1	TCP Socket Variable	N/A	Internal	No	No
Result_Rc8_1	TCP Transmit Result Variable	N/A	Internal	No	No
CfsIn_Rc8_1	West End Drain Inflow	CFS	Collected	No	No
CanHgt_Rc8_1	West End Drain Canal Height	ft	Collected	No	No
CfsIn_Rc8_7	Inflow from Drainage	CFS	Collected	Yes	No
CanHgtRc8_9	Dixie Upstream Canal Height	ft	Collected	No	No
Socket_Rc9_0	TCP Socket Variable	N/A	Internal	No	No

Tagname	Description	Unit	Internal/ Collected	User Settable?	Alarm?
Result_Rc9_0	TCP Transmit Result Variable	N/A	Internal	No	No
CfsOut_Rc9_0	Dixie Spill	CFS	Collected	No	No
CfsOutSP_Rc9_0	Dixie Spill Set Point	CFS	Collected	Yes	No
Gte1Hgt_Rc9_0	Dixie Gate 1 Height	ft	Collected	No	No
Gte2Hgt_Rc9_0	Dixie Gate 2 Height	ft	Collected	No	No
Gte3Hgt_Rc9_0	Dixie Gate 3 Height	ft	Collected	No	No
Gte4Hgt_Rc9_0	Dixie Gate 4 Height	ft	Collected	No	No
RadGteHgt_Rc9_0	Dixie Radial Spill Gate Height	ft	Collected	No	No
GteSet_Rc9_0	Dixie Gate Setpoint	ft	Collected	No	No
CanHgt_Rc9_1	Dixie Downstream Canal Height	ft	Collected	No	No
Cfs_Rc9_1	Dixie Downstream Canal Flow	CFS	Collected	No	No
LevSet_Rc9_1	Dixie Downstream Level Setpoint	ft	Collected	Yes	No
LevSet_Rc18_6	Dutton Upstream Canal Level Set Point	ft	Collected	Yes	No
CanHgt_Rc18_6	Dutton Upstream Canal Height	ft	Collected	No	No
Socket_Rc18_7	TCP Socket Variable	N/A	Internal	No	No
Result_Rc18_7	TCP Transmit Result Variable	N/A	Internal	No	No
CfsOut_Rc18_7	Dutton Canal Spill	CFS	Collected	No	No
Gte1Hgt_Rc18_7	Dutton Gate 1 Height	ft	Collected	No	No
Gte2Hgt_Rc18_7	Dutton Gate 2 Height	ft	Collected	No	No
GteSet_Rc18_7	Dutton Gate Height Set Point	ft	Collected	No	No
LevSet_Rc23_7	Holly Upstream Canal Level Set Point	ft	Collected	Yes	No
CanHgt_Rc23_7	Holly Upstream Canal Height	ft	Collected	No	No
Socket_Rc23_8	TCP Socket Variable	N/A	Internal	No	No
Result_Rc23_8	TCP Transmit Result Variable	N/A	Internal	No	No
CfsOut_Rc23_8	Holly Canal Spill	CFS	Collected	No	No
Gte1Hgt_Rc23_8	Holly Gate 1 Height	ft	Collected	No	No
Gte2Hgt_Rc23_8	Holly Gate 2 Height	ft	Collected	No	No
GteSet_Rc23_8	Holly Gate Height Set Point	ft	Collected	No	No

Appendix 2 – Equivalent Seasonal Load Reduction

Harrison, J. 2014. IPC Equivalent Seasonal Phosphorus Load Reduction. Technical Memorandum to Idaho Power Company. April 16, 2014.

HyQual
Hydraulics
Hydrology
Water Quality

Technical Memorandum

IPC Equivalent Seasonal Phosphorus Load Reduction

Prepared for: Idaho Power Company

Prepared by: Jack Harrison, PhD., PE, HyQual,P.A.

Date: April 16, 2014

HyQual
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Technical Memorandum

IPC Equivalent Seasonal Phosphorus Load Reduction

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Date: April 16, 2014

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JACK R. HARRISON

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Cover: Photograph showing macrophyte beds in Southwestern Snake River upstream of confluence with Boise River.

Introduction

Idaho Power Company (IPC) is proposing to address its dissolved oxygen (DO) load allocation assigned to the transitions zone and metalimnion of Brownlee Reservoir in the Snake River-Hells Canyon Total Maximum Daily Load (SR-HC TMD)(IDEQ and ODEQ 2004) by implementing the Riverside Operational Water Quality Improvement (ROWQI) Project. Working with the Riverside Irrigation District (Riverside) (Figure 1), IPC developed the Riverside Operational Water Quality Improvement Project (ROWQIP) with the intent that the Riverside will operate its primary delivery facility (Riverside Canal) in a way that reduces the loads of phosphorus and other pollutants in the Boise and Snake rivers by delivering more of these pollutants to use and treatment on Riverside farmland.

The SR-HC TMDL identified the HCC 401 certification as the process for detailing IPC's implementation plan for the required DO improvements. This memorandum provides the basis for calculating the phosphorus reduction that is equivalent to the nonpoint source Brownlee Reservoir Dissolve Oxygen (DO) load allocation established in the Snake River – Hells Canyon Total Maximum Daily Load (SR-HC TMDL)(IDEQ and ODEQ 2004). The ratios and component of a trade presented below were initially assessed for a potential point-nonpoint source trade with Heinz Foods. IPC initiated support for the ROWQIP in 2010, prior to acceptance of this program in the HCC CWA § 401 certification or FERC license. Studies and analyses performed since data collection began, and discussed in detail in Harrison 2014, show that when the ROWQIP is fully implemented by Riverside, the project load reductions will exceeded the phosphorus load shown to be equivalent to IPC's DO requirements identified in the SR–HC TMDL.

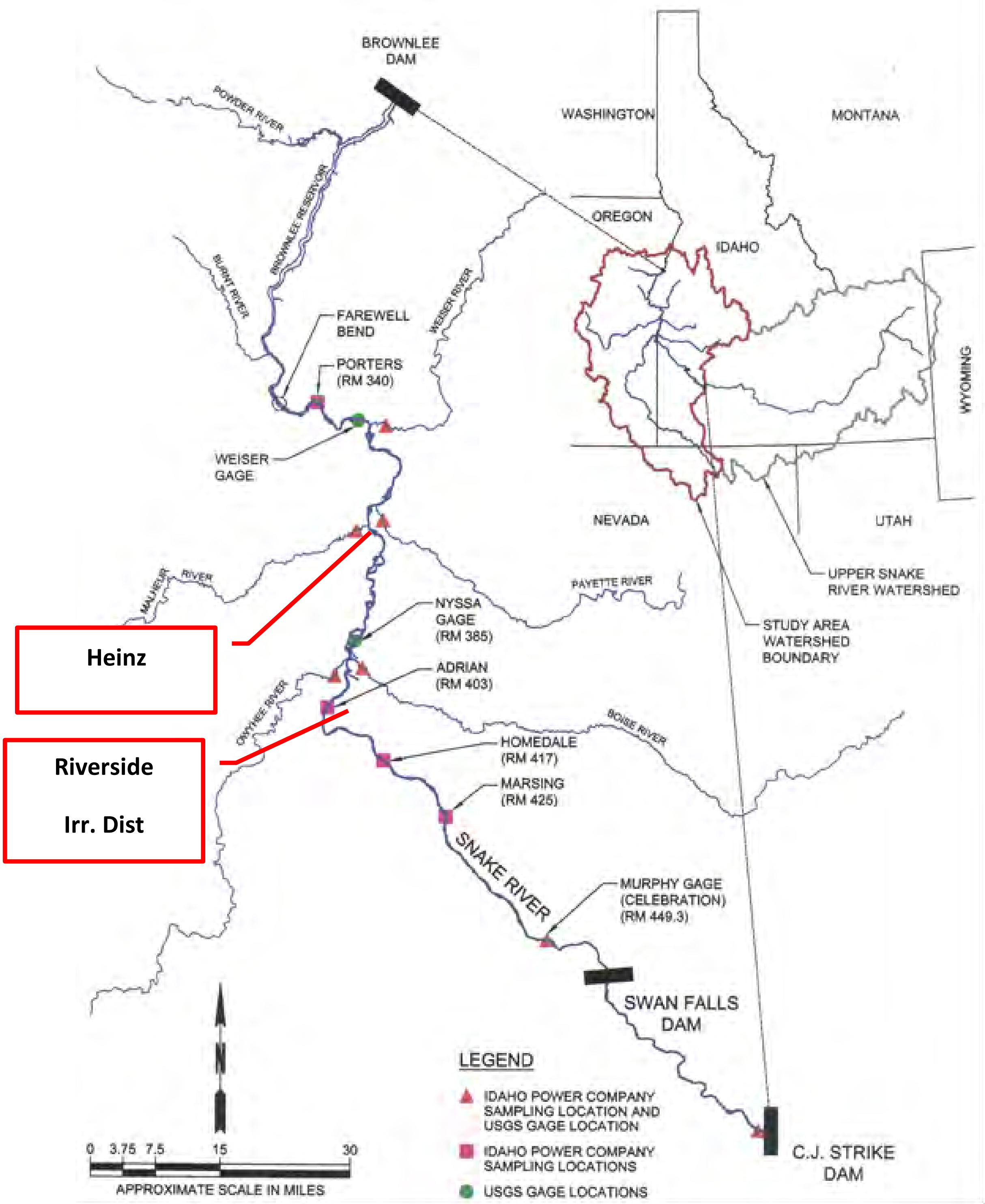


Figure 1. Map of Southwestern Snake River from CJ Strike Dam to Brownlee Dam (after Harrison 2005) showing the general location of Riverside Irrigation District and Heinz.

IPC Dissolved Oxygen Load Allocation

The Snake River – Hells Canyon Total Maximum Daily Load (IDEQ and ODEQ 2004) established phosphorus load and wasteload allocations for point and nonpoint sources in the southwestern Snake River watershed (Attachment A2). For example, the following allocations were set:

- The Heinz phosphorus wasteload allocation is 83 kg/d, which is about 183 lb/d.
- The Boise River phosphorus load allocation is 242 kg/d, which is approximately 532 lb/d.
- The Brownlee Reservoir DO allocation is 1,125 tons of oxygen per year (tons-DO/yr).

Regarding the Brownlee Reservoir, the TMDL states:

> *In addition to the total phosphorus load allocations for the Upstream Snake River segment (RM 409 to 335) and the tributaries, a dissolved oxygen load allocation has been established for Brownlee Reservoir (RM 335 to 285) (IPCo) to offset the calculated reduction in assimilative capacity due to the Hells Canyon Complex reservoirs.*

The Brownlee Reservoir annual DO allocation as stated in the SR-HC TMDL is:

> *The dissolved oxygen allocation requires the addition of 1,125 tons of oxygen (1.02 x106 kg) into the metalimnion and transition zone of Brownlee Reservoir (approximately 17.3 tons/day (15,727 kg/day)).*

The SR-HC TMDL also specifically allows for IPC to use upstream nutrient reduction projects to satisfy its requirement for reduced oxygen levels in the transition zone and metalimnion of Brownlee Reservoir.

> *This load allocation does not require direct oxygenation of the metalimnetic and transition zone waters. It can be accomplished through equivalent reductions in total phosphorus or organic matter upstream, or other appropriate mechanism that can be shown to result in the required improvement of dissolved oxygen in the metalimnion and transition zones to the extent required.*

As stated in the TMDL, this load allocation does not require direct oxygenation of the metalimnetic and transition zone waters. It can be accomplished through equivalent reductions in total phosphorus or organic matter upstream.

Equivalent Total Phosphorus Load

Stoichiometric ratios discussed below are used to determine total phosphorus loads that are “equivalent” to the oxygen load allocations.

Stoichiometric Ratios

Phosphorus, oxygen and organic matter can be related by inorganic stoichiometry, which varies in response to environmental conditions (Sterner and Elser 2002). For example, the classic Redfield ratios for algae organic matter are C106N16P1. Assuming organic matter is 50% carbon, this implies a TP to organic matter (TP/OM) ratio of approximately 0.005. This is a typical value used in CE QUAL-W2 (Table 1). However, under eutrophic conditions, algae can store phosphorus, causing the ratio to increase. For example, ratios used in the 1995 Snake River model application (Table A—SR’95) are appropriate for modeling current hypereutrophic conditions with relatively high phosphorus levels. More typical levels, such as the default values given for CE QUAL-W2 (Table 1—W2), would be anticipated as phosphorus loads decrease through implementation of the SR HC TMDL. Lower ratios are also observed in reservoirs in response to settling and organic matter processing (Table A—Brwn ’95).

Table 1. Phosphorus (TP), oxygen (Ox) and organic matter (OM) stoichiometric ratios.

Stiochiometry or Load	**W2**	**Brwn ’02**	**Brwn ’95**	**SR ’95**	**Proposed**
TP/OM	0.005	0.01	0.01	0.02	**0.01**
Ox/OM	1.4	1.7	1.4	1.4	**1.5**
TP/Ox	0.36%	0.59%	0.71%	1.43%	**0.67%**

Notes: W2 stoichiometry are model default values per Cole and Wells 2002.
Brwn ’95 stoichiometry are optimized model values used in the 1995 Brownlee model application.
SR ’95 stoichiometry are optimized model values used in the 1995 Snake River model application.
Brwn ‘02 based on data collected in upper end of reservoir.
Proposed: recomemnded for conversion of DO allocation to TP Reduction.

As discussed below, a stoichiometric ratio of 0.67 percent is used to convert conversion of Brownlee Reservoir DO load allocation to an equivalent phosphorus reduction.

Comparable Loads

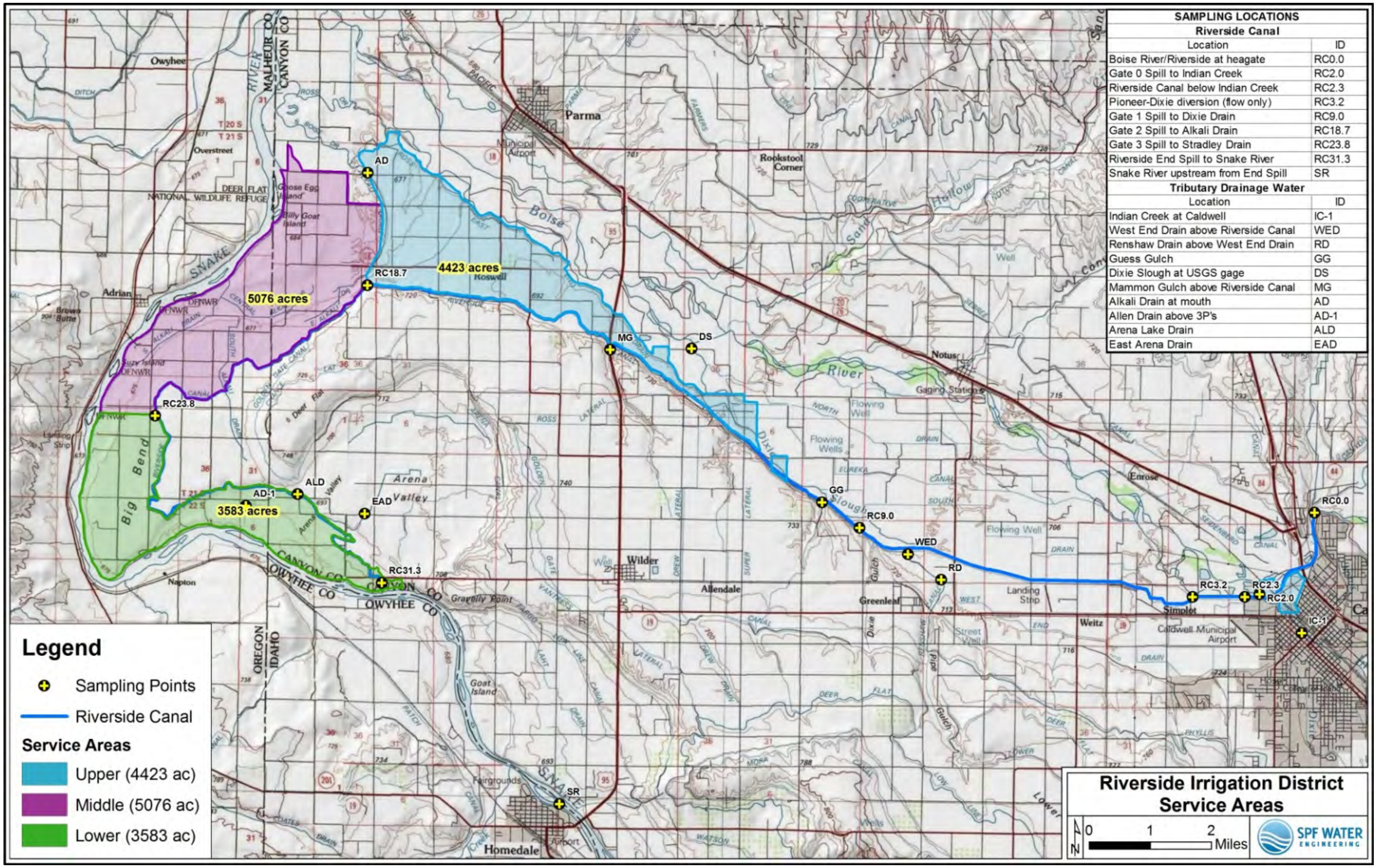
Based on typical stoichiometry, the equivalent seasonal phosphorus load reduction to IPC’s 1,125 tons of oxygen requirement is approximately 15,000 pounds of phosphorus per year (lb-P/yr) (Table 2). The table shows conversions of the Brownlee oxygen load allocation into a comparable phosphorus load using the nutrient ratios initially used to support a point-nonpoint trade with Heinz located in Ontario, Oregon. For comparison, the 15,000 lb annual phosphorus load was translated into a daily phosphorus load reduction (i.e., 82 lb-P/day) based on Riverside Canal operation period discussed below.

Table 2. Calculated IPC equivalent phosphorus Reduction; also shown are some of the estimated conversion given in the SR-HC TMDL.

	TMDL (Page 312)	Calculated	Units
Annual Allocation			
Oxygen	1125	1125	tons-Ox/yr
		2250000	lb-Ox/yr
	1020000	1022727	kg-Ox/yr
Organic matter		750	tons-OM/yr
		1500000	lb-OM/yr
	1700000	681818	kg-OM/yr
Total Phosphorus		7.5	tons-TP/yr
		15000	lb-TP/yr
		6818	kg-TP/yr
Stoichiometry	**Calculated DEQ**	**Typical**	
TP/OM	0.13	1.0%	
Ox/OM	0.60	150%	
TP/Ox		0.67%	
Conversions		2.2	lb/kg
		2000	lb/ton
ROWQIP Period	**Apr 15 to Oct 15**	**183**	**Days**
		82	lb-TP/day
		37	kg-TP/day
TMDL Critical Period	**May thru Sep**	**152**	**days**
Total Phosphorus		99	lb-TP/day
	1487	45	kg-TP/day
DO “Sag” Period	**Jul 1 to Sep 7**	**65**	**days**
Total Phosphorus		231	lb-TP/day
	3500	105	kg-TP/day

Proposed ROWIP

IPC developed the ROWQIP with the intent that the Riverside Irrigation District (Riverside) will operate its primary delivery facility, the Riverside Canal (Figure 2), in a way that reduces the loads of phosphorus and other pollutants discharged from the Riverside Canal to the Boise and Snake rivers and thereby meet the SR–HC TMDL allocation. IPC initiated support for this program in 2010, prior to acceptance of this program in the HCC CWA § 401 certification or FERC license. This early implementation, relative to IPC’s regulatory requirements, was justified by the opportunity to begin improving water quality. By initiating implementation of the program, including constructing control systems, establishing flow monitoring stations, and testing operations prior to program approval by the regulatory agencies, IPC has collected and analyzed data to ensure the value of the program toward meeting its SR–HC TMDL responsibility for DO in Brownlee Reservoir.



SAMPLING LOCATIONS	
Riverside Canal	
Location	ID
Boise River/Riverside at heagate	RC0.0
Gate 0 Spill to Indian Creek	RC2.0
Riverside Canal below Indian Creek	RC2.3
Pioneer-Dixie diversion (flow only)	RC3.2
Gate 1 Spill to Dixie Drain	RC9.0
Gate 2 Spill to Alkali Drain	RC18.7
Gate 3 Spill to Stradley Drain	RC23.8
Riverside End Spill to Snake River	RC31.3
Snake River upstream from End Spill	SR
Tributary Drainage Water	
Location	ID
Indian Creek at Caldwell	IC-1
West End Drain above Riverside Canal	WED
Renshaw Drain above West End Drain	RD
Guess Gulch	GG
Dixie Slough at USGS gage	DS
Mammon Gulch above Riverside Canal	MG
Alkali Drain at mouth	AD
Allen Drain above 3P's	AD-1
Arena Lake Drain	ALD
East Arena Drain	EAD

Figure 2. Riverside Irrigation District, approximate irrigated acreages, and sampling locations including Spill Gate.

Time Periods

The 15,000-lb annual phosphorus equivalent load can be converted into a daily average load reduction based on various time periods (Table 1). While a time period for the DO allocation was presented in terms of a 65-day period beginning July 1 and extending through September 7, this was only used to characterize the daily average DO needed to address the low DO conditions identified and assessed during development of the TMDL. The TMDL states that this time period was focused on DO periods when relatively low DO conditions occur:

> *Timing of oxygen addition or other equivalent implementation measures should be such that it coincides with those periods where dissolved oxygen sags occur and where it will be the most effective in improving aquatic life habitat and support of designated beneficial uses.*

While this would be appropriate for DO injection measures, it's not for TP reduction measures as this would assume only currently flows of DOP and labile organic matter contribute to the low DO conditions (without the internal recycling discussed below). This was acknowledged in the TMDL, which states that this time period should not be considered an "absolute" requirement:

> *The calculated time period when exceedences occurred in the metalimnion of Brownlee Reservoir is between Julian days 182 and 247 (the first of July through the first week of September) when dissolved oxygen sags are observed to occur to a greater degree than those identified as the result of poor water quality inflowing from the upstream sources. However, this time frame should not be interpreted as an absolute requirement.*

A 183-day period is used for calculating annual load reductions provide by the ROWQI Project. This period covers most of the Riverside Canal's typically operational season, which generally begins before April 15 and extends to October 15. This is also longer than the 152-day "critical period" identified in the Snake River –Hells Canyon that begins in May and extends through September (IODEQ 2004). While this was intended to address Snake River nuisance algae concerns, recent studies show that algal levels in the Snake River can exceed targets throughout much of the year (USGS 2011). This indicates that phosphorus reductions over longer time periods can be "*effective in improving aquatic life habitat and support of designated beneficial use"* as stated by ODEQ and IDEQ 2004 in the SR-HC TMDL. Additional discussion on the dynamic nature of phosphorus spiraling in a phosphorus-rich riverine system, such as the Snake River and Brownlee Reservoir, and the long term benefits provided by the phosphorus reductions upstream of and in Brownlee Reservoir, are discussed below.

Phosphorus Processing and Organic Matter Demand

The SR-HC TMDL states that a reduction of organic matter/algal biomass should equate to the identified dissolved oxygen allocation. The load reductions from preferential use of nutrient rich creek and drain water, as provided by the ROWQIP, will occur over the entire irrigation season. As discussed below, these TP reductions address the underlining causes of low DO and will have cumulative benefits that are occur throughout the year, as well as across many years. The qualitative discussion about algal dynamics and reservoir nutrient cycling shows how phosphorus and organic matter reductions in early spring and late fall provide cumulative benefits and address the mid-summer low DO period identified in the SR-HC

TMDL. This documentation provides the technical information needed to justify the use of canal operations period (i.e., 183 days) for calculating the annual phosphorus load reduction.

River Spiraling

The ROWQIP load reductions occur upstream of Brownlee Reservoir near the confluence of the Boise and Snake Rivers (Figure 1). There has been considerable study of organic matter (OM) and associated downriver "spiraling" of nutrients (Figure 3). For example, Cushing et al. 1992 stated "…OM introduced in headwater reaches can be transported large distances for later use or storage elsewhere in the river…"

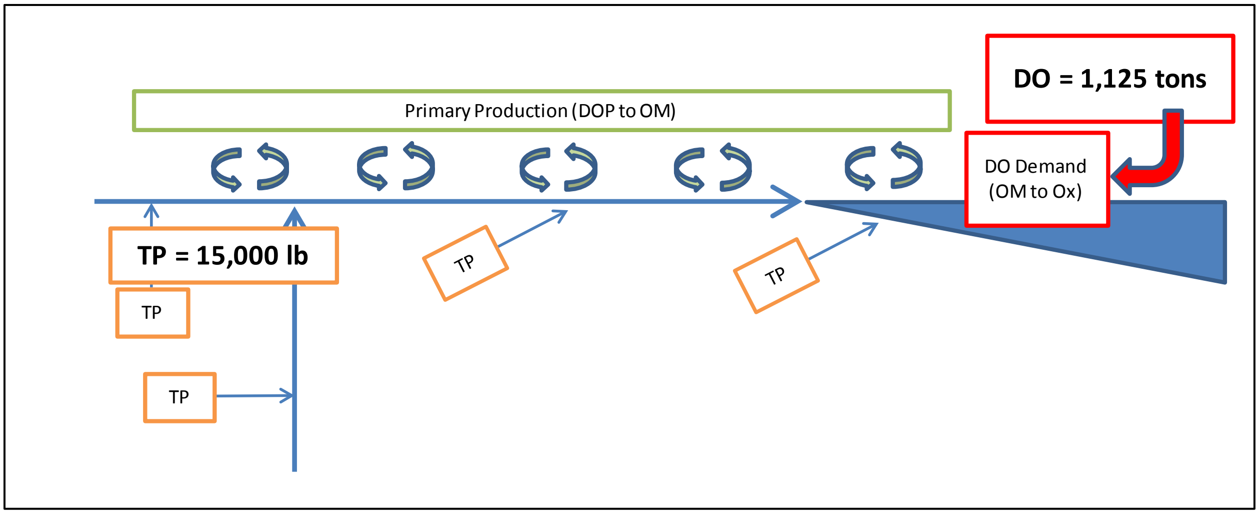


Figure 3. Schematic diagram showing TP processing in Snake River and upper reach of Brownlee Reservoir.

The following overview of river processes discusses how phosphorus discharged into the Boise and Snake River from the Riverside Irrigation District and other upstream sources moves through these rivers and discharges into Brownlee Reservoir:

- During the irrigation season relatively high loadings of inorganic particulate matter and nutrients are delivered to Snake River from tributaries and drains (IODEQ 2004, Harrison 2004, Holescher and Myers 2003).
- Throughout much of the year, available phosphorus (i.e., soluble reactive P) is used by algae via primary production in Snake River (Meyers et al, Harrison 2005, and USGS 2011). Some of the algae that are produced in the river senesces and settles to the bottom of the river. Additionally, some of the phosphorus absorbs to organic and inorganic particles (Wotton 1994) and settles to the bottom of the river.
- This results in an accumulation of rich sediments organic matter and nutrients during lower flow time periods (i.e., summer and winter), and lower velocity reaches and side channels of the Snake River.

- This organic and inorganic phosphorus associated with organic and inorganic particles then "spirals" downstream (Thomas et al., 2005) at varying rates throughout much of the year (Figure 3). For example, higher velocities in the spring can results in relatively large sediment and labile organic matter loads flowing into the reservoir during relatively short periods of time (Hoelscher and Myers, and Harrison, et al. 2000 , Harrison 2004, and IODEQ 2004) Additionally, summer season sediment release and uptake by phytoplankton and aquatic vegetation contributes to summertime downstream loadings of phosphorus and labile organic matter.

Reservoir Recycling

A relatively large fraction of the inflowing phosphorus loads are deposited in the sediments that accumulate in the mid-reaches of Brownlee Reservoir (Figure 4 – shown as red area). These organic and phosphorus rich sediment then re-cycles low oxygen water with phosphorus into the reservoir water column in a process described by many researchers (Ellis 1940, Fish and Wagner 1950, Lawrence 1967, Cole and Hannan 1990, Cole 1999, Myers et al. 2003, IODEQ 2004). The following is a brief description of the dominant processes involved:

- Phosphorus is delivered to the Brownlee Reservoir throughout the year, often with higher loads in the spring.
- A relative large fraction of phosphorus associated with the particulate material settles in the mid-reaches of the reservoir (Figure 4), which is where DO "sags" often occur (Meyers et al, 2001 and Harrison et al. 1999).
- Respiring algae and organic matter in the inflowing water column and near the bottom of reservoir exerts oxygen demand on the water column. At times this can be offset by primary production and reaeration.
- During the summer, DO demand can exceed respiration and reaeration in transition zone (and the metalinmion and epilimnion of the lacustrine zone of Brownlee Reservoir), causing low DO conditions in this area (Figure 4).

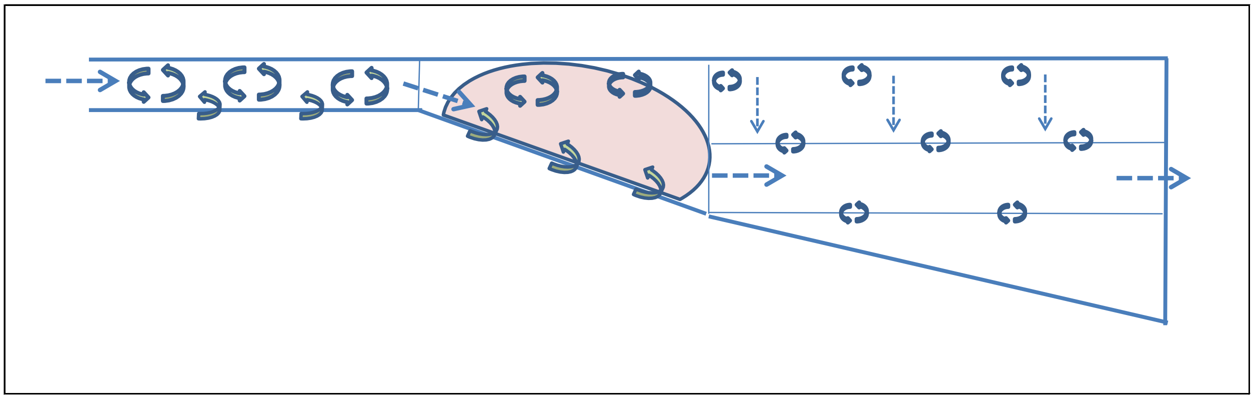


Figure 4. Schematic diagram showing mixing and formation of low DO area in reservoir transition zone (shown in red).

As stated above, the SR–HC TMDL DO allocated is 1,125 tons as an annual load. In the TMDL, one approach to meet this allocation was reservoir aeration over a low DO critical period, identified as beginning July 1 and extending through September 7. The timeframe was based on available data showing the low DO conditions in the transition zone using. The relatively short 65 day time period was based on the understanding that potential DO additions accomplished through reservoir aeration would have no benefits outside of the actual time period when aeration was occurring. Conversely, a reduction in phosphorus and organic matter loading, as proposed in the ROWQIP, addresses the underlying problem of excessively high oxygen demand, as discussed above. Therefore, phosphorus load reductions outside of the specific critical DO time period addresses the actual DO levels within the critical period, and are cumulative over the proposed decades-long duration of the ROWQIP.

Additional benefits of the RWQI Project

Additionally, the loads are reduced upstream of the Brownlee Reservoir transition zone (where the DO injection had been planned). This provided benefits in the Snake River and the riverine zone of Brownlee Reservoir…" *improving aquatic life habitat and support of designated beneficial use" (IODEQ 2004)…*over a much greater area and a longer time period. In addition to reducing phosphorus, the Project will reduce many other pollutants currently discharged the Boise and Snake Rivers including sediment, nitrogen, and pesticides (ISDA 2009).

Conclusions

To meet the SR–HC TMDL allocation, IPC developed the Riverside Operational Water Quality Improvement Project (ROWQIP) with the intent that the Riverside Irrigation District (Riverside) will operate its primary delivery facility (Riverside Canal) in a way that reduces the loads of phosphorus and other pollutants discharged from the Riverside Canal to the Boise and Snake rivers. The studies and analyses (e.g., Harrison 2014) show that when the ROWQIP is fully implemented by Riverside, it will meet IPC's DO requirements identified in the SR–HC TMDL.

As discussed above, the typical time period that the ROWQIP will reduce phosphorus loading to the Boise and Snake Rivers is 183 days, beginning April 15 and extending to October 15. In fact, in the early years of implementation, the ROWQIP is expected to decrease annual phosphorus loads by levels much greater than the equivalent phosphorus reduction. For example, estimated reductions exceed 30,000 lb-P/yr during 2011-2013 (Harrison 2014), compared the equivalent P load of 15, 000 lb-P/yr (Table 2).

IPC initiated support for this program in 2010, prior to acceptance of this program in the HCC CWA § 401 certification or FERC license, and benefits to the Boise and Snake Rivers are already occurring. These early phases of the project with relatively high reductions can address any uncertainty regarding:

- Timing
- Stoichiometric conversion
- Spiraling and Cycling
- OM processing

Additionally, a number of factors result in a conservative overall reduction including:

- SR-HCC TMDL includes safety factors
- Addresses the “source of problem” by reducing phosphorus (and not just injecting DO in the problem area)
- Seasonal reductions are cumulative and will reduce reservoir re-cycled loads
- Irrigators will be encouraged to increase on-farm management of water and nutrients

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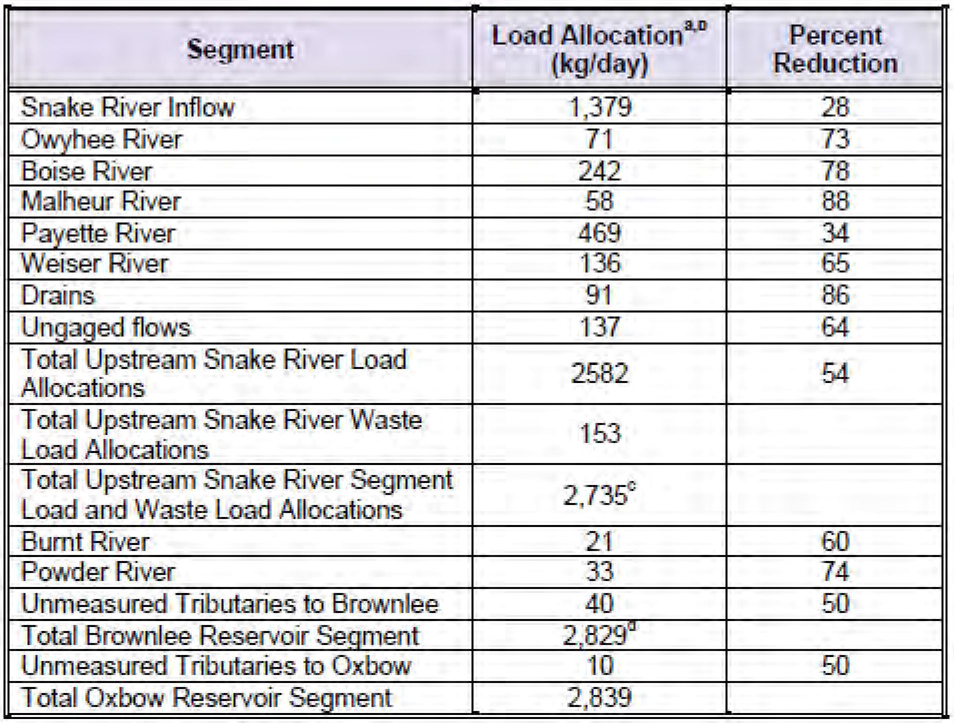
Attachments

Attachment 1 – Selected SR-HC TMDL load allocation information

Table A1. Mean phosphorus concentrations and loads as summarized from SR-HC TMDL.

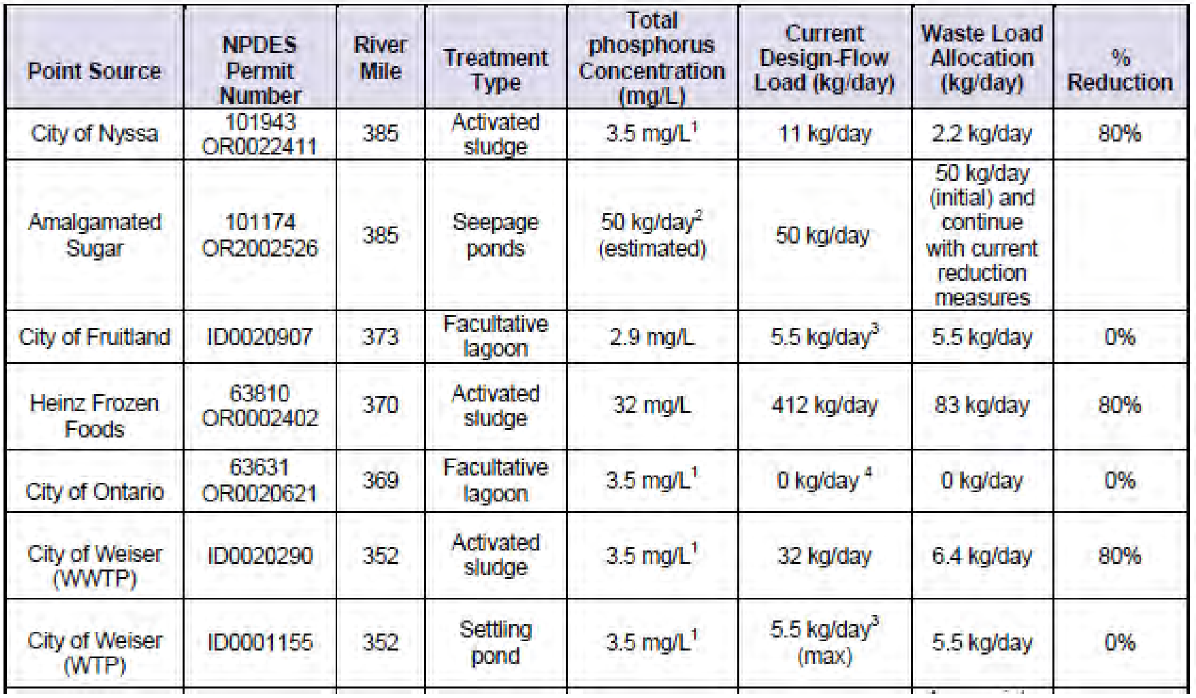
Location	Rivermile	TP (mg/L)	DOP (mg/L)	Load (kg/day)	Load (lb/day)	%NPS
Snake River Inflow	RM 409	0.08	0.01	1,912	4,206	31.5
Owyhee River	RM 396.7	0.20	0.07	265	583	4.4
Boise River	**RM 396.4**	**0.36**	**0.29**	**1,114**	**2,451**	**18.3**
Malheur River	RM 368.5	0.44	0.25	461	1,014	7.6
Payette River	RM 365.6	0.10	0.04	710	1,562	11.7
Weiser River	RM 351.6	0.17	0.07	392	862	6.5
Drains	U/S Seg	0.34	nd	660	1,452	10.9
Ungaged flows	U/S Seg	---	---	385	847	6.3

Table A2. Calculated total phosphorus load allocations for tributary, point and nonpoint sources (SR-HC Table 4.0.9).



Segment	Load Allocation[a,b] (kg/day)	Percent Reduction
Snake River Inflow	1,379	28
Owyhee River	71	73
Boise River	242	78
Malheur River	58	88
Payette River	469	34
Weiser River	136	65
Drains	91	86
Ungaged flows	137	64
Total Upstream Snake River Load Allocations	2582	54
Total Upstream Snake River Waste Load Allocations	153	
Total Upstream Snake River Segment Load and Waste Load Allocations	2,735[c]	
Burnt River	21	60
Powder River	33	74
Unmeasured Tributaries to Brownlee	40	50
Total Brownlee Reservoir Segment	2,829[d]	
Unmeasured Tributaries to Oxbow	10	50
Total Oxbow Reservoir Segment	2,839	

Table A3. Total phosphorus wasteload allocations (WLAs) for permitted point sources (SR-HC Table 4.0.8).



Point Source	NPDES Permit Number	River Mile	Treatment Type	Total phosphorus Concentration (mg/L)	Current Design-Flow Load (kg/day)	Waste Load Allocation (kg/day)	% Reduction
City of Nyssa	101943 OR0022411	385	Activated sludge	3.5 mg/L[1]	11 kg/day	2.2 kg/day	80%
Amalgamated Sugar	101174 OR2002526	385	Seepage ponds	50 kg/day[2] (estimated)	50 kg/day	50 kg/day (initial) and continue with current reduction measures	
City of Fruitland	ID0020907	373	Facultative lagoon	2.9 mg/L	5.5 kg/day[3]	5.5 kg/day	0%
Heinz Frozen Foods	63810 OR0002402	370	Activated sludge	32 mg/L	412 kg/day	83 kg/day	80%
City of Ontario	63631 OR0020621	369	Facultative lagoon	3.5 mg/L[1]	0 kg/day [4]	0 kg/day	0%
City of Weiser (WWTP)	ID0020290	352	Activated sludge	3.5 mg/L[1]	32 kg/day	6.4 kg/day	80%
City of Weiser (WTP)	ID0001155	352	Settling pond	3.5 mg/L[1]	5.5 kg/day[3] (max)	5.5 kg/day	0%

Attachment 2 – TMDL Excerpt on IPC/Brownlee Dissolved Oxygen Load Allocation

SR-HC TMDL excerpt from pages 449-450. Also see page 312-313 for additional discussion.

> 4.0.2.8 DISSOLVED OXYGEN LOAD ALLOCATION
>
> In addition to the total phosphorus load allocations for the Upstream Snake River segment (RM 409 to 335) and the tributaries, a dissolved oxygen load allocation has been established for Brownlee Reservoir (RM 335 to 285) (IPCo) to offset the calculated reduction in assimilative capacity due to the Hells Canyon Complex reservoirs.
>
> The dissolved oxygen allocation requires the addition of 1,125 tons of oxygen (1.02 x106 kg) into the metalimnion and transition zone of Brownlee Reservoir (approximately 17.3 tons/day (15,727 kg/day)). The total dissolved oxygen mass required to address the loss of assimilative capacity in the metalimnion over this time frame is 1,053 tons (957,272 kg). This is equivalent to an even distribution of 16.2 tons/day (14,727 kg/day) over 65 days. The total dissolved oxygen mass required to address the loss of assimilative capacity in the transition zone over this time frame is 72 tons (65,454 kg). This is equivalent to an even distribution of 3.0 tons/day (2,727 kg/day) over 24 days.

The calculated time period when exceedences occurred in the metalimnion of Brownlee Reservoir is between Julian days 182 and 247 (the first of July through the first week of September) when dissolved oxygen sags are observed to occur to a greater degree than those identified as the result of poor water quality inflowing from the upstream sources. However, this time frame should not be interpreted as an absolute requirement. This approach recognizes that the actual mass of dissolved oxygen necessary per day is not static. It is variable depending on system dynamics and may vary from a few tons to as many as 30 tons per day. Timing of oxygen addition or other equivalent implementation measures should be such that it coincides with those periods where dissolved oxygen sags occur and where it will be the most effective in improving aquatic life habitat and support of designated beneficial uses. Water column dissolved oxygen monitoring is expected to be undertaken as part of this scheduling effort.

This load allocation does not require direct oxygenation of the metalimnetic and transition zone waters. It can be accomplished through equivalent reductions in total phosphorus or organic matter upstream, or other appropriate mechanism that can be shown to result in the required improvement of dissolved oxygen in the metalimnion and transition zones to the extent required. A reduction of 1.7 million kg of organic matter/algal biomass would equate to the identified dissolved oxygen mass. This translates to approximately 11,000 kg/day over the critical period (May through September) or 26,000 kg/day over the 65-day load period identified in the calculations for reduced assimilative capacity. Direct oxygenation can be used, but should not be interpreted as the only mechanism available. Cost effectiveness of both reservoir and upstream BMP implementation should be considered in all implementation projects.

Appendix 3 – Phosphorus Load Reduction Calculation Methodology

Harrison, J. 2014. ROWQIP Phosphorus Load Reduction Calculation Methodology. Report to Idaho Power Company. May 19, 2014.

HyQual
Hydraulics
Hydrology
Water Quality

Riverside Operational Water Quality Improvement Project

Phosphorus Load Reduction Calculation Methodology

Report to: Idaho Power Company

Prepared by: Jack Harrison, PhD, P.E, HyQual, P.A.

Date: May 19, 2014

HyQual

Hydraulics
Hydrology
Water Quality

Riverside Operational Water Quality Improvement Project

Phosphorus Load Reduction Calculation Methodology

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Prepared by: Jack Harrison, PhD, P.E, HyQual, P.A.

Date: May 19, 2014

PROFESSIONAL ENGINEER
REGISTERED
6029
5/14/14
STATE OF IDAHO
JACK R. HARRISON

Executive Summary

Modified operation of the Riverside Canal achieved through automation of diversion, measurement, and spill facilities, and strategic operation of these facilities for maximum water quality benefit, can reduce downstream phosphorus load in the Snake River by more than 30,000 lbs/year. The Riverside Operational Water Quality Improvement Project (ROWQIP) can achieve this reduction by preferentially (1) maximizing diversion of tributary drain water that has relatively high concentrations of phosphorus, (2) minimizing diversion of Boise River water that has relatively low concentrations of phosphorus, and (3) minimizing spill of mixed river and drain water back to the Boise and Snake Rivers.

The intent of the ROWQIP is to reduce phosphorus loads in the Snake River to a level that meets the Brownlee Reservoir dissolved oxygen reduction allocation established in the Snake River-Hell Canyon Total Maximum Daily Load (TMDL) (IODEQ 2004). The phosphorus is removed from the hydrologic system by applying it to agricultural crops in areas that receive Riverside Canal water, primarily the Riverside Irrigation District. The sources of the phosphorus include upstream agricultural and storm water runoff and treated municipal wastewater discharged to creeks and drains flowing into the Riverside Canal (e.g., Indian Creek and West End Drain).

A conceptual model of phosphorus transport for canal operations demonstrates that the reduction in phosphorus load to the Boise and Snake Rivers can be simplified to the difference in delivered phosphorus load under water quality (WQ) and baseline (BL) operations (i.e., WQ load delivered minus BL load delivered). The BL operations assume diversion of Riverside's Boise River water right, whereas the WQ operations are based on measured Boise River diversions that are minimized. By holding irrigation delivery rates constant under both operations, the modeled load reduction becomes directly proportional to the change in phosphorus concentration of the water delivered from the canal for irrigation. Calculations of load reductions for these operations have been made using acanal flow and mass balance model with water quality sampling results and measured flow rates from canal and source water monitoring during the 2011 through 2013 irrigation seasons.

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Cover Photo: Riverside Canal “spill gates” at Indian Creek shown during SCADA system testing

Introduction

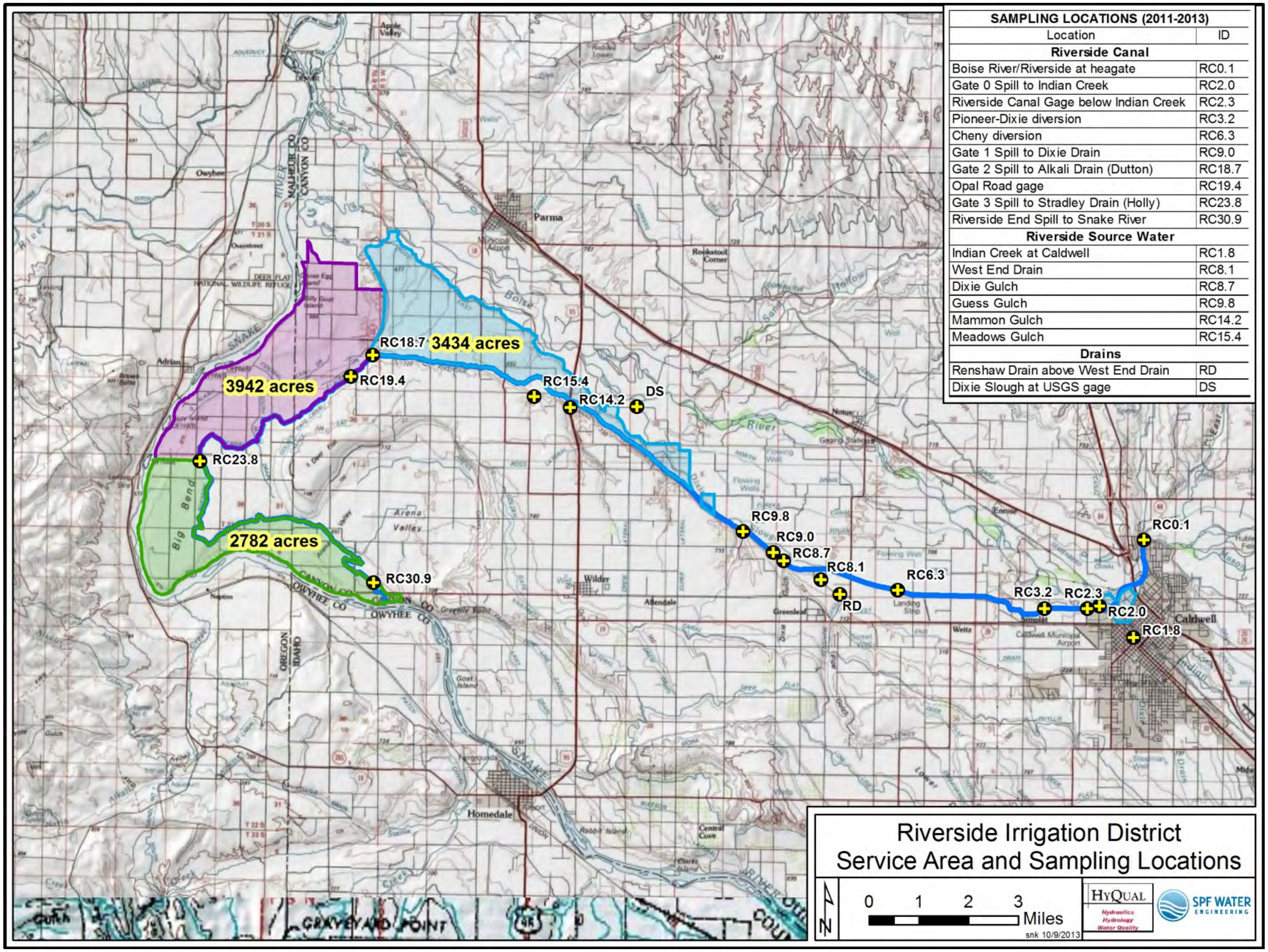
Idaho Power Company (IPC) is proposing to address the dissolved oxygen (DO) load allocation assigned to Brownlee Reservoir in the Snake River-Hells Canyon Total Maximum Daily Load (SR-HC TMDL) (IDEQ and ODEQ, 2004) by implementing the Riverside Operational Water Quality Improvement Project (ROWQIP). Based on typical stoichiometry, the equivalent seasonal phosphorus load reduction to IPC's 1,125 tons of oxygen requirement is approximately 15,000 lbs of phosphorus per year (Harrison 2014).

To meet the SR-HC TMDL allocation, IPC is currently funding the ROWQIP with the intent that Riverside Irrigation District (RID, Figure 1) will operate its primary delivery facility (Riverside Canal) in a way that reduces the levels of phosphorus and other pollutants discharged from the Riverside Canal to the Boise and Snake Rivers. The basic concept of the ROWQIP is to change canal operation to preferentially divert and deliver lower quality (i.e., higher phosphorus) drain water to RID for application on irrigated crop land. This would be accomplished by automating canal operations to both limit diversion of higher quality (lower phosphorus) Boise River water into the canal and limit the spill of canal water (a mixture of drain water and Boise River water) back to the rivers.

IPC initiated support for this program in 2010, prior to acceptance of this program in the HCC 401 certification, or FERC license. By initiating implementation of the program (including constructing control systems, establishing flow monitoring stations, and testing operations) prior to program approval by the regulatory agencies, IPC has been able to collect and analyze data to ensure the value of the program toward meeting its SR-HC TMDL responsibility for dissolved oxygen in Brownlee Reservoir.

As part of the ROWQIP, an automated canal control system is being designed and constructed that includes automatic control of spill gates and real-time flow monitoring of the canal flows, tributary inflows, and spills (Harrison, et al., 2013). After installation and setup of data loggers, cellular communications equipment, and a centralized server, the Riverside Canal will be controlled by a supervisory control and data acquisition (SCADA) system. When this equipment is fully operational, Riverside Irrigation District can prioritize use of flows into their canal (i.e., low quality drainage water) and limit the amount of canal discharge (i.e., spill) that flows unused to the Boise and Snake Rivers.

This report provides details of the ROWQIP needed to support 401 certification of the Hells Canyon Complex. Specifically, this report describes the methods used to calculate the phosphorus load reductions using the studies, analyses and water quality data collected during three irrigation seasons. As part of the analysis, a model of Riverside Canal was developed and used to calculate the daily phosphorus load reduction for the ROWQIP. The results provided below show that when the ROWQIP is fully implemented the anticipated load reductions can meet the requirements of the SR-HC TMDL. Additionally, this supporting information and the load reduction calculation methods can be used after implementation to ensure the project is transparent, reliable, and verifiable.



SAMPLING LOCATIONS (2011-2013)	
Location	ID
Riverside Canal	
Boise River/Riverside at heagate	RC0.1
Gate 0 Spill to Indian Creek	RC2.0
Riverside Canal Gage below Indian Creek	RC2.3
Pioneer-Dixie diversion	RC3.2
Cheny diversion	RC6.3
Gate 1 Spill to Dixie Drain	RC9.0
Gate 2 Spill to Alkali Drain (Dutton)	RC18.7
Opal Road gage	RC19.4
Gate 3 Spill to Stradley Drain (Holly)	RC23.8
Riverside End Spill to Snake River	RC30.9
Riverside Source Water	
Indian Creek at Caldwell	RC1.8
West End Drain	RC8.1
Dixie Gulch	RC8.7
Guess Gulch	RC9.8
Mammon Gulch	RC14.2
Meadows Gulch	RC15.4
Drains	
Renshaw Drain above West End Drain	RD
Dixie Slough at USGS gage	DS

Figure 1. Riverside Irrigation District, approximate irrigated acreages, and historical sampling locations including Spill Gates.

Riverside Irrigation District

Formed before 1900, the RID is a non-profit corporation that delivers water to approximately 230 water users for agricultural purposes. According to Idaho Department of Water Resources records (IDWR, 2013), the RID water rights authorize irrigation of 10,158 acres within a District boundary totaling 13,082 acres (the later estimated via GIS mapping).

The principal crops in the RID, which can vary greatly depending upon market conditions, include corn, pasture grass, onions, sugar beets, wheat, potatoes, alfalfa, beans, and hops. Based on discussions with RID producers, surface irrigation methods (i.e., furrow) is currently used on over half of the irrigated land (Table 1) (personal communication with RID Board Members, 2013).

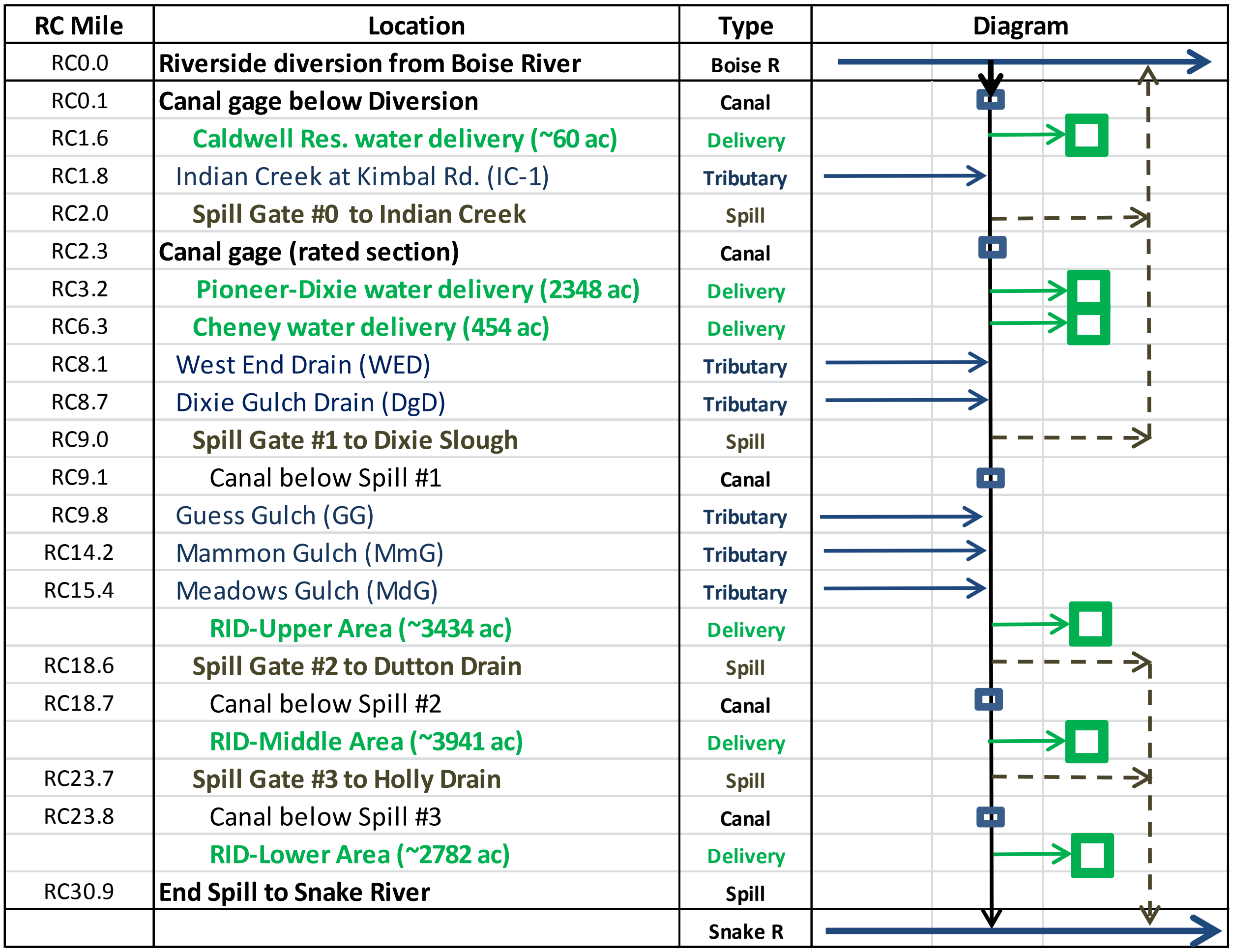
Table 1. Estimated cropping for 2013 and rough estimates of furrow irrigated acreage based on discussions with RID irrigators in early 2013.

Crop	**RID Area**		**Surface**	
	(ac)	**(%)**	**(ac)**	**(%)**
Onions	800	8%	400	50%
Corn	800	8%	640	80%
Wheat	2500	25%	2000	80%
Alfalfa	1500	15%	750	50%
Sugar Beets	500	5%	500	100%
Hops	200	2%	--	--
Beans	1000	10%	1000	100%
Pasture	1500	15%	750	50%
Other (e.g. Potatoes)	1200	12%	--	--
Total	**10000**		**6040**	**60%**

The Riverside Canal is also used to deliver water for irrigation of 2,348 acres within the service area of the Pioneer Dixie Ditch Company and 454 acres for W/T Land & Cattle (Todd Cheney, Figure 1). Thus, the total authorized irrigated acreage supplied by the canal is about 13,000 acres.

The Riverside Canal (Figure 1) is approximately 31 miles in length and primarily an earthen constructed channel. The Boise River is the primary source of water for the Riverside Canal with water rights totaling 271.48 cubic feet per second (cfs) as decreed in the Snake River Basin Adjudication (Attachment A). The RID also has decreed water rights to Indian Creek water totaling 178.4 cfs, and decreed rights to 113.16 cfs from other creeks and drains. Decreed water rights from all sources (i.e., the Boise River and tributaries) total about 563 cfs with priority dates ranging from June 1, 1884 to October 18, 1924. RID has additional claims to water rights pending in the Snake River Basin Adjudication. As previously noted, the Riverside Canal is also used to deliver water to the Pioneer Dixie Ditch Company and Cheney, with decreed Boise River rights of 60.5 cfs and 8 cfs, respectively, for an additional total of about 70 cfs.

When Boise River diversions and tributary source water exceed the water needed for deliveries, the excess is spilled from the canal at various locations (Figure 2). The majority of the excess water spilling to downstream drains discharges to the Boise or Snake Rivers with a minor amount diverted by irrigators. The schematic diagram (Figure 2) also shows the general locations and acreages of water deliveries. Numerous headgates and diversions from Riverside Canal (not shown in diagram) supply the irrigated land in these areas.



RC Mile	Location	Type	Diagram
RC0.0	**Riverside diversion from Boise River**	**Boise R**	
RC0.1	**Canal gage below Diversion**	**Canal**	
RC1.6	**Caldwell Res. water delivery (~60 ac)**	**Delivery**	
RC1.8	Indian Creek at Kimbal Rd. (IC-1)	**Tributary**	
RC2.0	**Spill Gate #0 to Indian Creek**	**Spill**	
RC2.3	**Canal gage (rated section)**	**Canal**	
RC3.2	**Pioneer-Dixie water delivery (2348 ac)**	**Delivery**	
RC6.3	**Cheney water delivery (454 ac)**	**Delivery**	
RC8.1	West End Drain (WED)	**Tributary**	
RC8.7	Dixie Gulch Drain (DgD)	**Tributary**	
RC9.0	**Spill Gate #1 to Dixie Slough**	**Spill**	
RC9.1	Canal below Spill #1	**Canal**	
RC9.8	Guess Gulch (GG)	**Tributary**	
RC14.2	Mammon Gulch (MmG)	**Tributary**	
RC15.4	Meadows Gulch (MdG)	**Tributary**	
	RID-Upper Area (~3434 ac)	**Delivery**	
RC18.6	**Spill Gate #2 to Dutton Drain**	**Spill**	
RC18.7	Canal below Spill #2	**Canal**	
	RID-Middle Area (~3941 ac)	**Delivery**	
RC23.7	**Spill Gate #3 to Holly Drain**	**Spill**	
RC23.8	Canal below Spill #3	**Canal**	
	RID-Lower Area (~2782 ac)	**Delivery**	
RC30.9	**End Spill to Snake River**	**Spill**	
		Snake R	

Figure 2. Diagram of Riverside Canal showing RC mile, location (with sampling ID or estimated acreage in parentheses), and type (i.e., source and receiving waters, diversion in green, tributary creek or drain in blue, and spill in dashed line to receiving water).

Conceptual Model

A conceptual model (Figure 3) was developed to show how canal operational management can affect the total phosphorus load discharged to the Boise and Snake Rivers. Note that the total phosphorus load (L) is the flow in units of cubic feet per second (cfs) multiplied by the total phosphorus concentration, reported in units of milligrams per Liter (mg/L), and then converted to units of pounds per day (lb/d).

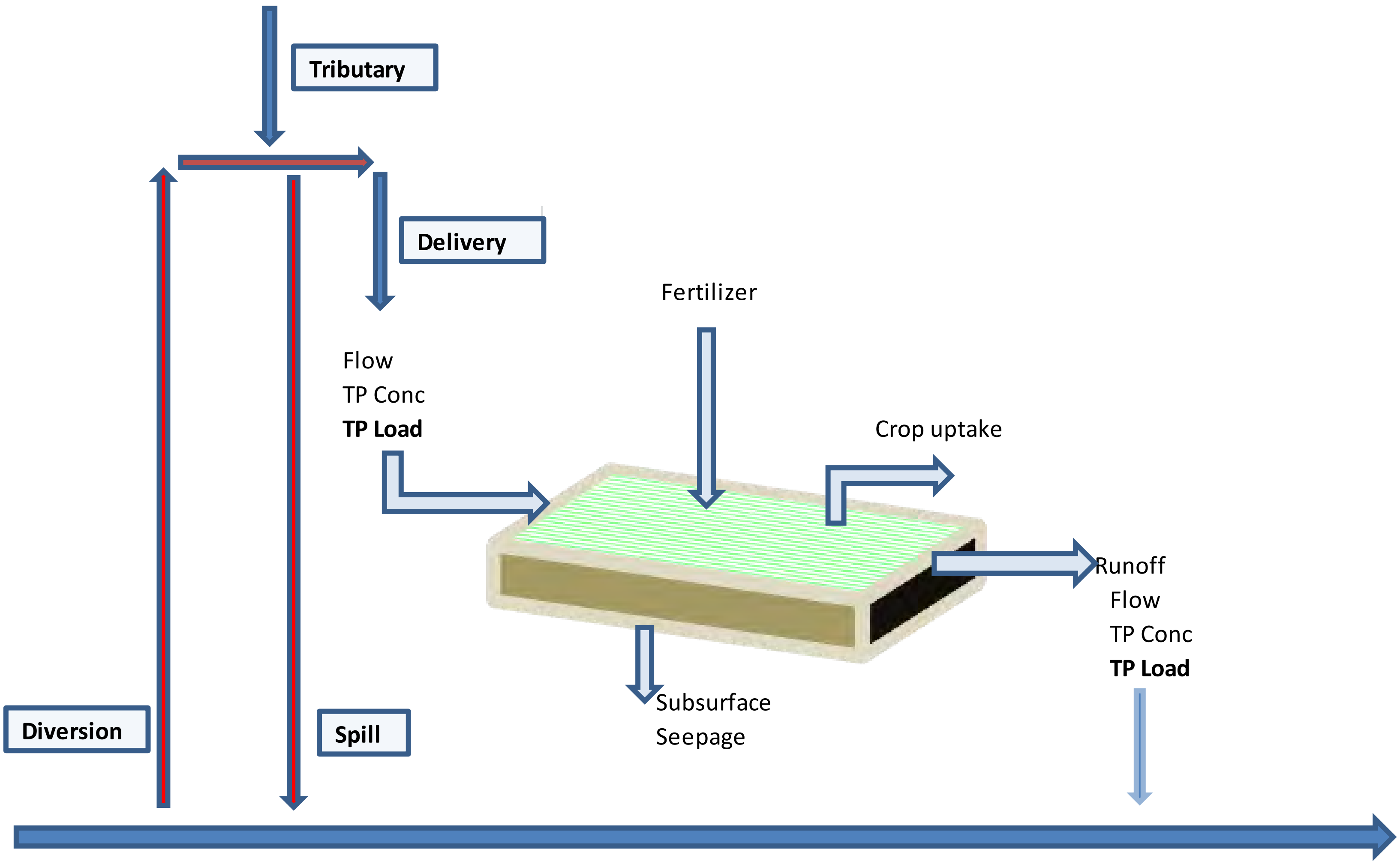


Figure 3. Conceptual diagram showing Riverside Canal (blue and red arrows). delivery to farm land, and drainage back to river (i.e., runoff and subsurface seepage from farm land).

Mass Balance Model

The conceptual model shows how the load in a river downstream of the agricultural area diversion is influenced by diversions and return flows (i.e., spills and agricultural runoff). Using a mass balance approach to compare upstream to downstream conditions in the river, diversions from the river will reduce downstream river loads, while canal spills and agricultural runoff tend to increase downstream river loads. Thus, the change in the TP load in the rivers downstream of the area ($L_{in\ rivers}$) is calculated as:

$$L_{in\ rivers} = -L_{BDiv} + L_{Spilled} + L_{Runoff} \qquad \textbf{EQ1}$$

Where:

L_{BDiv} the load diverted from the Boise River

$L_{Spilled}$: load in the canal that discharges (spills) back to the rivers

L_{Runoff}: the surface runoff and subsurface seepage load from the farm land

Also shown in the conceptual model, the load spilled from the canal to the river is calculated as:

$$L_{Spilled} = L_{BDiv} + L_{Tribs} - L_{Del} \qquad \textbf{EQ 2}$$

Where:

L_{BDiv}: the load diverted from the Boise River

L_{Tribs}: load from the drains that discharges into the canal

L_{Del} : the load delivered by the Riverside Canal

Note that the load diverted from the Boise River (Load $_{Bdiv}$), which is added into the Load $_{Spilled}$ (EQ2), is the same load subtracted out of the Load $_{in\ rivers}$ (EQ1). Combining Equations 1 and 2 gives the overall equation for the change in TP load in the river downstream below the Project (QE3).

$$L_{in\ rivers} = -L_{BDiv} + (L_{BDiv} + L_{Tribs} - L_{Del}) + L_{Runoff} \qquad \textbf{EQ 3}$$

As evident, Equation 3 can be then simplified to:

$$L_{in\ rivers} = L_{Tribs} - L_{Del} + L_{Runoff} \qquad \textbf{EQ4}$$

Equation 4 is used to calculate the change in the phosphorus load in rivers (i.e., Boise and Snake) downstream of the project for a specific canal operation. As will be shown below, it is the difference between the loads delivered to irrigators for two different operations (i.e., Table 2), that represents the change in loads in the Boise and Snake Rivers after implementation of the ROWQIP.

Table 2. Modeled Operations used to calculate phosphorus reductions for ROWQIP

Operations	Descriptions of Operations
BL	Model represents conditions prior to automation of the canal; Boise River diversion is based on adjudicated water rights (i.e., 272 cfs)
WQ	Model represents conditions after ROWQIP implementation; Boise River diversion is minimized, which reduce canal spills back to Boise and Snake Rivers, and increases delivery of phosphorus to irrigators

The equation for TP load reduction *($L\ Reduction_{in\ rivers}$)* after water quality improvements is the difference between load in the rivers (EQ4) for Baseline (BL) and Water Quality (WQ) operations:

$$L\ Reduction_{in\ rivers} = (L_{Tribs} - L_{Del} + L_{Runoff})_{BL} - (L_{Tribs} - L_{Del} + L_{Runoff})_{WQ} \qquad EQ5$$

Noting that the "tributary inflow load" would be the same for both operations, Equation 5 can be simplified by subtracting the $Load_{Tribs}$ out of each of the scenarios.

$$L\ Reduction_{in\ rivers} = (L_{Del} + L_{Runoff})_{WQ} - (L_{Del} + L_{Runoff})_{BL} \qquad EQ6$$

Agricultural Runoff

Additionally, in the Riverside Canal (RC) Model, as presented below, the surface runoff and subsurface seepage load from the farm land *($Load_{Runoff}$)* is assumed to remain unchanged (Attachment B), and is subtracted out of the rights side of Equation 6. This assumption is considered to be conservative (which implies runoff quality should actually improve and runoff quantity should decrease) given the following.

1. Research shows that typically more than 90% of phosphorus runoff from "clean-tilled row-crop" fields is in particulate form (i.e., erosion of soil). (Bjorneberg, et al., 2006, Westermann et al., 2001).
2. Research shows that soils typically have the capacity to retain a large percentage of the phosphorus applied (or delivered by source water).
3. The change in water quality anticipated for the canal is relatively small (i.e. increase of 0.13 mg/L in canal), and represents about only 3% of the phosphorus needed to produce crops.
4. On-farm water quality management has increased over last 10 years, and includes nutrient management and improved runoff control.

Simplified Load Reduction Equation

After these simplifications, the resulting equation (EQ7) shows that the estimated change in phosphorus load in the river can be calculated as the difference between the loads delivered to the agricultural area:

$$L\ Reduction_{in\ rivers} = (L_{Del})_{WQ} - (L_{Del})_{BL} \qquad EQ7$$

It should be noted that while the change in load could be calculated using the Boise River diversions and canal spills for each operation, the delivery is used in Equation 7 because it reduces uncertainty by mainly relying on inflow loads (measured flows and concentrations) to estimate the load delivered to irrigators and determine the overall ROWQIP load reduction. Additionally, because the delivery rate is the same for both operations, it is only the difference in the modeled delivery concentrations that produce the anticipated load reductions.

Canal Operations

As shown in Equation 7, the difference between the load delivered for the WQ and BL operations is equal to the reduction in phosphorus load in the Boise and Snake Rivers downstream of the ROWQIP. Additional details on the two canal operations used to calculate the load reduction are provided below.

Water Quality Operations

The ROWQIP includes phased implementation of an automated canal control system designed and constructed to allow for automated control of diversion and spill gates, and real-time flow-rate monitoring of the canal flows, tributary inflows, and spills (Harrison et al., 2013). Prior to implementation of the SCADA system in 2014 (referred to as Pre-Implementation), the WQ operations are modeled to represent the use of the SCADA system throughout the canal (i.e., upper, mid and lower). After completion of installation and startup (i.e., setup of cellular communications equipment and a centralized server), the Riverside Canal will be controlled by the supervisory control and data acquisition (SCADA) system. And, after the SCADA system is operational in 2014 (referred to as Post-Implementation), data collected during the irrigated season will be used to model the WQ operations.

When the SCADA system is in place and operational, Riverside Irrigation District can prioritize use of flows into their canal (i.e., low quality drainage water) and limit the amount of canal discharge (i.e., spill) that flows unused to the Boise and Snake Rivers. This canal-operations focused on water quality improvement will be modeled to represent canal flow and water quality with SCADA-controlled operations along the entire canal. The model setup is designed such that load reductions from WQ operations will be comparable to the load reductions modeling of the BL operations.

The Post-Implementation WQ operations (and Pre-Implementation WQ modeling assumptions) are based on the following operational objectives:

1. Limit Boise River diversion (Rc0_1) to
    a. "As low as possible" when tributary inflows (e.g., Rc1_8 and Rc8_1) are **less than** RID demand (Rc9_1);
    b. "Near zero" when tributary inflows are **greater than** RID demand (Rc9_1).
2. Limit Indian Creek spills (Rc2_0) to zero whenever possible.

3. Limit Dixie spills (Rc9_0) to as “low as possible”.
4. Reduce lower canal spills (i.e., Rc18_6, Rc21_7 and Rc30_9) to “as low as possible”.

Baseline Operations

As shown by Equation 7, defining BL operations is necessary to determine the amount of phosphorus load reduction resulting from the ROWQIP. While tributary inflows will be measured, the Boise River diversion rate for BL operations is set as a constant, which is then used to determine the difference between BL and WQ operations flows and loads once WQ operations are implemented. Thus, definition of the baseline Boise River diversion is a critical parameter because it determines the flow along the canal which will then be used to determine phosphorus loads for the BL operations.

The ROWQIP is specifically designed to modify canal operations in a way that reduces phosphorus loading to the Snake and Boise rivers. However, the program does not include any actions to modify or redefine Riverside’s overall irrigation requirements or the volume of water diverted as currently specified by adjudicated water rights. The RID water rights authorize irrigation of 10,158 acres within a District boundary. According to Idaho Department of Water Resources records (IDWR 2013), the Boise River is the primary source of water for the Riverside Canal with water rights totaling 271.48 cubic feet per second (cfs) as decreed in the Snake River Basin Adjudication (Attachment A). In addition to these water rights, RID is authorized to deliver water to Pioneer Dixie, and Cheney, totaling about 70 cfs, for a total potential Boise River diversion of 341.48 cfs.

At a minimum, it is appropriate that the baseline relative to water diverted from the Boise River be Riverside’s legally established water rights, which total to 271.5 cfs (IDWR 2013). Under Idaho law the adjudication of these rights constitutes a judicial determination that the decreed amount of water was put to use and that the users have the right to continue to put those decreed rates to use. While actual diversion may vary among years and specific times within a given year from the water-right diversion rate, it is the rate allowed under law and therefore the most logical and legally defensible flow estimate for use in baseline calculations. Furthermore, Riverside’s Boise River diversion is located within a reach of the Boise River where flow is generally adequate for full diversion under Riverside’s priority dates even during drought years (such as 2013).

Additionally, baseline flows for the Lower Canal spills (i.e., Rc18_6, Rc21_7 and Rc30_9) are needed to calculate the RID water delivery. For the baseline condition, the last three years (2011-2013) of spill data are used (Attachment C). This is considered conservative because these spills were automated for local control in 2010 (Harrison, et.al., 2013), and were likely higher under manual control prior to 2010.

Riverside Canal Model

The simplified equation (EQ7) as derived above shows that the change in phosphorus load between two operational scenarios is determined by the difference in “loads delivered” to an agricultural area. It is evident that the Riverside Canal (Figures 1 and 2) is much more complicated than the conceptual model (Figure 3). Using the conceptual model as the framework, the Riverside Canal (RC) Model was developed to calculate daily phosphorus loads for the operations and to calculate the projected load reduction for the ROWQIP.

The main steps in the RC Model used in calculating the change in phosphorus loads in the rivers downstream of the project are:

1. Calculate daily canal and spill flows (using a flow balance approach) for each of the flow control point where measurements are not collected (e.g., diversions and canal locations).
2. Calculate concentrations for each delivery and canal flow control point using measured phosphorus inflow concentrations and a mass balance equation (i.e., phosphorus load balance)
3. Sum the deliveries to the irrigated areas to estimate the total load delivered

For a given day, the phosphorus load reduction provided by the project is then calculated as the difference between the deliveries for the WQ and BL operations. Because the delivery flows are the same for both operations, the difference in load delivered to the irrigators is determined by the modeled water quality.

To introduce the RC Model, the model structure is presented first, followed by discussion of some of the measured and calculated flows used in the model. Then more detailed discussion of the Post-Implementation model is provided using average flow data collected for a single day (August 11) during automation system testing for the 2013 irrigations season. Finally, Pre-Implementation model results are given for 2011-2013 irrigation seasons.

Model Structure

The RC Model diagram (Figure 4) shows the flow control points for diversions, tributaries, spills, and deliveries along the Riverside Canal from upstream to downstream. Also shown are the automatically controlled diversion and spill gates, along with the cell links used to communicate real time data for the canal, which were installed during Phase 2 of the canal automation (Harrison et al., 2013).

The RC Model diagram (Figure 4) does not show (and the model does not included) the smaller tributaries shown in Figure 2 that enter the lower reach of the canal (i.e., below Rc9_1). These relatively small tributaries are not included in the model at this time because of the complexity added by multiple diversions along the lower canal, but will be added to the model as a more detailed understanding of lower canal operations becomes available and additional water control and automation are added.

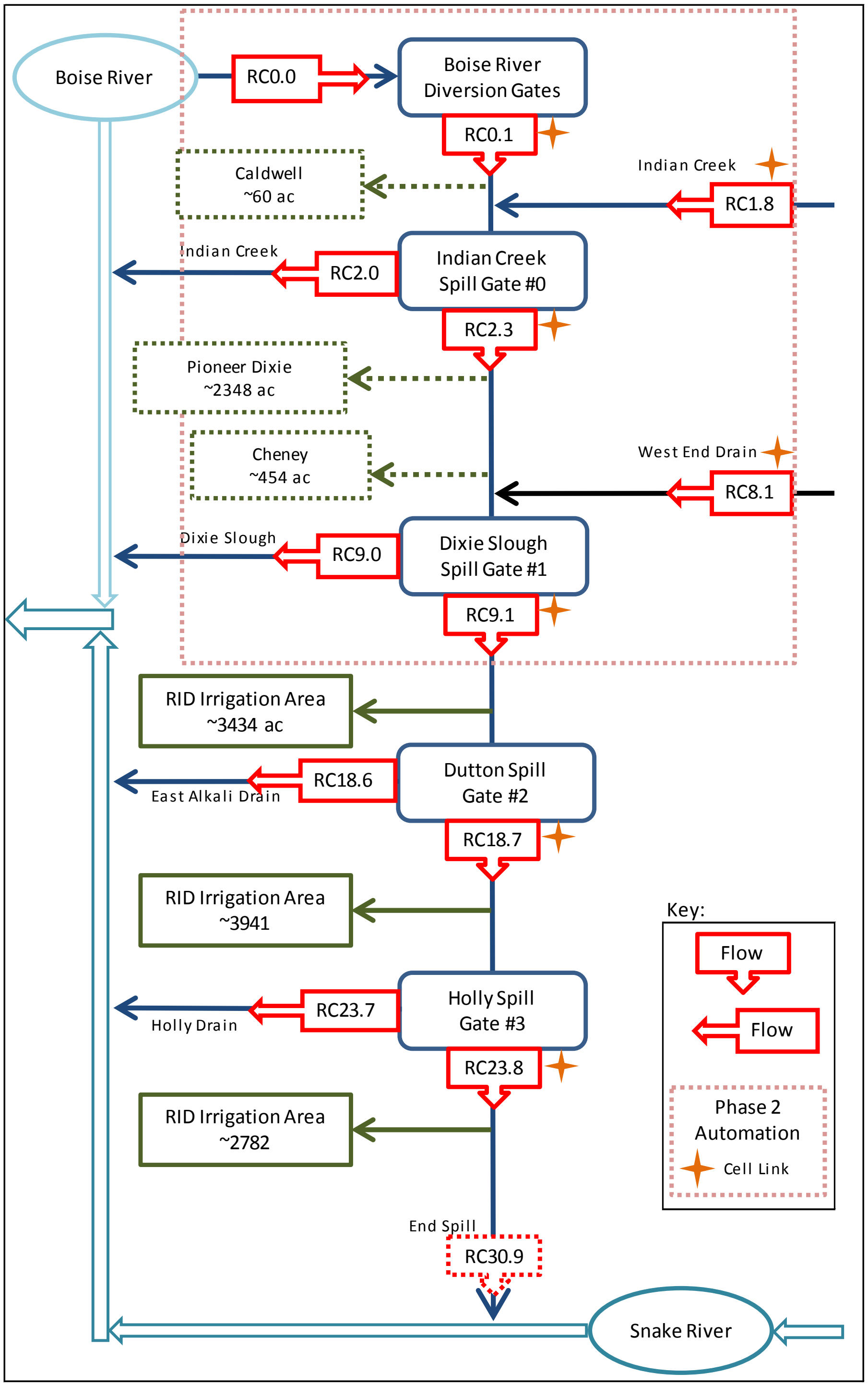


Figure 4. Automatically controlled diversion and spill gates, and flow control points in Riverside Canal Model; also shown is Phase 2 Automation with cellular links used to communicate real time data.

Flow Balance

A flow balance is used to calculate flows at control points along the 31-mile canal (Figure 4). This is a relative simple and often used modeling approach for calculating the change in flow along a river or stream. A detailed description of the general procedures can be found in Etheridge (2013) that presents a water (and phosphorus mass) balance model of the Boise River.

The flow balance model used for the Riverside Canal assumes (1) no losses related to evaporation and seepage; and (2) ignores minor inflow (i.e., relatively small agricultural drains from single or multiple fields); and (3) an instantaneous response to changes in flow along the entire canal. The flow data and calculations that are used for the water balance vary depending on the canal operations modeled (Table 2).

The key flow input and calculations are RID demand, total delivery, and Boise River diversion. The RID delivery, which is the larger fraction of total delivery, varies throughout the season and is estimated using the measured RID demand at Rc9_1 (Figure 4). Currently the RID demand is manually adjusted by the RID Superintendent to meet the anticipated irrigation demand (i.e., gates located below the Dixie spill are opened and closed). Under automated WQ operations, the RID Superintendent will adjust flows in the canal by changing the Rc9_1 control point settings in the RcMaster controller, and the controller will automatically adjust gate openings. Because of their importance relative to modeling the canal water quality under the differing operations, these two flow quantities (i.e., delivery and demand) and the Boise River Diversion are discussed further below.

RID Demand

The RID Demand flow is set and adjusted as needed by the RID Superintendent. It is typically based on the previous day's delivery and anticipated changes based on available producer information, crop conditions and weather. Unlike delivery, the source of data for the demand flow will vary for operations modeled.

Delivery

The primary purpose of the canal has and will continue to be delivery of water to irrigators, primarily farmers within the RID. The model is used to calculate deliveries for each agricultural area (Figure 4), which are then summed to determine total delivery. Recall, the difference between the total delivery for the WQ operations and BL operations is the phosphorus load reduction. And, while the delivery flows are the same for both operations, the phosphorus concentration of the delivered water is higher for WQ operations, and thus the load is higher for WQ operations.

Upper and MID Delivery. The flow delivered to irrigated land in the Upper and Mid Canal segments is calculated as the sum of deliveries to Caldwell, Pioneer-Dixie and Cheney (i.e., Rc1_6, Rc3_2, and Rc6_3, respectively). These deliveries are currently modeled as "settings" based on measured data. Because these flows are not available "real time" via cellular links, average values will be used for operations modeling during the irrigation season. After the end of the irrigation season when available data has be processed, values can be revised to reflect measured data.

RID Delivery. As discussed above, the RID Demand is set by the RID Superintendent on a daily basis, and then water in the canal in excess for the needed water actually delivered to irrigators is spilled. Thus, the flow delivered to RID agricultural area is equal to the measured RID Demand (Rc9_1) minus the Lower Spills (i.e., sum of Rc18_8, Rc23_8 and Rc30_9).

Total Delivery. The total delivery is the sum of the Upper Delivery and RID Delivery.

Boise River Diversion (Rc0_0)

A primary WQ operational objective is to minimize diversions from the Boise River. As discussed below, the diversion rate is back-calculated for Pre-Implementation modeling, and measured for Post-Implementation modeling. For BL operations modeling, the Boise River diversion is set at 272 cfs, which is based on Riverside's adjudicated water rights.

Mass Balance

Once the flows are calculated, the concentrations and loads are calculated. In general this is a step wise process, working from top to bottom of the canal. The model relies on total phosphorus concentrations measured for the primary inflows, which are the Boise River, Indian Creek and West End Drain. For most of the other flow control points (i.e., canal, diversion and spills) the concentrations are calculated using a mass balance approach similar to that explained in Etheridge (2013).

Post-Implementation Load Reduction Modeling

When the SCADA system is operational (referred to as Post-Implementation), data collected during the irrigated season will be used to model the operations. The Post-Implementation modeling is explained using data collected during the 2013 irrigation season when the automation system was tested to assess general performance. Water quality data used to model both operations is the laboratory reported total phosphorus concentrations collected at sampling locations for the Boise River Diversion, Indian Creek and West End Drain. The flow data are discussed in detail below.

Modeled Flows

The Post-Implementation Model calculates flow from upstream to downstream using measured data for the Boise River Diversion and tributary drain inflows. The SCADA system master controller and data logger (RcMaster) continuously polls and collects data from local data loggers based on a user defined interval (default 15 min) (Harrison et al., 2013). The logger stores all collected flow data in a table every 15 minutes. All other operations control variables are polled and stored once daily.

Historical data collected at measured control points (Table 3) were used to monitor and model canal flows. When implementation of the SCADA system is complete, these data will be used to operate canal gates. At this time (and after implementation), the flow data for a given year is compiled, preprocessed (e.g. missing data interpolated and daily averages calculated), and then used to model operations and determine load reductions.

Table 3. Measured (Meas), modeled (Calc), historical (Hist) and average (Avg) and settings (i.e., numbers shown) for canal flow control points for WQ and BL operations.

RC mile	11-Aug-13	WQ (cfs)	BL (cfs)
	Upper Canal		
0.1	Boise R. Diversion	Meas	271
1.6	Caldwell Delivery	5	5
1.8	Indian CK	Meas	Meas
2.0	Indian Ck Spill	0	Calc
2.3	Rated Section	Meas	Calc
	Mid Canal		
3.2	Pioneer Dixie Delivery	25	25
6.3	Cheney Delivery	10	10
8.1	West End Drain	Meas	Meas
8.7	Dixie Gulch	15	15
9.0	Dixie Spill	20	20
9.1	RID Demand	Meas	Calc
	Lower Canal		
18.6	Dutton Spill	Meas	Hist
23.7	Holly Spill	Meas	Hist
31.1	End Spill	Meas	Avg

The control points that are not measured continuously are either calculated using a flow balance for the canal (e.g., inflow minus outflow equals change in flow) or estimated based on the seasonal averages. For example, the relatively minor deliveries to Upper Canal irrigated areas are currently estimated and set based on available data and information. And, for modeling operations, some of settings that are based on seasonal averages do not vary.

The RID Demand flow for the WQ operations is measured at the canal head gates below Spill Gate #1 (Rc9_1). For BL operations, the RID Demand flow is adjusted for "Baseline" spills in the Lower Canal that are established based on historical data (Attachment C). This adjusts the measured RID Demand on a given day for the "reduced" spills that occur at Rc18_7, Rc23_8 and Rc31.1 due to water quality operations of lower canal spill gates (Figure 4). This demand flow will then be used to back-calculate flows at the Riverside Gage (Rc2_3), and subsequently at the Boise River diversion (Rc0_0).

Delivery does not change between operations, and is calculated using measured RID Demand and Lower Canal Spills (Rc18_6, Rc23_7 and Rc30_9).

Diversions from the Boise River will be minimized under future WQ operations. For this Post-Implementation modeling, the Diversion for WQ operations is equal to flow measured downstream of gate (RC0_1). For BL operations, the Diversion is set equal to water rights (i.e., Rc0_0 = 271 cfs).

Example of Post-Implementation RC Model for Operations

During the 2013 irrigation season, the automation system was tested to assess overall performance. As an example of the Post-Implementation modeling, one test day during the 2013 season (August 11) was selected to shows how the load reduction is modeled when the canal automation system is operable (Tables 4a and 4b). In this example, the flow at the Indian Creek spill was set to 0 based on observed flow. Also the flow calculations shows how measured canal flows compare to calculated flows. This is evident for the WQ operations (Table 4a) by comparing the canal flows “calculated” upstream of Rc2_3 and Rc9_1.

Once the flows have been calculated, the concentrations and loads are calculated. As previously stated, this is a step wise process, working from top to bottom of the canal, and is the same for both operations. In general, the model relies on total phosphorus concentrations measured for the primary inflows, which are the Boise River, Indian Creek and West End Drain. Note that Dixie Gulch is also included as an inflow to the model. This flow is an average based on available data, and the water quality is assumed to equal the water quality of the West End Drain, which is located nearby.

Table 4a. Example Post-Implementation Water Quality Model with input data for one day during August 2013 automation testing.

WQ	**11-Aug-13**	Flow (cfs)				Conc (mg/L)		Load (lb/d)			
RC mile		IN	Canal	Spill	Deliv.	Meas.	Calc	IN	Canal	Spill	Deliv.
	Upper Canal										
0.1	Boise R. Diversion	136	136			0.26	0.26	192	192		
1.6	Caldwell Res. Deliv.		131		5		0.26		185		7
1.8	Indian CK	97	227			1.10	0.62	571	756		
2.0	Indian Ck Spill		227	0			0.62		756	0	
2.3	Rated Section		217				0.65		756		
	Mid Canal										
3.2	Pioneer Dixie Deliv.		192		25		0.65		669		87
6.3	Chaney Deliv.		182		10		0.65		634		35
8.1	West End Drain	106	289			0.29	0.52	166	800		
8.7	Dixie Gulch	15	304			0.29	0.50	23	824		
9.0	Dixie Spill		272	31			0.50		739	85	
9.1	RID Demand		283				0.50		769		
	Lower Canal										
18.6	Dutton Spill			21			0.50			56	
23.7	Holly Spill			21			0.50			58	
31.1	End Spill			28			0.50			76	
	Totals										
	Upper/Mid subtotals	354		31	40			952		85	129
	Lower subtotals	0		70	213			0		190	578
	Totals	**354**		**101**	**253**			**952**		**275**	**707**

Note: Red numbers are measured or historical data

Table 4b. Example Post-Implementation Baseline Model with input data for one day during August 2013 automation testing.

BL13	**11-Aug-13**	Flow (cfs)				Conc (mg/L)		Load (lb/d)			
RC mile		IN	Canal	Spill	Deliv.	Meas.	Calc	IN	Canal	Spill	Deliv.
	Upper Canal										
0.1	Boise R. Diversion	271	271			0.26	0.26	383	383		
1.6	Caldwell Res. Deliv.		266		5		0.26		376		7
1.8	Indian CK	97	363			1.10	0.49	571	947		
2.0	Indian Ck Spill		280	83			0.49		731	216	
2.3	Rated Section		280				0.49		731		
	Mid Canal										
3.2	Pioneer Dixie Deliv.		255		25		0.49		666		65
6.3	Chaney Deliv.		245		10		0.49		640		26
8.1	West End Drain	106	351			0.29	0.43	166	806		
8.7	Dixie Gulch	15	366			0.29	0.42	23	829		
9.0	Dixie Spill		306	60			0.42		693	136	
9.1	RID Demand		306				0.42		693		
	Lower Canal										
18.6	Dutton Spill			36			0.42			82	
23.7	Holly Spill			29			0.42			65	
31.1	End Spill			28			0.42			63	
	Totals										
	Upper/Mid subtotals	489		143	40			1144		352	98
	Lower subtotals	0		93	213			0		211	482
	Totals	**489**		**236**	**253**			**1144**		**563**	**581**

Note: Red numbers are measured or historical data

Example of Post-Implementation RC Model Load Reduction

The modeled daily average total phosphorus loads delivered to irrigation on August 11, 2013 for each of the canal operations are shown in Tables 4a and 4b. Phosphorus load reduction for the day was calculated as the difference between WQ and BL operations (Table 5). This load reduction represents the calculated average change in daily phosphorus load in the Boise and Snake Rivers (e.g., Figure 3) that occurred under full implementation of the ROWQIP over a 183-day irrigation season.

Table 5. Modeled delivery and load reduction (lb P/day) for August 11, 2013, based on flow and water quality data collected during 2013 automation system testing.

Delivery	Up/Mid	Lower	Total
WQ (lb/d)	129	578	707
BL (lb/d)	98	482	581
Reduction (lb/d)	30	96	126

Pre-Implementation (Potential) Load Reductions

Canal automation began in 2010 and is proceeding in a phased approach to ensure full delivery of water to RID irrigators (Harrison et al., 2013). During this implementation and testing period, flow and water quality data were collected to monitor conditions at that time. These data were also used to model potential canal water quality improvements. The Pre-Implementation modeling is intended to represent operational objectives including limiting the Boise River diversion (RC0_1) to:

a. "As low as possible" when tributary inflows (e.g., RC1_8 and RC8_1) are **less than** RID demand (RC9_1; measured below Dixie Spill); And, keep spills at Dixie Spill (RC9_0) as low as possible.

b. "Near zero" when tributary inflows (e.g., RC1_8 and RC8_1) are **greater than** RID demand (RC9_1; measured below Dixie Spill).

The methodology, data and settings used to calculate the potential load reductions for the water quality operations are presented below. In addition to providing details on the flow balance calculations, the measured total phosphorus data used in the model (collected in 2011, 2012 and 2013) are provided for the three primary canal inflows (i.e., Boise River, Indian Creek and West End Drain). This is followed by a series of graphs showing the daily loads delivered for the WQ and BL operations and the daily phosphorus load reductions.

Pre-Implementation Flow Calculations

Flow and water quality data collected at flow control points (Table 6 "Meas") beginning in 2011 were used to characterize existing flow and water quality. When implementation of the SCADA system is complete, the measured data will be used to operate canal gates. For determination of load reductions, the flow data for a given year is compiled, preprocessed (e.g. missing data interpolated and daily averages calculated) and then used to model operations and calculation load reductions.

Table 6. Measured (Meas), modeled (Calc), and settings for canal flow control points for Pre-Implementation operations modeling.

RC Mile	Description	BL (cfs)	WQ (cfs)
	Upper Canal		
0.1	Inflow to Riverside Canal from BR	271	Calc
1.6	Delivery to Caldwell Residential area (est.)	5	5
1.8	Inflow from Indian Creek at Caldwell	Meas	Meas
2.0	Spill #0 to Indian Creek	Calc	0 (min)
2.3	Flow in canal at Riverside Gage	Calc	Calc
3.2	Delivery to Pioneer Dixie (est.)	25	25
6.3	Delivery to Cheney (est.)	10	10
8.1	Inflow from West End Drain	Meas	Meas
8.7	Inflow from Dixie Gulch (est.)	15	15
9.0	Spill #1 to Dixie Slough	20	20 (min)
9.1	Flow in canal below SG#1	Meas	Calc
	Lower Canal		
18.6	Spill #2 (Dutton)	Meas	20
23.7	Spill #3 (Holly)	Meas	20
31.1	Canal End Spill	Meas	20

The control points not measured are either set based on the operations modeled, average of data, or calculated using a flow balance for the canal (inflow equals outflow). As shown in Table 6, the relatively minor deliveries to Upper Canal agricultural areas are currently estimated and set based on available data and information. Note that for modeling, these settings generally do not vary during the irrigation season.

The Pre-Implementation WQ operations modeling is intended to represent the full automation throughout the canal (i.e., upper, mid and lower segments) and includes the operational objective as previously discussed for the Water Quality operations. The modeled delivery flows are the same for WQ and BL operations. However, diversions and demand flow inputs vary for each of the operations.

As shown in Table 6, RID Demand flow for BL operations is measured at the canal head gates below Spill Gate #1 (Rc9_1). For the BL operations the flow diverted from the Boise River is set based on water rights. Flows at other control points are either set or calculated using a water balance.

Under WQ operations the RID Demand flow is calculated by subtracting the "change" in the "Lower Spills" from the flow measured at Rc9_1. This adjusts the measured RID Demand on a given day for an assumed reduction in spills at Rc18_7, Rc23_8 and Rc31.1 (Table 6). This demand flow is then used to back-calculate flows at the Riverside Gage (Rc2_3), and subsequently at the Boise River diversion (Rc0_0). For example, the general equation to back-calculate the Diversion is:

$$\text{Boise River Diversion (Rc0\_0)} = \text{RID Demand (Rc9\_1)} + \sum \text{Spills} + \sum \text{Deliveries} - \sum \text{Inflows}$$

(note that sums are for upper and mid reach only)

Measured Water Quality Data for 2011, 2012 and 2013

As discussed above, a mass balance approach is used to calculate total phosphorus loads for years 2011 to 2013. To calculate the loads in the canal on a given day, total phosphorus concentration data measured at the three primary inflows are used (Table 7). These data were collected over the last three years as part of a Riverside Canal monitoring program (Harrison and King 2013).

To calculated concentrations in the canal and at spills, the model works from upstream to downstream along the canal. First, loads are calculated by adding inflows or subtracting outflows. When there is an inflow to the canal, the measured and/or modeled flows under various canal operations are used in the mass balance equation to calculate a load at that canal control. The measured total phosphorus data used for the inflows are for the Boise River, Indian Creek and West End Drain (Table 7). For most of the other flow control points (i.e., canal, diversion and spills) the concentrations are calculated using a mass balance approach as previously discussed.

Table 7. Water Quality data (Total P) collected for primary canal inflows of Boise River (Rc0_0), Indian Creek (Rc1_8) and West End Drain (Rc8_1) during 2011, 2012 and 2013

Date	**Locations**		
	Rc0_1	**Rc1_8**	**Rc8_1**
Year 2011			
4/19/2011	0.055	0.694	0.243
5/19/2011	0.070	0.623	0.275
7/8/2011	0.144	0.583	0.563
7/28/2011	0.260	0.790	0.616
8/17/2011	0.283	0.782	0.282
9/8/2011	0.251	0.605	0.285
10/6/2011	0.292	0.672	0.199
Year 2012			
5/8/2012	0.073	0.484	0.236
6/14/2012	0.195	0.885	0.430
7/11/2012	0.274	0.733	0.496
8/7/2012	0.256	0.956	0.562
9/17/2012	0.208	0.544	0.291
Year 2013			
4/2/2013	0.385	0.626	0.191
4/24/2013	0.265	1.080	0.351
5/3/2013	.304	0.921	0.351
5/22/2013	0.222	1.720	0.399
6/6/2013	0.244	0.710	0.419
6/19/2013	0.284	1.140	0.548
7/11/2013	0.309	0.774	0.392

Date	Locations		
	Rc0_1	Rc1_8	Rc8_1
7/24/2013	0.306	0.976	0.431
8/7/2013	0.260	1.070	0.275
8/21/2013	0.270	1.160	0.331
8/28/2013	0.252	0.966	0.263
9/24/2013	0.183	0.800	0.165

Modeled 2013 Canal Loads and Reductions

In 2013, the Riverside Canal master controller and data logger (RcMaster) continuously polled and collected data from local data loggers based on a user defined interval (default 15 min) (Harrison et al., 2013). The logger stores all collected flow data in a table every 15 minutes. At sites without communication to the Riverside Canal master controller, flow data were collected during water quality sampling or with a logger used to record water levels (Harrison and King 2013).

In 2013, daily total phosphorus loads delivered to RID irrigators for two operations were modeled using 2013 daily average flow and interpolated water quality data. The 2013 daily loads for the two canal operations (Table 2) are presented below (Figure5). Also shown is the Total Phosphorus (TP) Load Reduction calculated as the difference between WQ and BL Operations. This curve represents the daily load reduction in the Boise and Snake Rivers for the irrigation season.

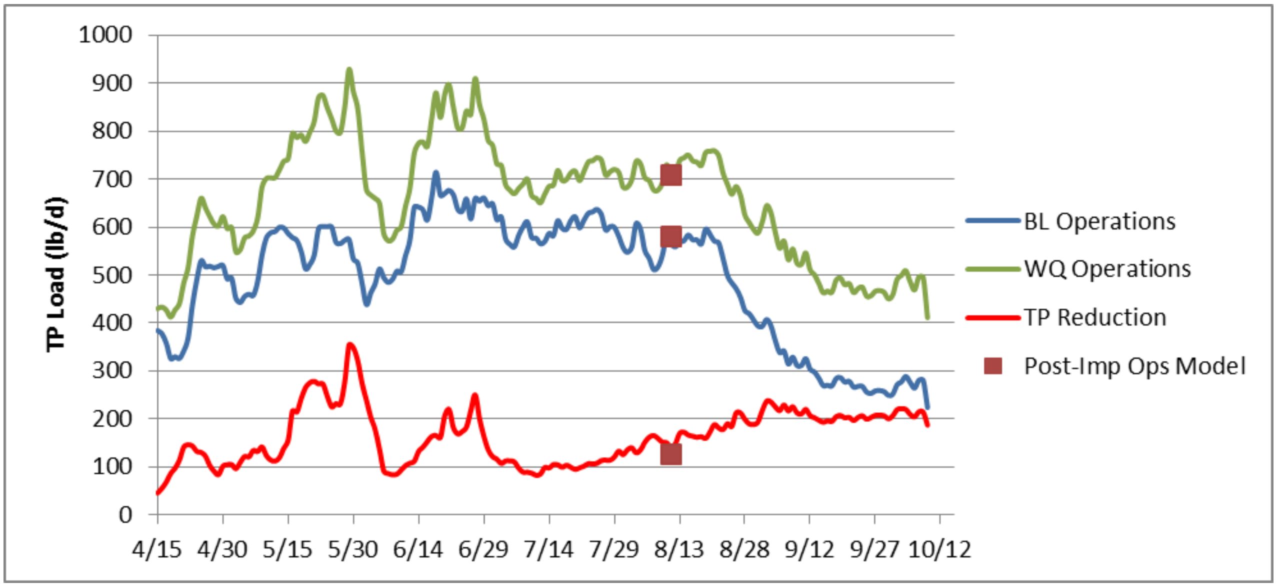


Figure 5. Modeled 2013 daily TP delivery loads and TP load reductions (WQ-WR). Note that loads are modeled daily using daily average flow and interpolated concentrations. Also shown are loads for Post-Implementation modeling.

Under WQ operations the RID Demand flow is calculated by subtracting the “change” in the “Lower Spills” from the flow measured at Rc9_1. This adjusts the measured RID Demand on a given day for an assumed reduction in spills at Rc18_7, Rc23_8 and Rc31.1 (Table 6). This adjustment in demand (based projected reductions in the lower canal spill) counters the potentially adverse effects of spilling canal water with higher TP concentrations and results in slightly higher modeled TP loads reductions. Additionally, because spills will be lower, the loads from relatively minor inflowing tributaries in the lower reach (Figure 2) will also be reduced. While these potential load reductions were not included in the model due to the additional complexity, they may be added in the future as more information on the lower canal system is collected.

In 2013, the automation was tested in the upper reach of the canal (i.e., above Rc9_1) to assess benefits from minimizing Boise River (BR) diversions and thereby maximizing use of lower quality drain water from Indian Creek and West End Drain. The test results collected in July were used to shows how the Post-Implementation loads reductions are modeled (Figures 4a and 4b, and Figure 5 – Post-Imp Ops Model). The Post-Op modeled WQ operations represents additional implementation of SCADA controlled operations along the entire canal (i.e., beyond the level of operations tested in the upper and mid reaches of the canal). These results indicate that the “potential” load reductions modeled using the Pre-Imp Ops Model (Figure 5 – TP Reduction), which are consistent with both Post-Ops model results and the measured data, provide an accurate estimate of phosphorus load reductions.

Modeled 2012 and 2011 Canal Loads and Reductions

During the 2012 and 2011 irrigation seasons, which was prior to continuous flow data collection for many of the key locations, the flow and concentration data were collected on sampling days only. The RC Modeled delivery loads for operations were calculated for each of the five sampling dates using the same methods as discussed for the 2013 data (Figures 6 and 7). The average calculated load reduction for the five days was in a similar range as for the 2013 season when continuous flow data were available.

Figure 6. Modeled 2012 delivery loads for 2 operations and potential TP Reductions (WQ-BL). (note that dates modeled are shown with markers)

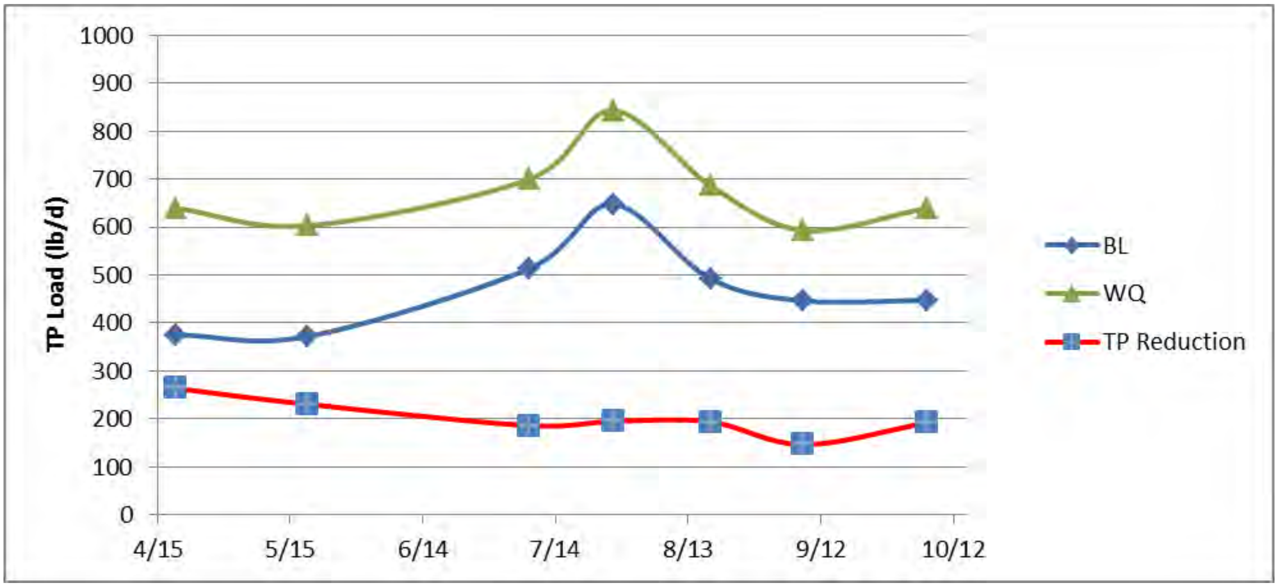


Figure 7. Modeled 2011 delivery loads for 2 operations and potential TP Reductions (WQ-BL). Note that dates modeled are shown with markers.

Potential Cumulative Load Reductions for 2011, 2012, and 2013

Phosphorus load reductions (Table 8) were calculated as the difference between WQ and BL operations. These potential load reductions represent the change in phosphorus load in the Boise and Snake Rivers (e.g., Figure 3) that could occur under full implementation of the ROWQIP over a 183-day irrigation season.

Table 8. ROWQIP modeled load reductions for 2011 to 2013 based on 183-day irrigation season.

Model	**Phosphorus Load Reductions (lb-P/yr)**		
Year	Upper/Mid	RID	Total
2013	8755	21343	30098
2012	10256	23454	33711
2011	9180	27647	36827
Average	9397	24148	33545

RC Model Limitations

The RC Model calculates flows, concentrations and loads over the 31 miles of the Riverside canal. As with any model intended to represent a complex system, the model results are expected to vary from actual conditions. To provide an indication of the level of error, graphs showing difference between modeled and measured flows, concentrations and loads are provided in Appendix D. The differences, generally referred to as model error, are due to the necessary simplifying assumptions, processes not included in the mass balance model, and measurement error.

Simplifying assumptions include:

- Canal is fully mixed at all locations.
- Minor inflows and loads are not included in model because data are not generally available.

Processes not included in the model simplified flow and mass balance model:

- Canal water loss processes such as seepage and evaporation and uptake by canal vegetation.
- Canal flow dynamics such as the delayed response in spill gate adjustments as the upstream diversion gate is adjusted.
- Water quality related process such as sedimentation and phosphorus uptake by periphyton, macrophytes, and canal vegetation.

Measurement error includes:

- Flow measurement error due in part to the difficulties in measuring flow changes in rated sections with seasonal changes in vegetation and sediment.
- Unmeasured inflows and loads.
- Water quality data collected on instantaneous basis do not capture short-term variability.

Verification

The project will be implemented consistent with quality standards and guidelines outlined by The Freshwater Trust (2014). Verification will include detailed review of the monitoring and annual reports, along with regularly scheduled site visits for visual inspection of flow and control systems, and observation during water quality sampling. The annual reports will include the results from the Post-Implementation RC model applied with validated measured daily average flows (where available) and interpolated water quality data after appropriate quality control (QC; i.e., graphs similar to Figure 5). Additionally, results from the “single-day spreadsheet” RC model (Figure 4a and 4b), which will be used during the irrigation season to validate preliminary results produced by the RC model in real time, will also be provided for review.

Conclusions

The methods used to calculate the ROWQIP load reductions rely on the studies and analyses collected over three years (i.e., 2011 to 2013). As part of the analyses, a model of the Riverside Canal was developed and used to calculate the phosphorus load reduction capacity of the ROWQIP. The modeling results show that when the ROWQIP is fully implemented the phosphorus load reduction can exceed 30,000 lb/year. This load reduction represents phosphorus from upstream sources that is applied to RID and other farm land via the Riverside Canal, and is thereby removed from the Snake River. The modeled load reductions occurring over the 183-day irrigation season for each of the three years exceeds the equivalent phosphorus load reduction of 15,000 lb/yr, which is comparable to the SR-HC TMDL dissolved oxygen allocation. This supporting information provides details of the project and the load reduction calculation methods needed to support 401 Certification. And, after implementation, the methods can be used to ensure the project performance is transparent, reliable, and verifiable.

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Attachments

Attachment A – Water Rights

Riverside Irrigation District

The Boise River is the primary source of water for the Riverside Canal with water rights totaling 271.48 cubic feet per second (cfs) as decreed in the Snake River Basin Adjudication. The District also has decreed water rights to Indian Creek water totaling 178.4 cfs, and decreed rights to 113.16 cfs from various other sources that carry drainage from lands within the Boise Project (i.e., Arena Lake Drain, Meadows Gulch Drain, Mammen Gulch Creek and West End Drain). Also, beneficial use claim no. 63-33252 for 6.0 cfs from East Arena Drain is pending recommendation by Idaho Department of Water Resources (IDWR) and subsequent partial decree. All rights combined yield a total of 569.04 cfs, with priority dates ranging from June 1, 1884 to October 18, 1924. Table A-1 (below) is a current list of Riverside's irrigation water rights.

Table A-1. Riverside Water Rights (Water use is Irrigation).

Water Right Number	Status	Priority Date	Source	Diversion Rate (cfs)	Volume Limit (AFA)
63-226	Decreed (SRBA)	6/1/1884	Boise River	20	none
63-227	Decreed (SRBA)	5/1/1893	Boise River	80	none
63-228	Decreed (SRBA)	10/1/1899	Boise River	20	none
63-229	Decreed (SRBA)	6/1/1901	Boise River	70	none
63-299	Decreed (SRBA)	4/1/1910	Boise River	63.78	none
63-300	Decreed (SRBA)	4/1/1914	Boise River	17.7	none
63-2279	Decreed (SRBA)	11/4/1915	Indian Creek	89.9	20,232
63-2374	Decreed (SRBA)	8/2/1922	Indian Creek	88.5	none
63-2389	Decreed (SRBA)	10/18/1924	Arena Lake Drain	14.56	3,271
63-4007	Decreed (SRBA)	4/15/1916	Meadows Gulch Drain	8.6	none
63-4008	Decreed (SRBA)	4/15/1916	Mammen Gulch Creek	20	none
63-4010	Decreed (SRBA)	4/15/1916	West End Drain	70	none
63-33252	Beneficial Use Claim	10/18/1924	East Arena Drain	6	none
		Totals	Boise River, decreed	271.48	
			Indian Creek, decreed	178.4	
			Other, decreed	113.16	
			Claimed	6	
			Grand Total	569.04	

The water rights above are limited to irrigation of 10,158 acres within Riverside's service area. Annual diversion volume limits (acre-feet per annum) are quantified for two water rights (63-2279 & 63-2389), but are not quantified on the remaining water rights. IDWR's standard annual diversion volume for groundwater rights in the lower Boise River area is 4.5 ac-ft/acre, which would equal 45,711 ac-ft for the 10,158 acres; however, actual diversion volumes for lands irrigated from surface water sources (such as RID) commonly exceed 4.5 acre feet per acre.

Pioneer Dixie Ditch Company

Idaho Department of Water Resources on-line water rights database identified seven active water rights in the name of Pioneer Dixie Ditch Company. As indicated in Table A-2, all seven rights have been decreed in the Snake River Basin Adjudication (SRBA).

Table A-2. Pioneer Dixie Ditch Company Water Rights (Water use is Irrigation).

Water Right Number	Status	Priority Date	Source	Maximum Diversion Rate (cfs)	Water Uses
63-137A	Decreed (SRBA)	6/1/1869	Boise River	35.1	Irrigation
63-222C	Decreed (SRBA)	6/1/1883	Boise River	0.6	Irrigation
63-222M	Decreed (SRBA)	6/1/1883	Boise River	1	Irrigation
63-222N	Decreed (SRBA)	6/1/1883	Boise River	0.7	Irrigation
63-233C	Decreed (SRBA)	10/1/1887	Boise River	1	Irrigation
63-233L	Decreed (SRBA)	10/1/1887	Boise River	1.2	Irrigation
63-374	Decreed (SRBA)	7/9/1914	Boise River	20.9	Irrigation
			Total:	60.5	

When combined, the decreed rights are limited to 60.5 cfs of Boise River water for irrigation of 2,348 acres within the service area of Pioneer Dixie Ditch Company.

W/T Land & Cattle, Inc. (Todd Cheney)

Idaho Department of Water Resources on-line water rights database identified water right 63-222J delivered through the Riverside Canal for W/T Land & Cattle, Inc. This decreed water right authorizes diversion of 8.0 cfs for irrigation of 454 acres with a priority date of June 1, 1883. The same lands are also served with up to 6.4 cfs from the West End Drain under water right 63-2070B. The diversion is generally referred to as the Cheney diversion.

Attachment B – Ag Runoff

In the initial period of implementation, the ROWQIP can reduce phosphorus levels discharged to the Boise and Snake River by over 30,000 lbs during the irrigation season. And while there may be concerns that the use of irrigation water with higher concentrations of phosphorus could cause an increase in the phosphorus in the runoff, the phosphorus required to grow the crops far exceeds the phosphorus supplied in the water.

Thus, application of irrigation water with increased levels of phosphorus to crop land is desirable and will “offset” crop fertilization requirements when included in an adaptive fertilizer management plan. This “offsetting reduction” in phosphorus is implemented by providing irrigators with information on phosphorus loads in their supply water. Adaptive fertilizer management can lead to further decreases in phosphorus runoff, not accounted for in the load reduction methods.

The following research and analysis shows that the anticipated increase in irrigation water phosphorus load resulting from the ROWQIP is well within the crop uptake capacity of Riverside Irrigation District (RID) and is not expected to increase runoff loads discharged to the Snake and Boise Rivers

Typically more than 90% of phosphorus runoff is TP

Westermann, et al., (2001) studied “Phosphorus Losses in Furrow Irrigation Runoff” and found that there was a linear relationship between total phosphorus (TP, not dissolved) and sediment concentrations in runoff. And, while the average dissolved reactive phosphorus (DRP) concentrations in runoff increased linearly as soil P concentrations increased, the average TP concentration of runoff was not related to soil phosphorus. Thus, if appears, the DRP is such a minor fraction of the TP that it is insignificant when compared to the sediment fraction of TP. This was further confirmed by Bjornberg, et al., (2006) who showed that TP concentrations related directly to sediment concentrations because typically >90% of the phosphorus in runoff from “clean-tilled row-crop” fields was particulate P (PP), emphasizing the need to control soil erosion to reduce phosphorus loss. They also showed that dissolved reactive phosphorus (DRP) concentrations tended to increase with distance down the furrow as contact time with soil and suspended sediment increased, but that there was a decrease in DRP during subsequent irrigations at a specific furrow site. They stated that their results indicated differences in flow hydraulics, suspended sediment loads, and the “non-equilibrium conditions” overshadowed the effects of soil P. The results of this research support the focus of efforts to improve irrigation return-flow water quality through reduction in sediment.

The research also shows water quality runoff from agricultural land can have sediment over 10,000 mg/L (Table B1). Based on typical TP in sediment of 0.1% (Westermann et al., 2001), this would produce TP concentrations of 10 mg/L. Bjorneberg, et al., (2002) reported on nutrient losses in surface irrigation runoff and showed that orthophosphorus (Ortho-P, equivalent to DRP) accounted for only about 3% of the total phosphorus in surface runoff.

Table B1. Reported concentrations in surface irrigation runoff (Bjorneberg et.al. 2002)

Parameter	Range	Median
Soil erosion (ton/ac)	0.25 - 79	4.4
Total P (lb/ac)	0.34-147	4.9
Ortho-P (lb/ac)	0.02-2.64	0.15

Soils typically have the capacity to retain a large amount of P

Lentz and Westermann, (2001) assessed "percolation losses" for furrow irrigated soils in southern Idaho. They found mean TP concentrations in water moving below the crop root zone at levels of 0.15 mg/L and 1.1 mg/L, at upper and lower field locations, respectively. With these concentrations, the TP losses due to subsurface seepage for the furrow irrigated fields were estimated to be less than 0.1 lb/acre/year. Again, this is a relative small fraction of the total P applied for crop production (i.e. about 0.3%).

The ROWQIP is expected to cause a decrease in subsurface seepage loss of phosphorus to the groundwater system, which ultimately discharges to drains and the river. This positive benefit is caused by:

1. The availability of nutrient data for the canal can be used to reduce fertilizer application. Previously, the fertilizer management planning did not account for the phosphorus in the water. Growers would estimate fertilizer requirement by subtracting the available soil phosphorus (rather than combined soil and water phosphorus) from the crop phosphorus requirement. Based on the example shown below (Table B2 – Example 5), this resulted in an "overloading" of about 5 lb/acre/year for Example C. Now, with the concentration in the water accounted for, this overloading will not occur, even with the higher irrigation water phosphorus loading rates.

Table B2. Examples of phosphorus fertilizer application rates in lb/ac

Example	**A**	**B**	**C**
Crop P required	30	30	30
soil P available	10	10	10
Water P available	0	3	5
Fertilizer Needed	**20**	**17**	**15**

2. The application of the irrigation-water portion of the fertilizer requirement on a more continuous basis can reduce leaching because the phosphorus will be applied at an even rate over the entire growing season when corps require nutrients instead of during "event" based applications (UI Extension 2014).

Under ROWQIP operations, RID will deliver irrigation water with a higher concentration of nutrients; these higher nutrient concentrations in canal water will now be available to irrigators on a regular basis. Thus, irrigators can adjust their fertilizer applications by accounting for nutrients supplied in the delivered irrigation water, minimizing their nutrient loading and lowering fertilizer costs. And, because these reductions have not been accounted for within the load reduction methods, any nutrient credits that may result from on-field BMPs will be subject to quality standards specific to each BMP.

Change in water quality anticipated for the canal is relatively small

The modeled change in canal phosphorus concentrations in the lower canal reach, which is the reach where most delivery occurs, varies during the season as shown in the graph below (Figure B1). The modeled average phosphorus concentrations and loading rates for current and proposed water quality based on the Riverside Canal Model concentrations at RC9_1 are given in Table B3.

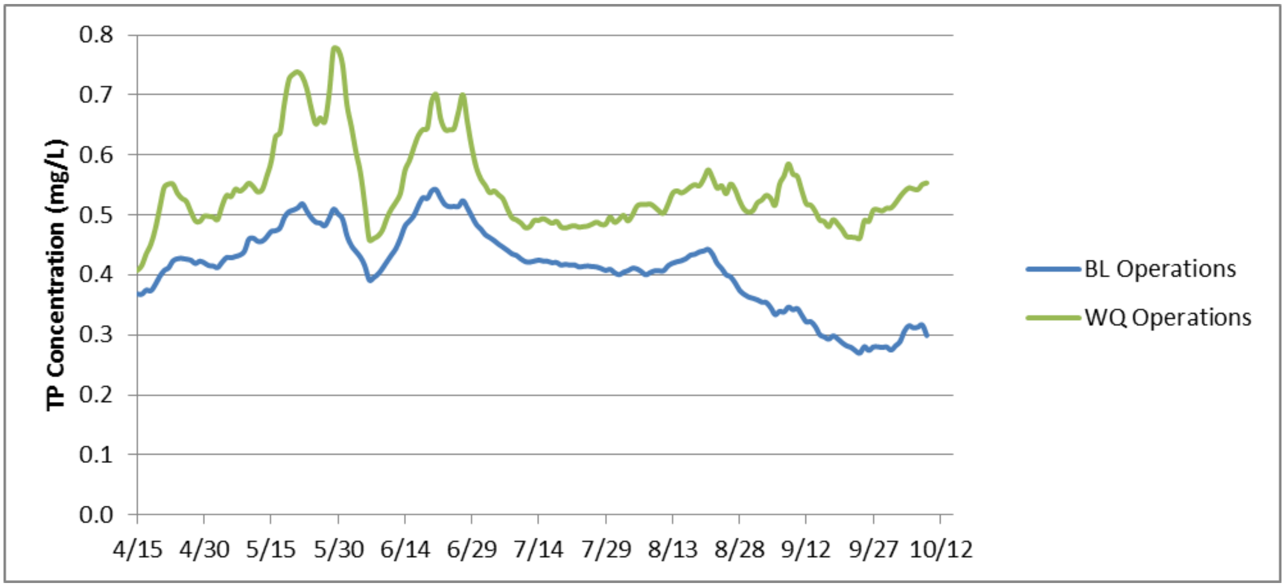

Figure B1. Modeled TP concentration in lower reach of Riverside Canal (i.e. at RC9_1)

Table B3. Modeled phosphorus concentrations and loading rates based on the Riverside Canal Model concentrations at RC9_1

RC9_1	**Avg P Conc (mg/L)**	**P Load (lb/ac/yr)**
BL	0.41	4.5
WQ	0.54	5.9
Difference (WQ-BL)	0.13	1.4

Table B3 shows that the change in canal TP concentration is only about 0.13 mg/L on average. Also, note that the change in the dissolved fraction would be less. Roughly 3 to 5 feet (ac-ft/ac) of irrigation water is needed to grow crops in southwestern Idaho. Assuming 4 feet of water is applied with an increased phosphorus concentration of 0.13 mg/L (based on the Riverside Canal Model), the annual phosphorus loading due to ROWQIP would be about 5.9 lb/ac, and the increased phosphorus load over the baseline condition would be about 1.4 lb/ac.

The annual phosphorus uptake capacity in the RID can be estimated using crop fertilization recommendations. Fertilization rates (Table B4) provide an indication of nutrients applied to produce corps. Fertilization rates will vary by crop, soils characteristics and farming practices. The following table shows a mid-range of recommend fertilization rates for selected corps and soil conditions. Generally some fraction of this added phosphorus would be subject to leaching and runoff.

Table B4. Mid-range of recommended fertilization rates for selected crops based on University of Idaho Fertilization Guidelines (UI 2013)

Crop	Phosphorus (lb/ac)
Alfalfa hay	44
Sugar Beet	88
Pasture grass	53
Corn silage	26
Wheat (spring)	62
Average	**55**

The 55 lb/ac average estimate for annual phosphorus requirement (Table B4) is relatively large compared to the change in phosphorus load that would be applied to cropland under the proposed RID Program (Table B3). The annual phosphorus loading due to ROWQIP would be about 5.9 lb/ac, which is just over 10 percent of fertilization recommendations. Also, note that the increase in annual phosphorus loading would be about 1.4 lb/ac (Table B3). This is less than 3 percent of annual phosphorus fertilizer recommendation.

On-farm water quality management has increased in recent years

In recent years, efforts have been made to reduce the sediment and phosphorus loads discharged from irrigation lands. Management approaches, referred to Best Management Practices (BMPs), generally focus on both water and water-quality management. Additional water quality benefits (above those estimated for ROWQIP), may be realized if individual irrigators were to implement additional BMPs and on-field actions, such as adaptive fertilizer management plans (TFT 2014).

As observed in other regions, many of the RID irrigators have been working to reduce runoff from their farms over the last 10 years (i.e., since the SR-HC TMDL was approved). These water quality improvement actions, which appear to be wide spread over the past decade, include conversion to sprinkler irrigation systems, installation of furrow end ponds and sediment basins, straw mulching and application of polyacrylamide (PAM). Specifically, sprinkler irrigation has increased substantially in the last 10 years and is now estimated to be used on greater than 30% of acreage in RID. Also, during conversations with RID farmers, they estimated that:

- Approximately 20% of the land has been now been converted from furrow to sprinkler irrigation.

- PAM is applied to about 50% of the land still using furrow irrigation methods (personal communication with selected RID irrigators 2013).
- All the hops and 50% of the onions are irrigated with drip systems. (This would equate to about 6% overall and increased from near zero just a few years ago).

While these improvements reduce the potential for increased runoff resulting from the ROWQIP, they are not considered a part of the canal operational improvements. Thus, any load reduction benefits provided by the on-farm improvements should be available for trading within the Boise River or Snake River TMDL frameworks (TFT 2014).

Attachment C – Baseline for Lower Canal Spills

Baseline for the Lower Canal Spills are based on data collected during the 2011 through 2013 irrigation seasons. Tables C1 and C2 provide summary statistics, and Figures C1 and C2 show the daily average data.

Table C1. Flow statistics for Dutton Spill (Rc18_7)

Rc 18_7	**Flow (cfs)**			
Year	2011	2012	2013	Avg
Average	35.3	41.4	31.6	36.2
Max	62.4	60.1	59.4	53.9
Min	17.1	20.1	8.7	21.2

Table C2. Flow statistics for Holly Spill (Rc23_8)

Rc23_8	**Flow (cfs)**			
Year	2011	2012	2013	Avg
Avg	29.6	31.7	26.3	28.9
Max	56.2	51.6	46.1	47.4
Min	8.1	7.0	6.8	10.3

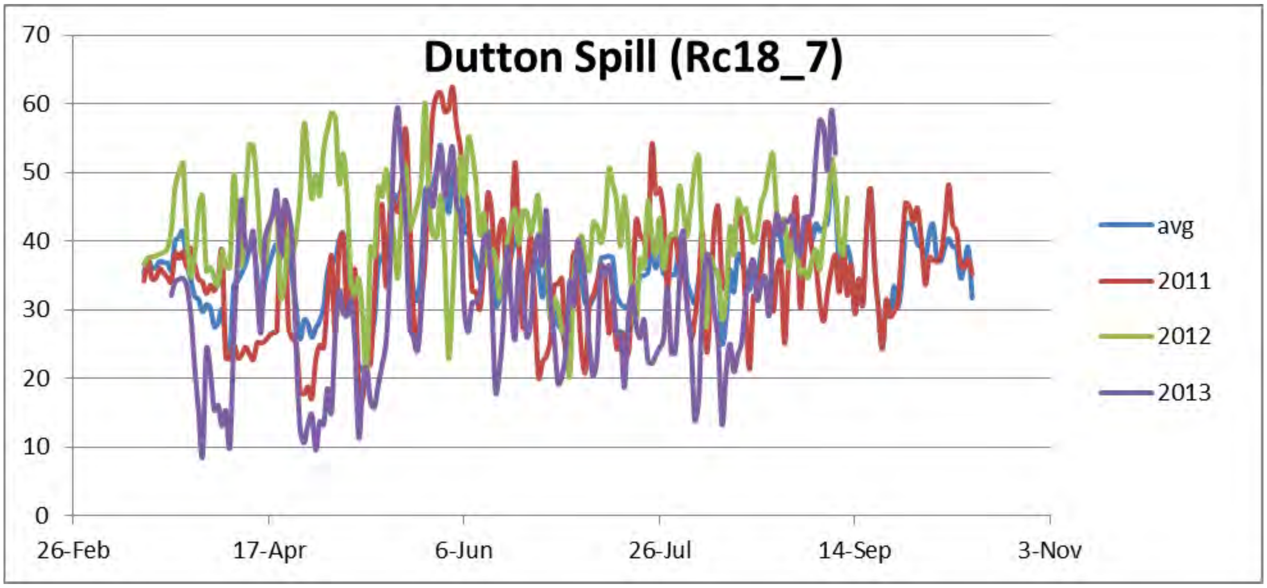

Figure C1. 2013 Daily average flow data (cfs) for Dutton Spill

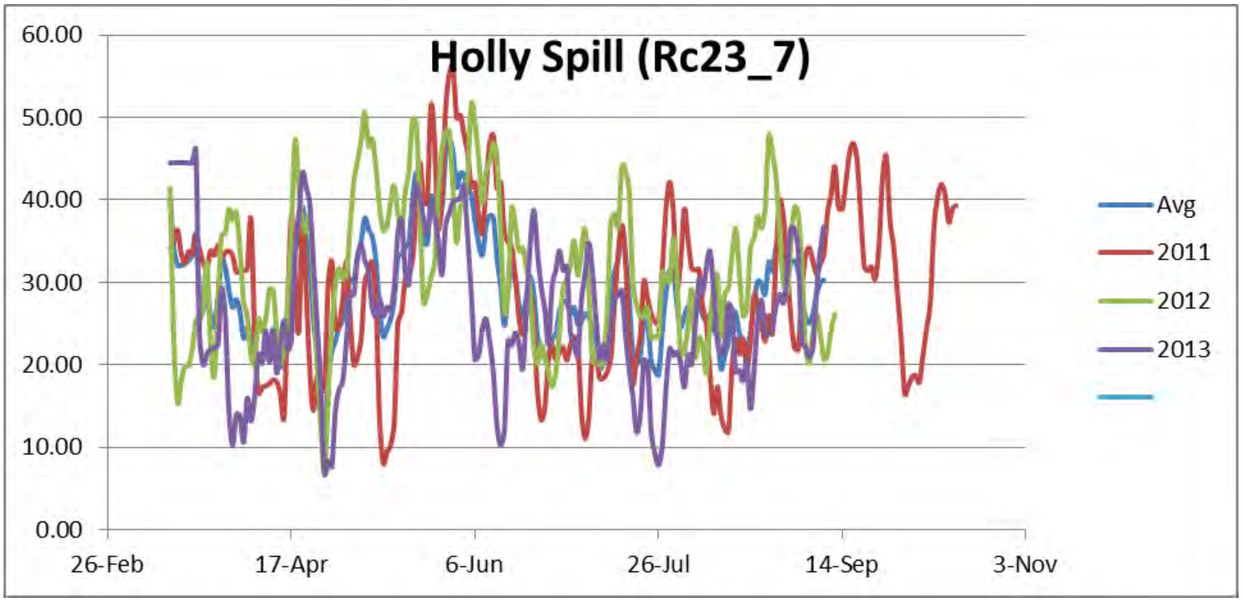

Figure C1. 2013 Daily average flow data (cfs) for Holly Spill

Attachment D – Model QC

The scenario results for 2013 are used to compare modeled results with measured data to provide an indication of model performance. The "error" in flows in upper canal is shown by calculating the difference between a "Calculated Delivery" (as the sum of Br diversion plus tributaries minus spills) and the "Total Delivery" (as the sum of Upper Delivery and Lower Delivery), which is based on measured flows at Rc9_1 Therefore, this can be considered the flow calculation error that occurs are RC9_1. The error can exceed 50 cfs at times, but the average error over the period is 12.8 cfs (about 6%).

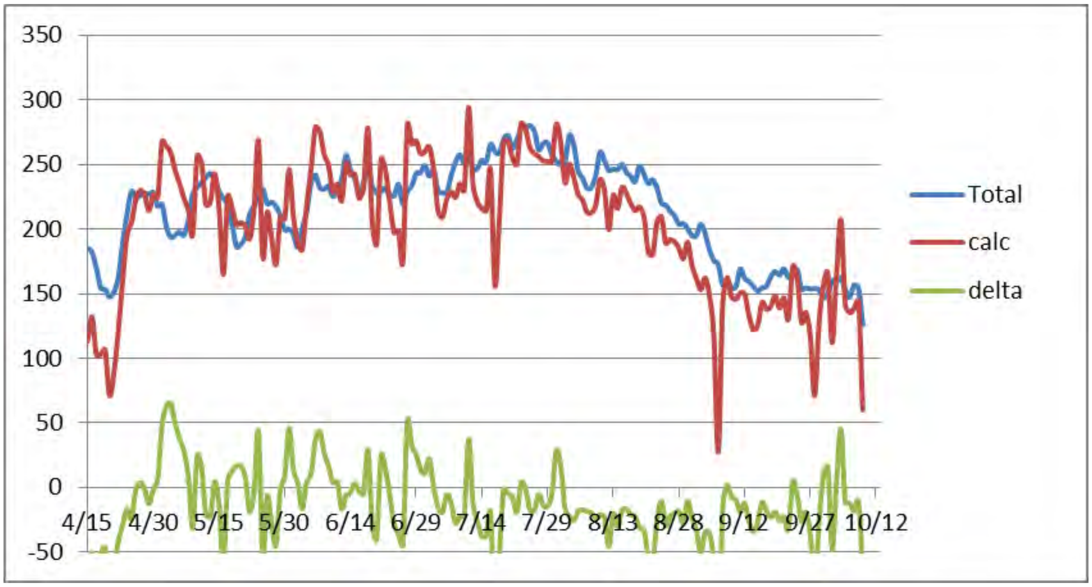

Figure D1. 2013 Total delivery and "calculated" deliveries (flow in cfs) and error.

The error in delivery load is calculated as the difference between a "Calculated Delivery" (as the sum of BR diversion plus tributaries minus spills) and the "Total Delivery" (as the sum of Upper Delivery and Lower Delivery). Again, this is considered the load calculation error that occurs at RC9_1. The error can exceed 150 lb/d at times, but the average error over the period is 30 lb/d (about 6%).

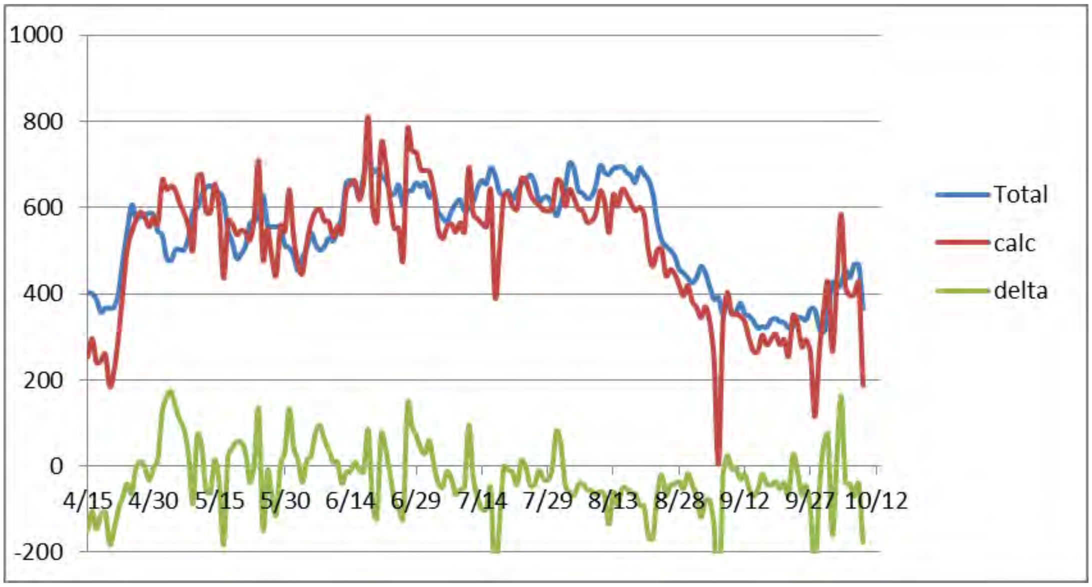

Figure D2. 2013 Total delivery and "calculated" deliveries (load in lbs P/d) and error

Model and measured phosphorus concentrations for the canal at Rc9_1 are also provided for general comparison. Note measured data is instantaneous and includes samples collected during test periods. The cause of high TP observed in May is not fully understood, but high unusually high levels were observed at other sites over a relatively short time periods.

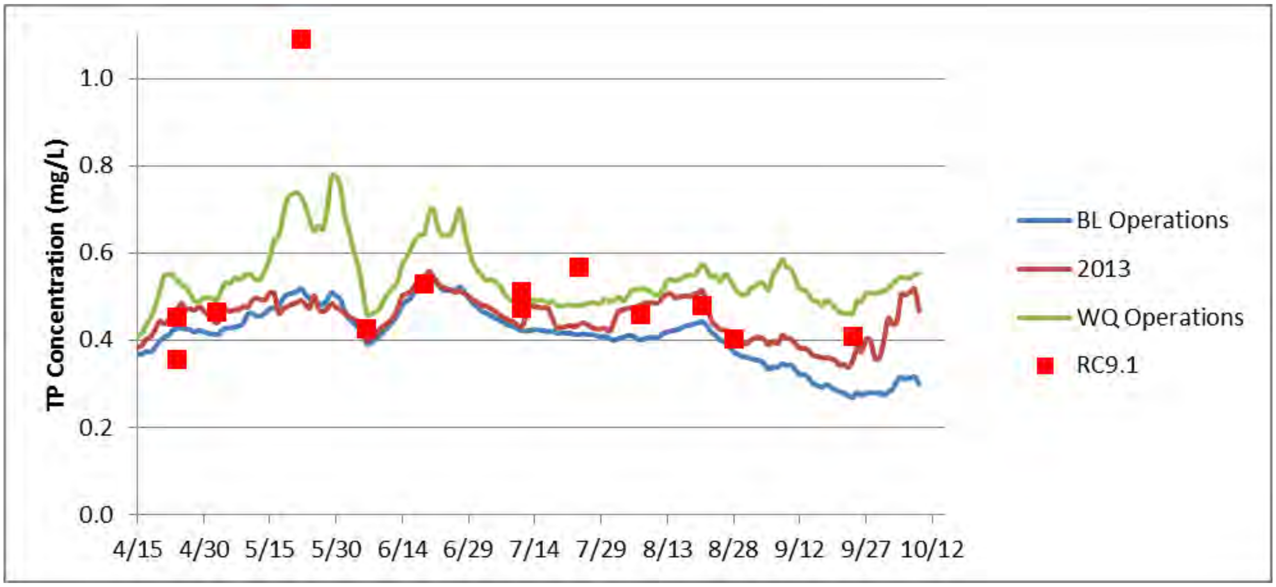

Figure D3. Graph of total phosphorus concentrations at Rc9_1 for the three scenarios, and measured data

Appendix 4 – Riverside Canal Water Quality Monitoring Status Report for 2011, 2012, and 2013

Harrison J. and S. King. 2014. Riverside Canal Water Quality Monitoring Status Report for 2011, 2012, and 2013. Report to Riverside Irrigation District and Idaho Power Company. May 12, 2014.

Riverside Canal Water Quality Monitoring Status Report for 2011, 2012 and 2013

Prepared for: Idaho Power Company
Boise, Idaho

Riverside Irrigation District, LTD.
Parma, Idaho

Prepared by: Jack Harrison, PhD, P.E. / HyQual, P.A.

Scott N. King, P.E. / SPF Water Engineering

Date: May 12, 2014

HYQUAL
Hydraulics
Hydrology
Water Quality

SPF WATER
ENGINEERING

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Note: Cover photo shows the automatic spill gate, which discharges to Indian Creek, installed in 2012 as part of this water quality improvement project.

A. Introduction

Riverside Canal, operated by Riverside Irrigation District (RID), is located at the lower end of the Boise River watershed and provides water to over 10,000 acres of RID land. RID has implemented improvements to the canal and water delivery system in the form of automated spill gates (Attachment A) that allow more efficient and selective management of source water for irrigation.

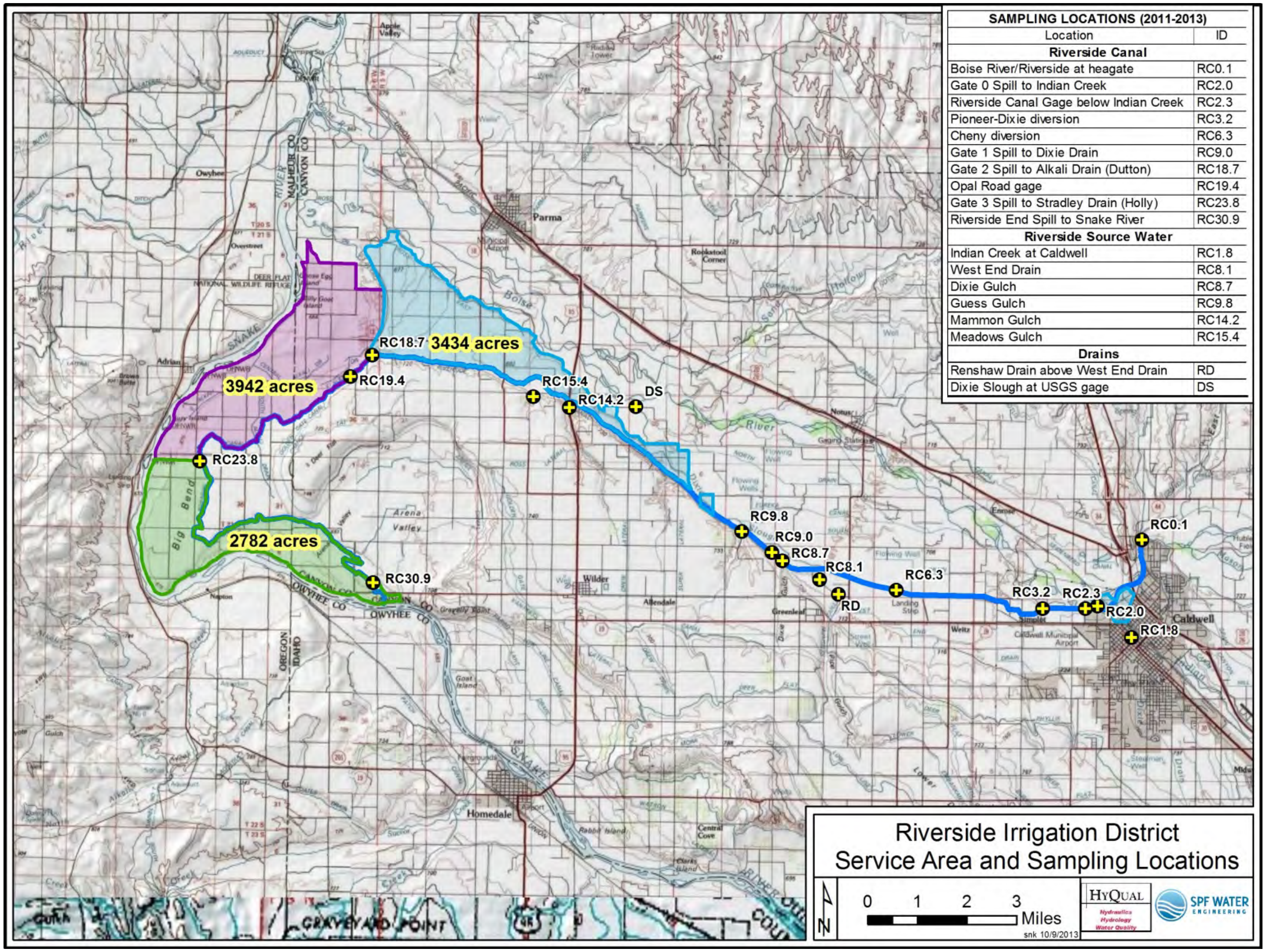
The primary objective of this monitoring effort is to measure phosphorus concentrations and estimate phosphorus loads throughout the RID system. This information is needed to understand how the RID canal water, which carries a sizeable nutrient and sediment load from upstream creeks and drains, can be managed to improve water quality in the Boise and Snake Rivers.

This report summarizes 2011, 2012 and 2013 water quality monitoring results for the Riverside Irrigation District, including the monitoring approach, monitoring locations, measured flows, and water quality concentrations. These flow and water quality data were used to estimate current phosphorus loads into the Riverside Canal from various tributary sources, and loads discharged to the Boise and Snake Rivers, which can be managed by RID to improve water quality.

It should be noted that in 2011 and 2012, the water available for irrigation in the valley was relatively abundant (i.e., above average water supply) due to the relatively high mountain runoff (Bishop 2012, personal communication). Whereas, in 2013, runoff and irrigation water was in relatively short supply and resulted in an overall reduction in water deliveries (Bishop 2013, personal communication).

B. Riverside Irrigation District

The RID is located at the western end of the Boise River valley, near the confluence of the Boise and Snake Rivers (Figure 1). The RID diverts water from the south bank of the Boise River near Caldwell (Figure 1: RC0.1), and receives inflows from other tributaries and drains along its length. The main canal (Riverside Canal) flows northwesterly and crosses US Highway 95 approximately five miles southeast of Parma, Idaho. The canal turns westerly then southwesterly, crossing into Oregon approximately two miles southeast of Adrian, Oregon. The canal then flows south and east, re-crossing the state line into Idaho, before draining into the Snake River approximately four miles west of Wilder, Idaho (Figure 1: near RC31.3).



SAMPLING LOCATIONS (2011-2013)	
Location	ID
Riverside Canal	
Boise River/Riverside at heagate	RC0.1
Gate 0 Spill to Indian Creek	RC2.0
Riverside Canal Gage below Indian Creek	RC2.3
Pioneer-Dixie diversion	RC3.2
Cheny diversion	RC6.3
Gate 1 Spill to Dixie Drain	RC9.0
Gate 2 Spill to Alkali Drain (Dutton)	RC18.7
Opal Road gage	RC19.4
Gate 3 Spill to Stradley Drain (Holly)	RC23.8
Riverside End Spill to Snake River	RC30.9
Riverside Source Water	
Indian Creek at Caldwell	RC1.8
West End Drain	RC8.1
Dixie Gulch	RC8.7
Guess Gulch	RC9.8
Mammon Gulch	RC14.2
Meadows Gulch	RC15.4
Drains	
Renshaw Drain above West End Drain	RD
Dixie Slough at USGS gage	DS

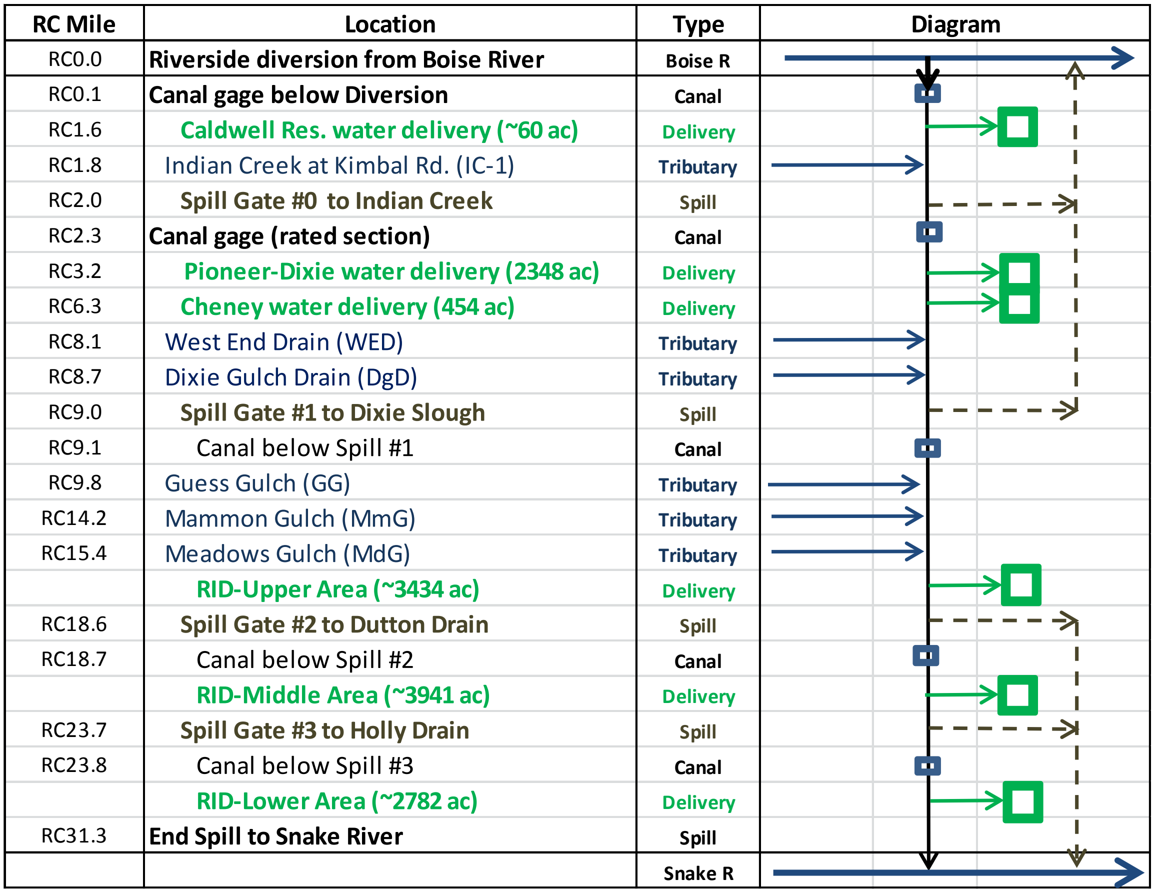
Figure 1. Riverside Irrigation District, irrigated acreages divided into general delivery areas, and sampling locations.

The RID delivers water to approximately 230 water users for agricultural purposes, with principal crops being onions, sugar beets, wheat, potatoes, alfalfa, beans, and hops. According to Idaho Department of Water Resources records, the RID water rights authorize irrigation of 10,158 acres within a District boundary totaling 13,082 acres (the later estimated via GIS mapping). The Riverside Canal is also used to deliver water for irrigation of 2,348 acres within the service area of the Pioneer Dixie Ditch Company, and for 454 acres at the Cheney Diversion (Figure 1: RC3.2 and RC6.3, respectively). Thus, the total irrigated acreage supplied by the canal is over 12,000 acres.

Riverside Canal

The main line canal length is approximately 31 miles and is primarily open channel. The Boise River is the primary source of water for the Riverside Canal with water rights totaling 271.48 cubic feet per second (cfs) as decreed in the Snake River Basin Adjudication. The RID also has decreed water rights to Indian Creek water totaling 178.4 cfs, and decreed rights to 113.16 cfs from other creeks and drains. Decreed water rights from all sources (i.e., the Boise River and tributaries) total about 563 cfs with priority dates ranging from June 1, 1884 to October 18, 1924. RID has additional claims to water rights pending in the Snake River Basin Adjudication. As previously noted, the Riverside Canal is also used to deliver water to the Pioneer Dixie Ditch Company with the decreed Boise River rights of 60.5 cfs.

Excess Boise River and tributary source water, not needed for deliveries, is spilled from the canal at various locations as shown in a schematic of the canal (Figure 2). The majority of the excess water spilling to downstream drains discharges to the Boise or Snake Rivers with a minor amount diverted by irrigators. The schematic diagram also shows the general locations and acreages of water deliveries. Numerous headgates and diversions from Riverside Canal (not shown in diagram) supply the irrigated land in these areas.



RC Mile	Location	Type	Diagram
RC0.0	**Riverside diversion from Boise River**	**Boise R**	
RC0.1	**Canal gage below Diversion**	**Canal**	
RC1.6	**Caldwell Res. water delivery (~60 ac)**	**Delivery**	
RC1.8	Indian Creek at Kimbal Rd. (IC-1)	**Tributary**	
RC2.0	**Spill Gate #0 to Indian Creek**	**Spill**	
RC2.3	**Canal gage (rated section)**	**Canal**	
RC3.2	**Pioneer-Dixie water delivery (2348 ac)**	**Delivery**	
RC6.3	**Cheney water delivery (454 ac)**	**Delivery**	
RC8.1	West End Drain (WED)	**Tributary**	
RC8.7	Dixie Gulch Drain (DgD)	**Tributary**	
RC9.0	**Spill Gate #1 to Dixie Slough**	**Spill**	
RC9.1	Canal below Spill #1	**Canal**	
RC9.8	Guess Gulch (GG)	**Tributary**	
RC14.2	Mammon Gulch (MmG)	**Tributary**	
RC15.4	Meadows Gulch (MdG)	**Tributary**	
	RID-Upper Area (~3434 ac)	**Delivery**	
RC18.6	**Spill Gate #2 to Dutton Drain**	**Spill**	
RC18.7	Canal below Spill #2	**Canal**	
	RID-Middle Area (~3941 ac)	**Delivery**	
RC23.7	**Spill Gate #3 to Holly Drain**	**Spill**	
RC23.8	Canal below Spill #3	**Canal**	
	RID-Lower Area (~2782 ac)	**Delivery**	
RC31.3	**End Spill to Snake River**	**Spill**	
		Snake R	

Figure 2. Diagram of Riverside Canal showing RC mile, location (with sampling ID or estimated irrigated acreage in parentheses), and type (i.e., source and receiving waters, delivery in green, tributary creek or drain in blue, and spill in dashed line to receiving water).

C. Monitoring Approach

The RID water quality monitoring began in 2011 and has varied somewhat over the years as understanding, data needs and available resources have changed. However, consistent over this period, the overall approach has focused on monitoring the primary sources to canal (i.e., inflows), and major discharges from the canal (i.e., spills). The flow measurement and sampling locations and water quality parameters for these primary locations are presented below.

Primary Monitoring Locations

Water quality samples and flow measurements were collected for select locations along the Riverside Canal, tributary creeks and drains discharging into the canal (Figure 1 and Table 1). The sampling locations were selected to assess (1) flow and loads in major sources that flow into the Riverside Canal and (2) flow and load out of the canal from spills that drain to the Boise or Snake Rivers.

Table 1. Primary water quality sampling locations for Riverside Canal, Spills and Boise River tributary drainage waters. (note: these are current 2013 locations).

Canal Designation	Sampling Location Description
BR0.0/RC0.1	Boise River diversion / measurement location
RC1.8	Indian Creek in Caldwell (below Kimball Ave)
RC8.1	West End Drain above Greenleaf WWTP
RC9.0 / 9.1	Gate 1 spill / canal below Dixie Drain
RC18.7 / 18.8	Gate 2 spill / canal below Dutton spill
RC23.8 / 23.9	Gate 3 spill / canal below Holly Drain
RC31.3	Riverside Canal End Spill to Snake River

Monitoring Parameters

Discharge was recorded or measured during each sampling event. Many sampling locations have continuous stage or gate opening data loggers (Table 2). At these sites, the reported flow was recorded during the sampling event. At some sites the stage was read from a staff gage during the sampling event to verify flow reported by SCADA system.

Table 2. Summary of primary discharge measurement locations, methods and communications.

ID	Description	Method	Uplink
RC0.1	Boise River/Riverside at headgate	Stage	Yes
RC1.8 (IC-1)	Indian Creek in Caldwell (Kimball Ave)	Stage	Yes
RC2.3	Riverside Canal at Gage	Stage	Yes
RC3.2	Pioneer-Dixie diversion (flow only)	Stage	No
RC8.1 (WED)	West End Drain at Greenleaf WWTP	Stage	Yes
RC9.0	Spill Gate #1 Spill to Dixie Drain	Gate	Yes
RC9.1	Canal downstream of Spill Gate #1	Gate	Yes
RC18.6	Spill Gate #2 to Dutton/E.Alkali Drain	Gate	Yes
RC18.7	Canal downstream of Spill Gate #2	Stage	Yes
RC23.7	Spill Gate #3 to Holly Drain	Gate	Yes
RC31.3	Riverside End Spill to Snake River	Stage	No

As shown in Table 2, the discharge methods varied by site depending on conditions such as available structures, equipment, and need. Measurements are currently recorded continuously and most are linked to SCADA system.

Water samples collected during each sampling event were analyzed for total suspended solids (EPA 160.2), total phosphorus (EPA 365.4 and 365.1), and dissolved ortho-phosphate (reported as P) (EPA 365.1). Additional information is available in a Sampling and Analyses Plan available upon request.

Monitoring Procedures

Monitoring procedures are summarized below. Additional information is available in a Sampling and Analyses Plan available upon request.

Flow Measurement Procedures

Flow was measured directly by current meter or indirectly using stage height together with stage-discharge, weir, or orifice relationships. Continuous flow measurements procedures with rating curves are provided in a technical memorandum by King and Harrison (2013). The flow measurements were used to develop new, or verify and update existing, ratings for rated sections and gate openings. Direct flow measurements were generally performed by the sampling team using current meters (Price AA or Pygmy) (Rantz 1982). Additionally, flows at selected locations with deep profiles and/or high velocities were measured by IPC using acoustic Doppler current profiler instruments. A minimum flow measurement accuracy of approximately +/-15% was targeted for current meter readings. In most instances, this accuracy was achievable. Additional details regarding flow measurement practices are provided in Attachment B.

Water Quality Sampling Procedures

Water samples were collected from locations of significant flow (ideally mid-channel) directly into designated containers provided by the laboratory for total suspended solids, total phosphorus, and dissolved ortho-phosphate. Samples were placed on ice and stored in darkness (i.e., within an ice chest) during transport from the field to the laboratory.

All sampling equipment was cleaned and checked before going into the field. All field meters were calibrated per manufacturer recommendations. All sampling containers were clean and laboratory supplied.

Quality Assuarance

Standard sampling protocols were used to assure that the samples collected are representative of field conditions (e.g., EPA 1999). Sample handling protocols, including storage, transportation, and preservation, were used to protect the representativeness of the samples gathered during the project. Standardized field documentation procedures were utilized to ensure that sample identification and integrity was preserved.

Field precision was evaluated by measuring the variability of replicate measurements. The replicates were sampled consecutively (i.e., one after the other) to limit temporal variability (total collection time will be just a few minutes).

D. Monitoring Results

Irrigation season monitoring results for flow, total suspended solids (TSS) and phosphorus (total and dissolved ortho) are provided in Attachment 3. The flow rates provided in the water quality summary tables for each event and location were generally recorded at the time of samples recollected. However, some flow rates have been “rerated” based on improved rating curves (King and Harrison, 2013). Additionally, continuous flow measurements for selected locations are provided in Attachment B.

E. Discussion of Results

Discussion of monitoring results focuses on flow and total phosphorus as these parameters are of most interest relative to nutrient trading. Total phosphorus data collected for the three years is compared for the locations that used to model canal automatic operations (Figure 3). The figure shows total P for 2 canal locations (RC0.1 and RC9.1), and for the primary tributaries source waters Indian Creek (RC1.8) and West End Drain (RC8.1). In general Total P concentrations are in a similar range for the years. The lowest concentrations shown are for the Boise River (RC0.0/RC0.1). The highest phosphorus concentrations observed are in Indian Creek, which tends to have higher concentrations during 2013.

Based on water rights, the Boise River is the largest single source of water to Riverside Canal (Attachment 3) and often has the lowest TP levels (Figure 3). Just downstream of the Boise River diversion from the Boise River, water is diverted to the Caldwell Residential area. Beyond this minor diversion, the canal mixes with Indian Creek (RC1.8) the largest tributary to the canal (Attachment B). Water quality data for Indian Creek (Figure 3) shows that phosphorus concentrations in this water source are considerably higher that the Boise River.

Just downstream from merging with Indian Creek, the Riverside Canal continues flowing to the west and excess water “spills” northward into the Indian Creek channel, which then discharges to the Boise River (Figure 1). This Indian Creek spill (aka, Gate 0), (Figure 2), is assumed to have water quality similar to that reported for the Riverside Canal gage at RC2.3, which is the location historically used for reporting of Riverside diversions to the Boise River Watermaster. (Note that beginning in 2013, the flows at RC0.1 were reported to the Water Master).

Downstream of Riverside Canal gage (RC2.3) there is a relatively small diversion for delivery of irrigation water. The Pioneer-Dixie Ditch Company then delivers this water to

2,348 acres of agricultural land (Figure 2 – diagram). Another smaller diversion, the Cheney diversion, is located downstream at RC6.3, for delivery to approximately 454 acres of farmland.

Further west, the West End Drain (RC8.1) discharges into the canal at RC8.1. This is second largest tributary (Attachment B). The monitoring results for the West End Drain (Figure 3) show total phosphorus levels ranging from about 0.2 to near 0.6 mg/L (Appendix 3). Note the TSS levels in the West End Drain are some of the highest measured.

Below the West End Drain there is another minor inflow (RC8.7) just above the Gate 1 spill that discharges excess water to the Dixie Slough. Below this spill the Riverside Canal continues west as the primary source water used to irrigate over 10,000 acres within the RID boundaries. The water quality at this location (RC9.1) is modeled to determine phosphorus loads delivered to the RID irrigators.

Other smaller tributaries (e.g., Guess, Mammon and Meadow Gulches) discharge into the canal, or bypass the canal and discharge to the Boise or Snake Rivers and/or are used by downstream water users (Figure 2). Excess water discharging into the canal from these tributaries and other unnamed drains can spill at Gates 2 and 3. These spill gates, located at RC18.7 and RC23.8, are generally referred to as the Dutton and Holly spills, respectively. The majority of the water spilled from Gates 2 discharges to the Snake River. Some of the water discharged at Gage 3 is used by downstream water users. Excess water from these gated spills and the canal end spill (RC31.3) discharge to the Snake River.

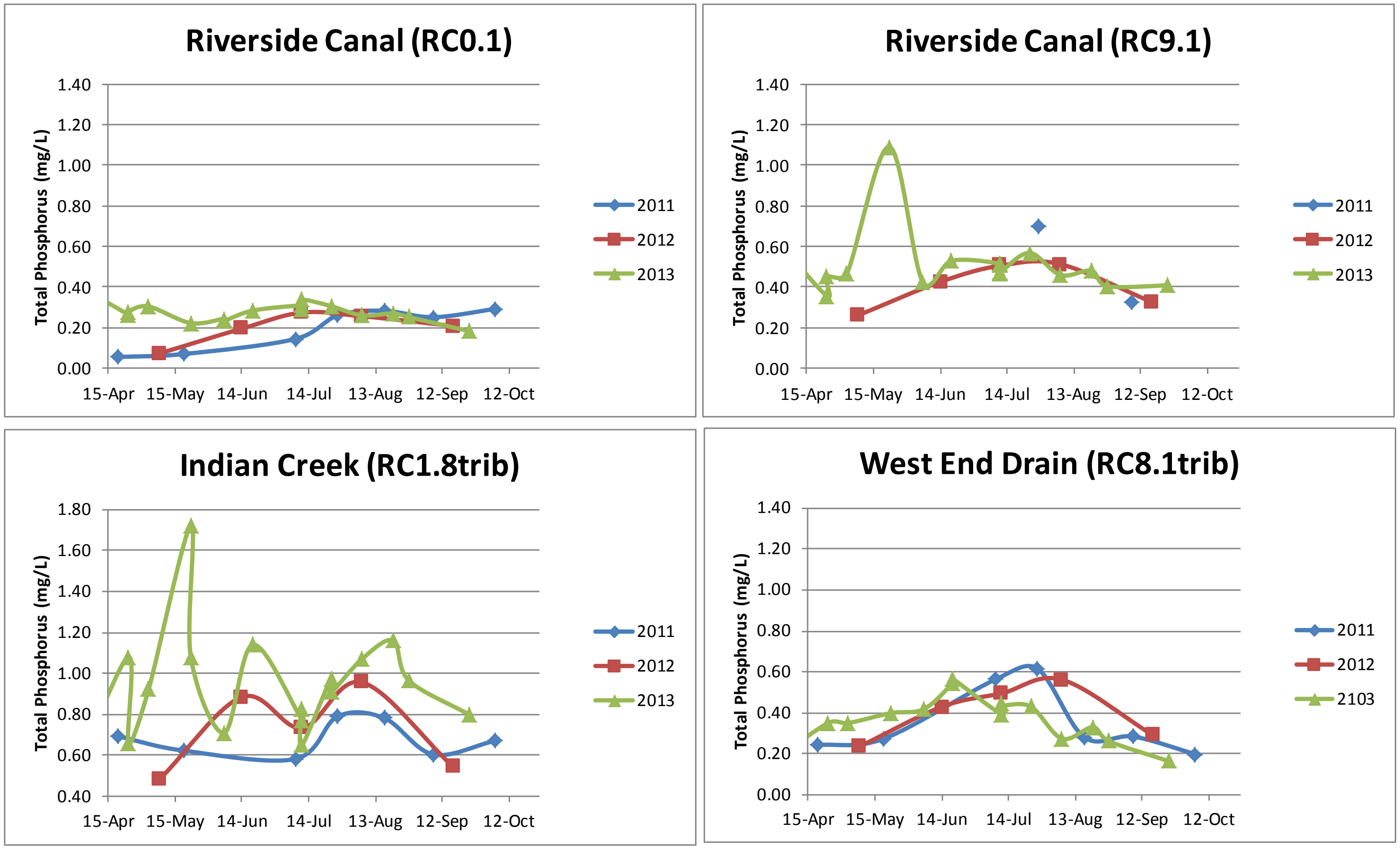


Figure 3. Graphs comparing 2011 2012 and 2013 total phosphorus at selected locations in and discharge to the Riverside Canal; Note scale shift lower right graph.

F. Summary

Water quality data were collected in 2011, 2012 and 2013 from multiple locations along the Riverside Canal, creeks and drains flowing into the canal (i.e., its source waters) and downstream drains that discharge excess canal water to the Boise and Snake Rivers. The data were collected to support assessment of the potential water quality improvements that can be accomplished through improved water control and management by the Riverside Irrigation District.

Results show that Indian Creek and the West End Drain, which have relatively high total phosphorus levels (i.e., maximums of 1.720 and 0.612 mg/L, respectively), discharge sizable phosphorus loads into the canal. While these levels are considerably higher than the Boise River (i.e., maximum 0.420 mg/L in March 2011), historically much of the tributary source water exceeds irrigation demands and is “spilled” to drains that discharge back to the Boise and Snake Rivers.

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H. Acknowlegements

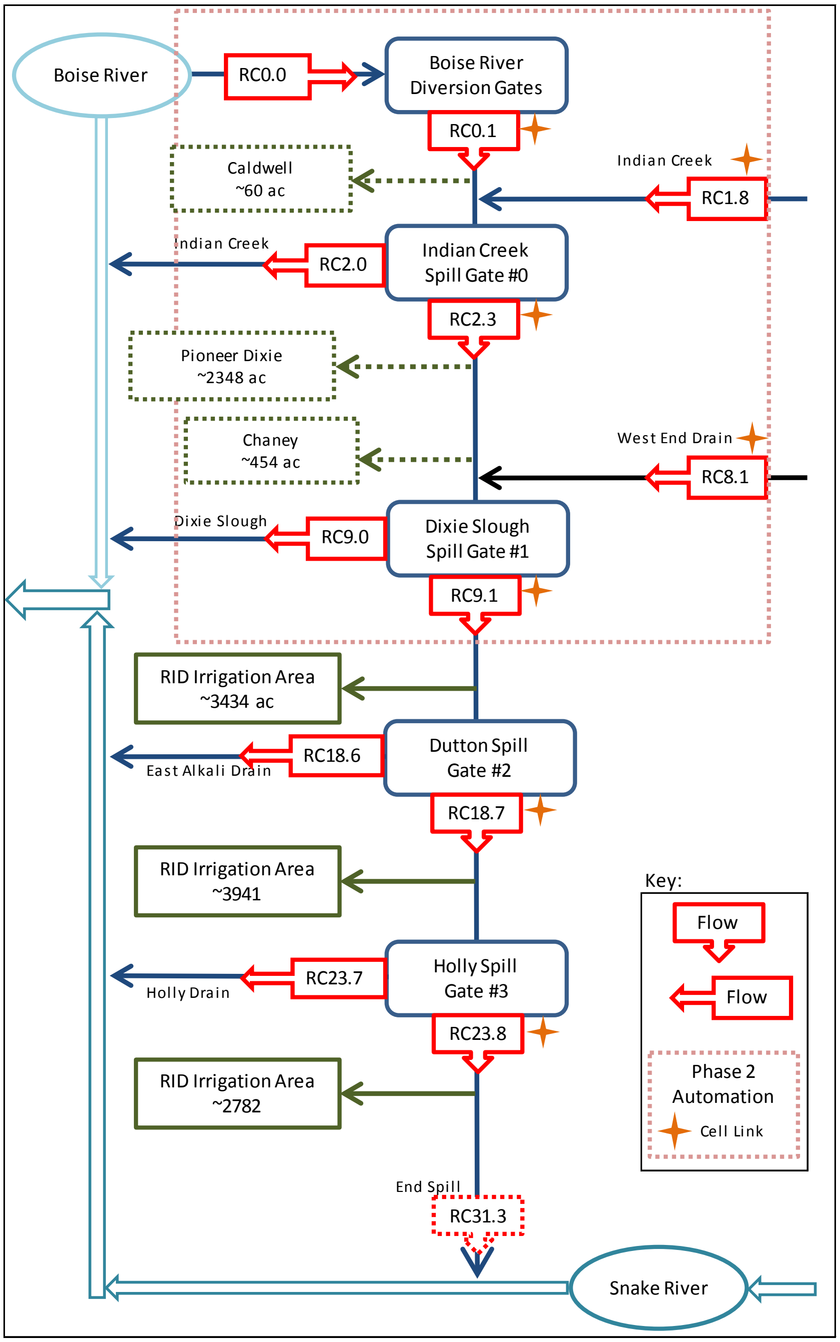
This monitoring program was developed and implemented in collaboration with Riverside Irrigation District (RID), Idaho Power Company (IPC) and many others:

- The monitoring program was developed by HyQual and SPF with significant input from RID and IPC.
- Water quality sample collection and laboratory analyses were primarily funded by IPC.
- West End Drain and Indian Creek discharge monitoring was conducted in cooperation with the Cities of Greenleaf and Caldwell, respectively.
- Flow was measured and water quality samples were collected by, Riverside Irrigation District, SPF and IPC staff, under the direction of HyQual.

I. Attachments

Attachment A – Riverside Canal Automation Diagram

Riverside Canal automation diagram shows source waters (e.g., Indian Creek and West End Drain (WED)), diversions to agricultural areas, and continuous flow measurement linked by cellular system for canal automation.



Attachment B – Flow Measurements and Continuous Flow Data

Data for each sampling event, as provided in the summary tables, was measured by one of the following methods:

Stage in rated section: Periodic and Continuous

- Continuous water level (i.e., stage) data were collected using either
    - HOBO U20 Water Level Logger pressure transducer to record stage level and a second transducer to record barometric pressure for barometric compensation of level readings,
    - Barometrically-vented In-Situ Level TROLL 500 Water Level Data Logger and to Campbell Scientific CR800 dataloggers, or
    - Standard level-float stream gage stations with potentiometers and Campbell Scientific CR1000 dataloggers used for the gate automation systems.
- Continuous stage level readings are used to calculate discharge using a stage-discharge relationships developed for the monitoring site. The stage-discharge relationships (i.e., rating curves) were developed or updated during the 2012 and 2013 monitoring period for many of the locations.

Gate (Opening): Continuous

- Gate opening and water level data were recorded by CR1000 dataloggers from Campbell Scientific used for the gate automation system. This data along with orifice-type relationships are used to compute discharge.

Gage: Continuous

- The RC gage is a rated section located at RC2.3. It is used to report canal diversions to the Boise River Watermaster.

Weir: Continuous

- At locations with weirs, depth of flow over the weir was used to calculate flow, which was generally continuously recorded beginning in late May.

Measurement: Monthly

- Flows were measured by the velocity-area method using a current meter, an acoustic-doppler current profiler, or estimated using other methods when the channel was unwadable due to high flows or discharge too low to measure with available equipment.

Riverside Canal Tributary Inflows

Selected continuous and other available data are given in Attachment B.

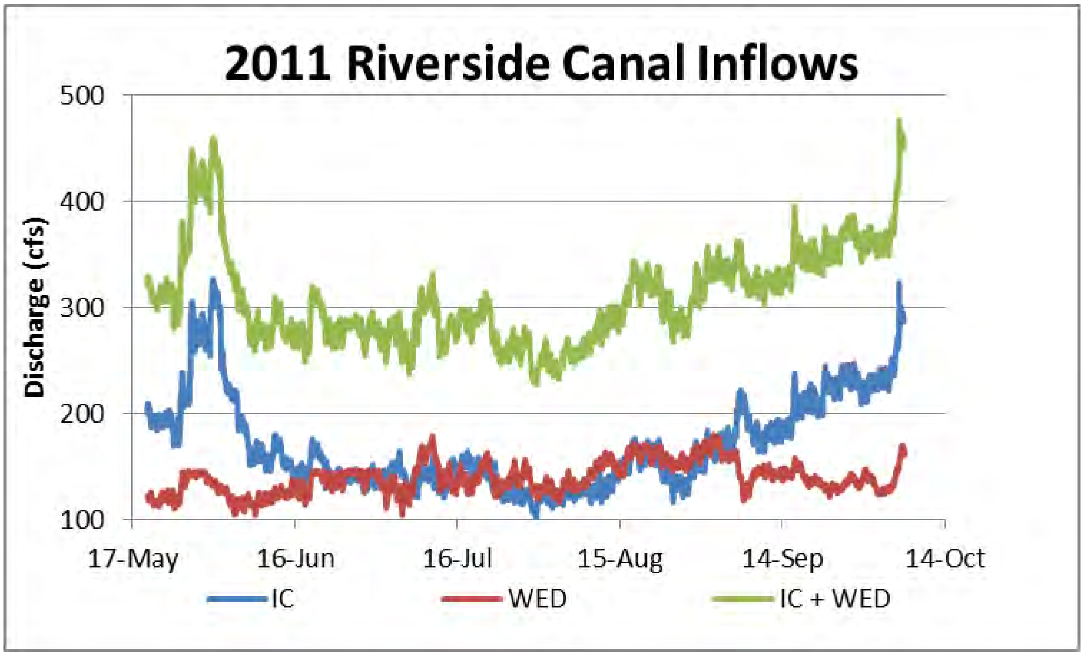


Figure. B1. 2011 Riverside Canal tributary flows.

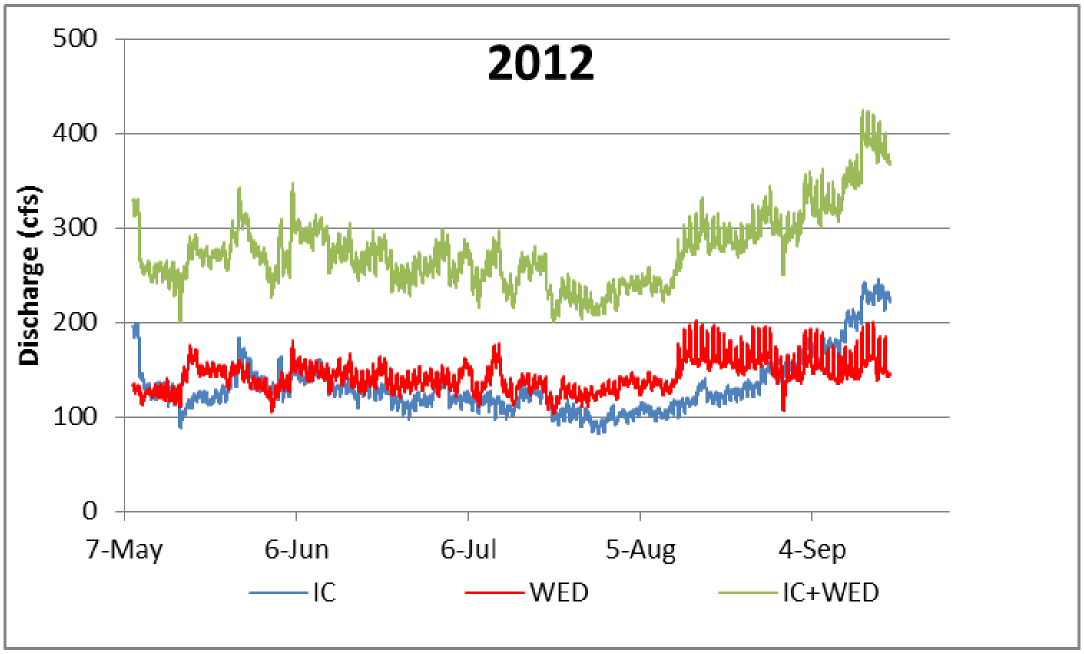


Figure. B2. 2012 Riverside Canal tributary flows.

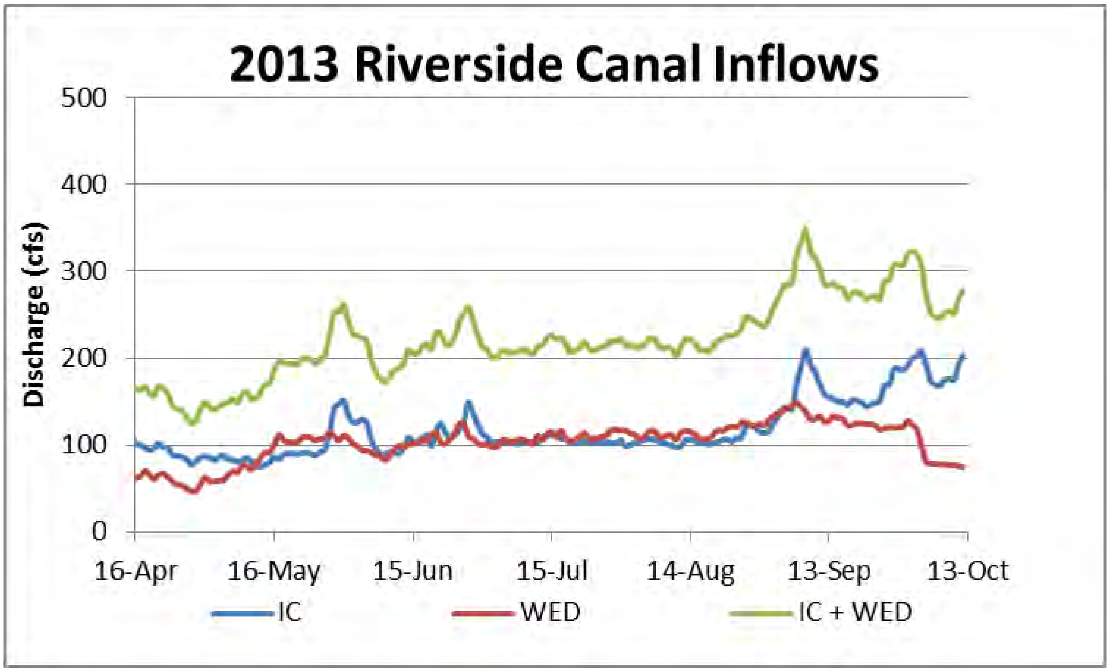


Figure. B3. 2013 Riverside Canal tributary flows.

Riverside Canal Flow below Gate 1 (and Dixie Spill)

RID Riverside Canal irrigation water flow (provisional) for 2011 and 2012 measured below Gate 1 at RC9.1

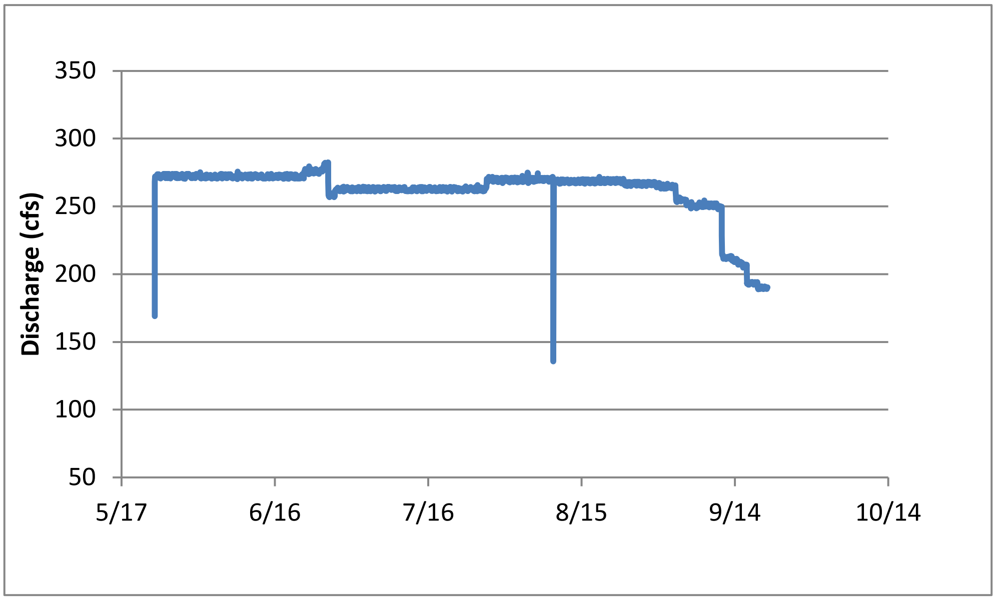


Figure B4. 2011 Canal provisional flow below Gate 1.

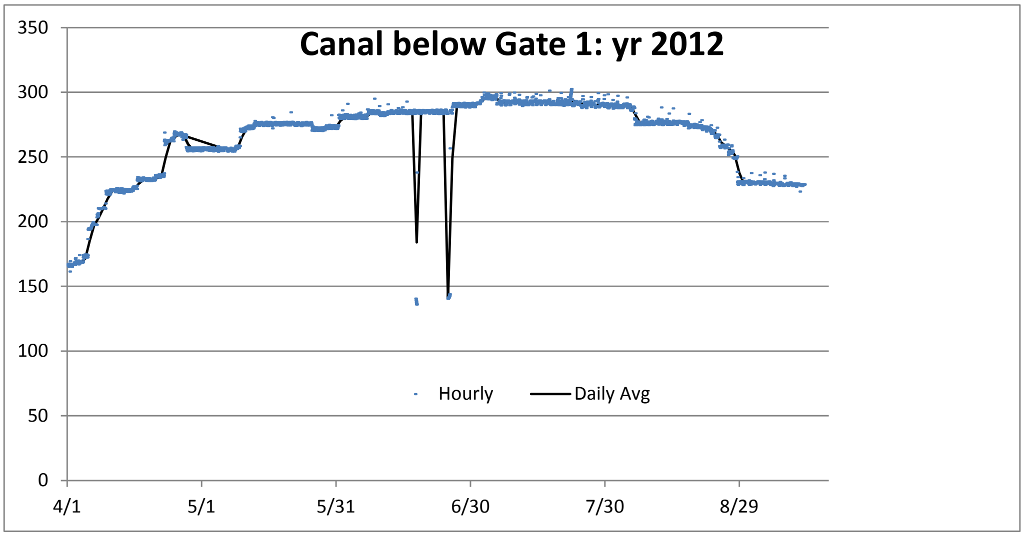


Figure B5. 2012 Canal provisional flow below Gate 1.

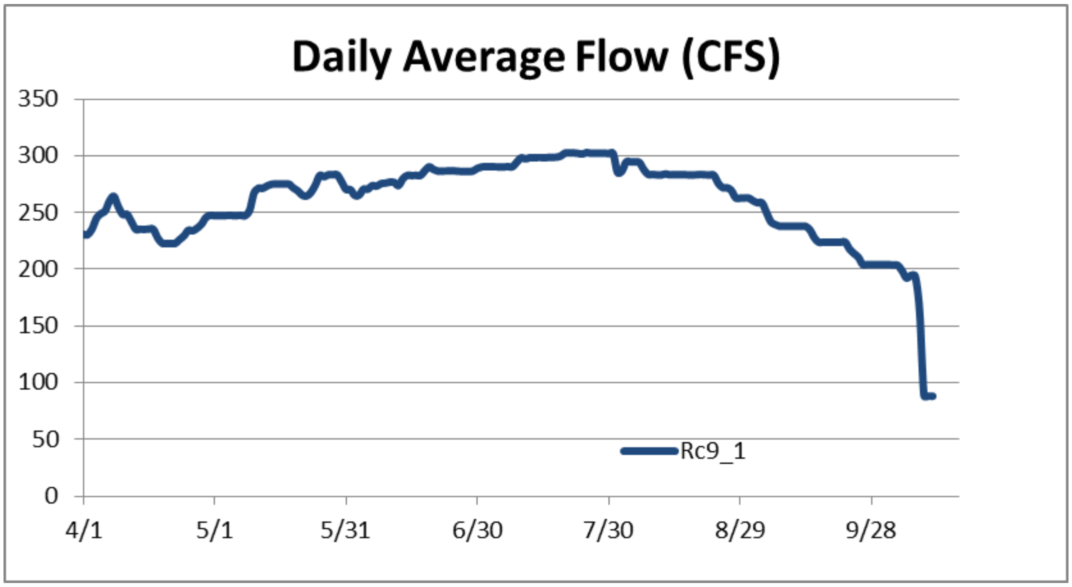


Figure B6. 2013 Canal provisional flow below Gate 1 (Rc9.1).

The following flow data were collected in 2012 but not provided in the report.

Table B7. Pioneer Dixie Diversion Data are based on staff gage reading.

Date	Discharge (cfs)
Diversion to PD	
7/11/2012	31.3
8/7/2012	29.3
9/17/2012	26.6
9/17/2012	25.5

Attachment C – Water Quality Data

Table C1. Water quality sampling results for Boise River Diversion at RC0.1.

Boise River and Diversion at RC0.1				
		Laboratory Analysis		
Date	Discharge (cfs)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/17/2011	3.9	0.340	0.42	43
4/19/2011	232	0.031	0.055	4
5/19/2011	399	0.043	0.070	9
7/8/2011	347	0.078	0.144	25
7/27/2011	208	0.182	0.260	95
8/17/2011	206	0.178	0.283	62
9/8/2011	209	0.179	0.251	39
10/6/2011	234	0.223	0.292	25
11/10/2011	3.75	0.306	0.338	<3
5/8/2012	304	0.035	0.073	12
6/14/2012	279	0.103	0.195	41
7/11/2012	261	0.152	0.274	87
8/7/2012	201	0.165	0.256	43
9/17/2012	196	0.158	0.208	25
3/19/2013	91	0.270	0.339	21
4/2/2013	112	0.277	0.385	41
4/24/2013	171	0.160	0.265	56
4/24/2013	179	0.189	0.279	53
5/3/2013	200	0.167	0.304[1]	42
5/22/2013	334	0.106	0.222	42
6/6/2013	234	0.176	0.244	64
6/19/2013	226	0.152	0.284	65
7/11/2013	226	0.177	0.309	65

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[1] The May 3, 2013 laboratory-reported Total P value of 3.04 appears to be inconsistent, possibly due to a lab reporting error, and in our professional opinion was changed to 0.304 for reporting, modeling and computations.

Boise River and Diversion at RC0.1				
7/11/2013	142	0.162	0.292	61
7/11/2013	124	0.180	0.337	76
7/24/2013	204	0.168	0.306	73
8/7/2013	134	0.177	0.260	44
8/21/2013	170	0.184	0.270	30
8/28/2013	240	0.169	0.252	28
9/24/2013	118	0.158	0.183	16

Table C2. Water quality sampling results for Indian Creek below Kimball Road at Caldwell, Idaho (IC-1).

Indian Creek (IC-1) upstream of RC1.8				
		Laboratory Analysis		
Date	Discharge (cfs)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/17/2011	184	0.42	0.47	47
4/19/2011	190	0.460	0.694	35
5/19/2011	208	0.497	0.623	60
7/8/2011	145	0.421	0.583	81
7/27/2011	128	0.646	0.790	56
8/17/2011	169	0.585	0.782	46
9/9/2011	188	0.476	0.605	33
10/6/2011	287	0.411	0.672	30
11/10/2011	230	0.439	0.571	19
5/8/2012	191	0.377	0.484	29
6/14/2012	144	0.690	0.885	66
7/11/2012	133	0.571	0.733	81
8/7/2012	123	0.772	0.956	36
9/17/2012	215	0.500	0.544	17
3/19/2013	159	0.615	0.721	37
4/2/2013	107	0.535	0.626	43
4/24/2013	86	0.872	1.080	32
4/24/2013	84	0.628	0.658	25
5/3/2013	84	0.947	0.921	25

Indian Creek (IC-1) upstream of RC1.8				
5/22/2013	90	0.780	1.720	33
6/6/2013	99	0.767	0.710	20
6/19/2013	111	0.780	1.140	68
7/11/2013	104	0.636	0.774	54
7/11/2013	99	0.624	0.827	40
7/11/2013	100	0.522	0.651	40
7/24/2013	101	0.925	0.976	32
8/7/2013	109	0.965	1.070	20
8/21/2013	110	0.910	1.160	15
8/28/2013	120	0.827	0.966	14
9/24/2013	166	0.606	0.800	21

Table C-3. Water quality sampling results for West End Drain above Riverside Canal (RC8.1).

West End Drain upstream of RC8.1				
		Laboratory Analysis		
Date	Discharge (cfs)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/17/2011	54	0.09	0.12	53
4/19/2011	87	0.048	0.243	3
5/19/2011	144	0.079	0.275	139
7/8/2011	141	0.122	0.563	310
7/28/2011	151	0.120	0.616	311
8/17/2011	156	0.131	0.282	108
9/8/2011	137	0.135	0.285	710
10/6/2011	163	0.141	0.199	37
11/10/2011	61	0.068	0.090	11
5/8/2012	132	0.057	0.236	119
6/14/2012	152	**	0.430	410
7/11/2012	164	0.130	0.496	404
8/7/2012	140	0.095	0.562	234
9/17/2012	145	0.175	0.291	89
3/19/2013	64	0.062	0.110	30
4/2/2013	48	0.061	0.191	96

West End Drain upstream of RC8.1				
4/24/2013	81	0.087	0.351	161
5/3/2013	88	0.1	0.351	172
5/22/2013	111	0.094	0.399	186
6/6/2013	97	0.096	0.419	260
6/19/2013	111	0.108	0.548	290
7/11/2013	99	0.114	0.392	240
7/11/2013	99	0.119	0.446	301
7/11/2013	98	0.114	0.436	264
7/24/2013	108	0.104	0.431	219
8/7/2013	110	0.105	0.275	89
8/21/2013	116	0.12	0.331	121
8/28/2013	121	0.111	0.263	91
9/24/2013	109	0.105	0.165	47

Table C-4. Water quality sampling results for Riverside Canal to Indian Creek (RC2.0).

Riverside Canal at RC2.0 Spill to Indian Creek					
	Discharge		Laboratory Analysis		
	Canal	Spill	Ortho P	Total P	TSS
Date	(cfs)	(cfs)	(mg/L)	(mg/L)	(mg/L)
7/11/2013		28	0.336	0.442	82

Table C-5. Water quality sampling results for Riverside Canal at RC2.3 (Water Master Gage).

Riverside Canal at RC2.3 (Water Master Gage)					
	Discharge		Laboratory Analysis		
	Canal	Spill	Ortho P	Total P	TSS
Date	(cfs)	(cfs)	(mg/L)	(mg/L)	(mg/L)
3/17/2011	<0.25	--	0.440	0.460	17
4/19/2011	200	--	0.271	0.336	20

Riverside Canal at RC2.3 (Water Master Gage)					
5/19/2011	283	--	0.257	0.332	26
7/8/2011	304	--	0.212	0.308	50
7/27/2011	272	--	0.367	0.575	93
8/18/2011	307	--	0.363	0.561	49
9/8/2011	251	--	0.281	0.288	46
10/6/2011	207	--	0.297	0.373	23
11/10/2011	.04 est	--	0.385	0.543	18
5/8/2012	262	--	0.185	0.241	21
6/14/2012	315	--	0.301	0.397	53
7/11/2012	295	--	0.323	0.458	91
8/7/2012	286	--	0.403	0.543	47
9/17/2012	233	--	0.370	0.406	21
4/24/2013	194	--	0.318	0.422	39
4/24/2013	170	--	0.358	0.432	37
7/11/2013	296	--	0.346	0.449	81
7/11/2013	247	--	0.415	0.529	66
7/11/2013	219	--	0.401	0.485	51

Table C-6. Water quality sampling results for Riverside Canal Spill at RC9.0.

Riverside Canal Spill at RC9.0					
	Discharge		Laboratory Analysis		
Date	Canal (cfs)	Spill (cfs)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
7/28/2011		117	0.311	0.701	194
9/8/2011	252	89	0.211	0.322	52
5/8/2012	256	130	0.154	0.260	59
6/14/2012	284	171	0.245	0.425	124
7/11/2012	292	128	0.265	0.505	201
8/7/2012	277	89	0.301	0.512	108
9/17/2012	224	110	0.289	0.326	37
4/2/2013	229	41	0.435	0.626	70
4/24/2013	--	--	0.336	0.356	71

Riverside Canal Spill at RC9.0					
4/24/2013	--	--	0.378	0.453	65
5/3/2013	248	--	0.303	0.466	100
5/22/2013	--	63	0.219	1.090	109
6/6/2013	274	45	0.293	0.426	136
6/19/2013	277	68	0.310	0.529	129
7/11/2013	299	86	0.314	0.513	109
7/11/2013	--	46	0.319	0.508	128
7/11/2013	--	42	0.325	0.474	123
7/24/2013	299	56	0.325	0.568	149
8/7/2013	290	40	0.367	0.459	84
8/21/2013	283	77	0.355	0.480	59
8/28/2013	261	112	0.250	0.404	51
9/24/2013	213	95	0.344	0.408	38

Table C-7. Water quality sampling results for Riverside Canal Spill at RC18.7.

Riverside Canal Spill at RC18.7					
	Discharge		Laboratory Analysis		
	Canal	Spill	Ortho P	Total P	TSS
Date	(cfs)	(cfs)	(mg/L)	(mg/L)	(mg/L)
7/27/2011	--	43	0.221	0.808	280
9/8/2011	--	35	0.203	0.313	61
5/8/2012	244	31	0.112	0.239	82
6/14/2012	248	34	0.214	0.423	150
7/11/2012	198	40	0.221	0.694	313
8/7/2012	248	30	0.250	0.501	104
9/17/2012	131	31	0.270	0.301	22
4/2/2013	198	15	0.457	0.744	165
4/24/2013	281	12	0.313	0.788	87
5/3/2013	287	29	0.266	0.500	127
5/22/2013	265	38	0.210	1.080	122
6/6/2013	281	28	0.264	0.480	199
6/19/2013	326	39	0.264	0.537	178

7/11/2013	304	41	0.255	0.481	198
7/24/2013	354	29	0.248	0.565	194
8/7/2013	315	47	0.255	0.417	104
8/21/2013	309	35	0.286	0.472	110
8/28/2013	254	41	0.225	0.362	67
9/24/2013	159	24	0.291	0.341	27

Table C-8. Water quality sampling results for Riverside Canal Spill at RC23.8.

Riverside Canal Spill at RC23.8					
	Discharge		Laboratory Analysis		
	Canal	Spill	Ortho P	Total P	TSS
Date	(cfs)	(cfs)	(mg/L)	(mg/L)	(mg/L)
7/27/2011	--	40	0.215	0.660	226
9/8/2011	--	32	0.204	0.297	42
5/8/2012	--	51	0.108	0.259	95
6/14/2012	--	26	0.221	0.404	196
7/11/2012	--	28	0.197	0.525	230
8/7/2012	--	16	0.250	0.487	94
9/17/2012	--	23	0.244	0.286	22
4/2/2013	--	15	0.397	0.626	127
4/24/2013	--	26	0.267	0.776	135
5/3/2013	--	38	0.223	0.402	124
5/22/2013	--	42	0.177	1.060	141
6/6/2013	--	23	0.231	0.375	136
6/19/2013	--	16	0.229	0.451	146
7/11/2013	--	20	0.233	0.409	130
7/24/2013	--	14	0.242	0.464	122
8/7/2013	--	32	0.266	0.416	77
8/21/2013	--	26	0.304	0.500	89
8/28/2013	--	27	0.236	0.359	51
9/24/2013	--	22	0.325	0.374	22

Table C-9. Water quality sampling results for Riverside Canal End Spill at RC31.3.

Riverside Canal End Spill at RC31.3					
	Discharge		Laboratory Analysis		
	Canal	Spill	Ortho P	Total P	TSS
Date	(cfs)	(cfs)	(mg/L)	(mg/L)	(mg/L)
4/19/2011	24	"same"	0.156	0.259	41
5/19/2011	40	"same"	0.118	0.257	72
7/8/2011	28	"same"	0.114	0.191	19
7/27/2011	32	"same"	0.135	0.229	40
8/17/2011	21	"same"	0.128	0.205	30
9/8/2011	30.8	"same"	0.141	0.252	54
10/6/2011	22.7	"same"	0.130	0.172	9
11/10/2011	1.5 est	"same"	0.041	0.047	3
5/8/2012	33	"same"	0.136	0.240	42
6/14/2012	9	"same"	0.141	0.190	27
7/11/2012	8	"same"	0.117	0.199	25
8/7/2012	6	"same"	0.160	0.255	9
9/17/2012	23	"same"	0.123	0.191	17
4/2/2013	8.45	"same"	0.377	0.410	14
4/24/2013	3.5	"same"	0.223	0.352	35
5/3/2013	18	"same"	0.203	0.197	20
5/22/2013	16	"same"	0.188	0.275	10
6/6/2013	5.4	"same"	0.143	0.148	<3
6/19/2013	1.7	"same"	0.217	0.279	8
7/11/2013	3.5	"same"	0.066	0.087	8
7/24/2013	0	"same"	0.072	0.182	11
8/7/2013	3.5	"same"	0.249	0.265	6
8/21/2013	1.9	"same"	0.281	0.379	<3
8/28/2013	3.5	"same"	0.140	0.201	<3
9/24/2013	0	"same"	0.090	0.103	<3

Table C-10. Water quality sampling results for Guess Gulch above RC.

Guess Gulch above RC				
		Laboratory Analysis		
Date	Discharge (cfs)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/17/2011	3.5	0.070	0.100	37
7/28/2011	21	0.048	0.235	117
9/8/2011	22	0.079	0.253	87
5/8/2012	12	0.057	0.229	95
6/14/2012	18	0.109	0.295	125
7/11/2012	26	0.109	0.164	43
8/7/2012	23	0.047	0.230	61
9/17/2012	--	0.076	0.179	55

Table C-11. Water quality sampling results for Mammon Gulch above RC.

Mammon Gulch above RC				
		Laboratory Analysis		
Date	Discharge (cfs)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/17/2011	4.6	0.180	0.250	68
7/27/2011	40-60 est	0.062	0.186	55
9/9/2011	35	0.068	0.282	107
5/8/2012	6	0.051	0.185	70
6/14/2012	28	0.081	0.303	12
7/11/2012	39	0.025	0.259	127
8/7/2012	39	<0.005	0.255	83
9/17/2012	26	0.046	0.194	81
8/7/2013	30	0.081	0.323	129

Table C-12. Water quality sampling results for Meadow Gulch above RC.

Meadow Gulch above RC				
		Laboratory Analysis		
Date	Discharge (cfs)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
5/8/2012	2.26	0.014	0.075	14
6/14/2012	3.9	0.082	0.169	31
7/11/2012	5.9	0.047	0.512	197
8/7/2012	5	0.034	0.242	36
9/17/2012	1.70	0.111	0.283	24

Table C-13. Water quality sampling results for Dixie Gulch (RC8.7).

RC8.7 Dixie Gulch above RC				
		Laboratory Analysis		
Date	Discharge (cfs)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
7/11/2013	9	0.075	0.166	52

Table C-14. Water quality sampling results for Alkali Drain.

Alkali Drain				
		Laboratory Analysis		
Date	Discharge (cfs)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/17/2011	6.1	0.130	0.200	29
7/27/2011	49	0.231	0.306	19
9/8/2011	39	0.170	0.386	47

Table C-15. Water quality sampling results for Allen Drain above 3-P's.

Allen Drain above 3-P's				
		Laboratory Analysis		
Date	Discharge (cfs)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/17/2011	6.5	0.080	0.130	37
7/27/2011	41	0.067	0.149	39
9/8/2011	65	0.081	0.124	15

Table C-16. Water quality sampling results for Arena Lake Drain.

Arena Lake Drain				
		Laboratory Analysis		
Date	Discharge (cfs)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/17/2011	2.9	0.120	0.140	8
7/27/2011	38	0.025	0.113	31
9/8/2011	40	0.058	0.121	16

Table C-17. Water quality sampling results for East Arena Drain.

East Arena Drain				
		Laboratory Analysis		
Date	Discharge (cfs)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/17/2011	1.9	<0.05	<0.05	8
7/27/2011	3.8	0.025	0.038	6
9/8/2011	4.8	0.042	0.069	9

Table C-18. Water quality sampling results for Dixie Slough.

Dixie Slough				
		Laboratory Analysis		
Date	Discharge (cfs)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/17/2011	114 +/-	0.22	0.27	32
4/19/2011	? (back water)	0.190	0.277	30
5/19/2011	? (back water)	0.218	0.326	60
7/8/2011	? (back water)	0.188	0.330	66
7/27/2011	221	0.253	0.358	70
8/17/2011	>250	0.287	0.386	45
9/8/2011	>250	0.236	0.302	38
10/6/2011	>250	0.254	0.326	27
11/10/2011	121	0.133	0.177	12
5/8/2012		0.139	0.249	58
6/14/2012		**	0.390	130
7/11/2012	268.0	0.247	0.409	105
8/7/2012	290.1	0.279	0.403	41
9/17/2012	334.1	0.260	0.303	25

Table C-19. Water quality sampling results for Renshaw Drain / Pipe Gulch.

Renshaw Drain / Pipe Gulch				
		Laboratory Analysis		
Date	Discharge (cfs)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/17/2011	17	0.050	0.100	31
7/28/2011	29+ (est)	0.083	0.165	52
9/8/2011	43+ (est)	0.109	0.210	52
7/11/2012	--	0.097	0.180	87
8/7/2012	--	0.065	0.381	177
9/17/2012	--	0.110	0.175	35

Table C-20. Water quality sampling results for Snake River.

Snake River				
		Laboratory Analysis		
Date	Discharge (cfs)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/17/2011	13,000 +/-	<0.05	0.090	43
4/19/2011	22,000 +/-	<0.005	0.130	33
5/19/2011	29,300 +/-	0.024	0.145	26
7/8/2011	6,510 +/-	0.017	0.04	6
7/27/2011	9100 +/-	0.03	0.104	26
8/17/2011	10300 +/-	0.019	0.077	23
9/8/2011	9990 +/-	0.046	0.073	16
10/6/2011	14100 +/-	0.042	0.079	19
11/10/2011	12000 +/-	<.005	0.06	13

Appendix 5 – ROWQIP Flow Measurement Methodology

King, S. and Harrison J. 2014. ROWQIP Flow Measurement Methodology. Technical Memorandum to Idaho Power Company and Riverside Irrigation District. May 11, 2014.

Technical Memorandum

Riverside Canal Flow Measurement Methodology for the ROWQI Project

Prepared for: Ralph Myers / Idaho Power Company
Jesse Naymik / Idaho Power Company
Andy Bishop / Riverside Irrigation District

Prepared by: Scott King / SPF Water Engineering
Jack Harrison / HyQual
Scott Mooney / Control Engineers

Date: May 12, 2014

Technical Memorandum

Riverside Canal Flow Measurement Methodology for the ROWQI Project

Prepared for: Ralph Myers / Idaho Power Company
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Prepared by: Scott King / SPF Water Engineering
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Cover: Photo of Riverside Canal gage, located just below Boise River diversion gates on the right bank in a natural canal channel, showing stilling well water level measurement float connected via cellular uplink to canal SCADA system in foreground and staff gage on left bank in background.

Introduction

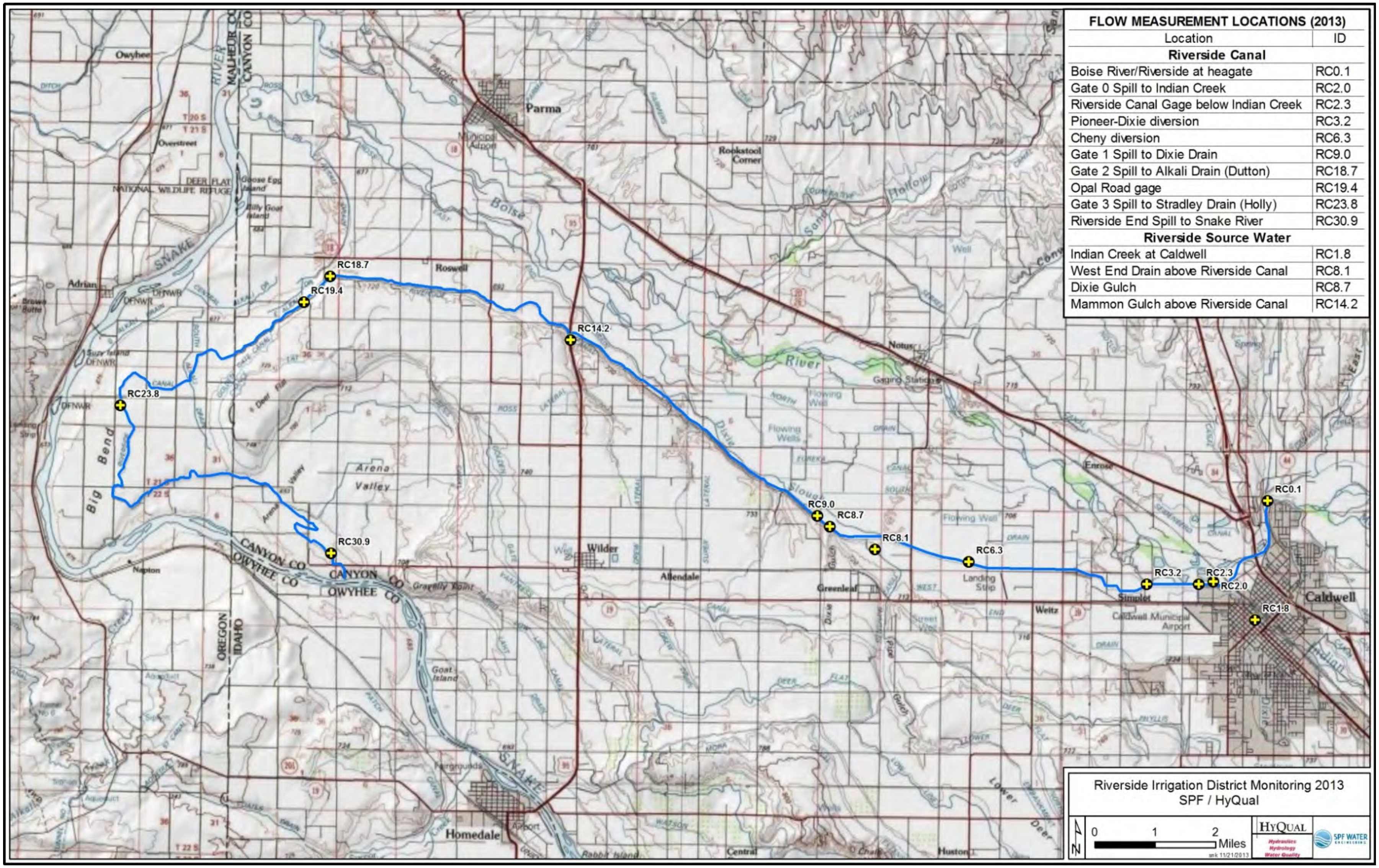
The following rating curves and discharge equations are used in the Riverside Canal SCADA System programing to calculate flows for the Riverside Canal. Many of the discharge equations are based on current meter measurements taken by SPF Water Engineering (SPF), and supplemented by Idaho Power Company (IPC) using sonic acoustic flow measurements. The canal gate controller and SCADA System programing have been performed by US Bureau of Reclamation (USBR) and Control Engineers. Also included in this technical memorandum are data and information developed and/or provided by USBR, United States Geological Survey (USGS) and the Boise River Water Master. The curves and measurement data are also provided in an Excel file developed by SPF entitled: Riverside Discharge Measurements and Ratings - 2013.10.28.

At most locations, flow is continually measured and recorded as part of the SCADA system. When sampling at these locations the flow and water levels are recorded at the time of sampling by connecting to the SCADA system and reading the reported values. Additionally, if there is a staff gage nearby or equipment with readout, these readings will also be noted, as an additional quality control check.

For sites not connected to the SCADA system, but with continuous logging, the staff gage water level will be recorded so that flow can be determined or verified at a later date based on a rating curve.

When needed at locations without rated sections, the sampling team used a current meter (Price AA or Pygmy) to measure the stream flow velocity at locations where gate openings or stage reading could not be used for flow measurement (Rantz 1982).

Map and Summary Table



FLOW MEASUREMENT LOCATIONS (2013)

Location	ID
Riverside Canal	
Boise River/Riverside at heagate	RC0.1
Gate 0 Spill to Indian Creek	RC2.0
Riverside Canal Gage below Indian Creek	RC2.3
Pioneer-Dixie diversion	RC3.2
Cheny diversion	RC6.3
Gate 1 Spill to Dixie Drain	RC9.0
Gate 2 Spill to Alkali Drain (Dutton)	RC18.7
Opal Road gage	RC19.4
Gate 3 Spill to Stradley Drain (Holly)	RC23.8
Riverside End Spill to Snake River	RC30.9
Riverside Source Water	
Indian Creek at Caldwell	RC1.8
West End Drain above Riverside Canal	RC8.1
Dixie Gulch	RC8.7
Mammon Gulch above Riverside Canal	RC14.2

Figure 1. Map of Measurement Locations.

Table 1. Overview of flow measurement locations, type, and status.

Updated May 13, 2013 (jrh)		**Type**	**Status / to do**
ID	Description		
Riverside Canal			
RC0.1	Boise River/Riverside at headgate	Rated Section	Staff gage, stilling well and logger; measurements from 43 to 325 cfs, -1.5 to +1.6 ft.
RC2.0	Spill Gate #0 to Indian Creek	Gate	Estimated spill = RC0.1 + RC1.8 (IC-1) – RC2.3. Plan to measure spill flow by calibrating new gates with upstream level and gate height (will need costs). Re-rating of the staff gage below the spill was initiated with measurements from near zero to 125 cfs, -0.6 to +1.23 ft.
RC2.3	Riverside Canal at Gage	Rated Section	Watermaster gage and rating table. Re-rating initiated with measurements from 187 to 294 cfs, 2.6 to 3.5 ft.
RC3.2	Pioneer-Dixie diversion (flow only)	Rated Section	Rated section with staff gage. Section would benefit from sediment and weed removal; needs further assessment.
RC6.3	Cheney diversion (flow only)	Rated Section	Staff gage installed 2013 in canal below diversion structure. Four discharge measurements from 8 to 14 cfs. Rating accuracy suffers from downstream vegetation as season progresses.
RC9.0	Spill Gate #1 Spill to Dixie Drain	Gate	Revise "programed" equation based on new measurements.
RC9.1	Canal downstream of Spill Gate #1	Gate	RID equipment in place; submerged weir type equation appears OK based on five measurements ranging from 190 to 300 cfs.
RC18.7	Spill Gate #2 to Dutton/East Alkali Drain	Gate	Rating based on BOR gate height and canal level appears fair being about 12% high at 20 cfs to 10% low at 47 cfs.
RC18.8	Canal downstream of Spill Gate #2	Rated Section	RID equipment in place. Rating is inconsistent based on four measurements from 100 to 200 cfs. Channel is generally not wadable.
RC19.4	Canal at Opal Rd	Rated Section	Staff gage used by RID for downstream canal management. One measurement made in 2013. Additional measurements required to assess sufficiency as a rated section.
RC23.7	Spill Gate #3 to Holly Dn	Gate	Rating based on BOR gate height and canal level appears fair being about 5% low at 42 cfs.
RC23.9	Canal downstream of Spill Gate #3	Rated Section	RID equipment in place. Rating is inconsistent based on four measurements from 46 to 81 cfs. Channel is generally not wadable. Assess opportunities for a nearby rated section.
RC30.9	Riverside End Spill to Snake River	Weir	Recommend logger at end spill check structure. Logger used at 31.1 during 2013, but poor location. Spills to Snake River at RC31.5 (0.6 miles below end spill check).
Riverside Tributaries			

RC1.8 IC-1	Indian Creek at Kimball Ave	Rated Section	Revised original USGS rating with four additional measurements. Measurements from 82 to 245 cfs, 4.1 to 5.2 ft.
RC8.1 WED	West End Drain near Greenleaf	Rated Section	New rated section with level logger. Calibration by Greenleaf and IP. Revised rating curve established with measurements from 50 to 120 cfs, 4.0 to 5.2 ft.
RC 8.7	Dixie Gulch	Weir	Discharge measurements based on depth over concrete check structure using weir equation. Three measurements ranted from 0.9 to 6 cfs.
RC9.8	Guess Gulch	Current Meter	Discharge measurements made in 2011 and 2012 ranged from 3.5 to 26 cfs.
RC14.2	Mammon Gulch	Weir	Discharge rating based on depth over check boards and weir equation. May need to be evaluated each year as check board height is likely not consistent from year to year.
RC15.4	Meadows Gulch	Weir	Discharge rating based on depth over check boards and weir equation. May need to be evaluated each year as check board height is likely not consistent from year to year.

Table 2. Summary of selected rating curves and coefficients.

	Equation	**Q**	**Gage Ht**	**G (Gage Ht + X)**	**P (Q @ G-e+X=1)**	**e (G @ Q = 0)**	**b (slope)**	**X (adjustment for negative gage readings)**	**Sensor Shift**	**Notes**
RC0.1	$Q = P(G + X - e)^b$	Discharge (cfs)	Level on Staff Gage	see Gage Ht & X	0.98	0	3.09	5	-4.04	Apply sensor shift to sensor data so that sensor ht = Gage Ht
RC2.3	$Q = 6.5172G^3 - 19.795G^2 + 74.928G - 3.1786$	Discharge (cfs)	Level on Staff Gage	see Gage Ht & X	n/a	n/a	n/a	0	0.1	Polynomial equation fit to prior rating table
RC2.3	$Q = P(G + X - e)^b$	Discharge (cfs)	Level on Staff Gage	see Gage Ht & X	38.4	0	1.63	0	0.1	Updated equation based on four Idaho Power discharge measurements.
RC1.8 IC-1	$Q = P(G + X - e)^b$	Discharge (cfs)	Level on Staff Gage	see Gage Ht & X	11.13	2	2.68	0	2.56	
RC2.0 IC-2	$Q = P(G + X - e)^b$	Discharge (cfs)	Level on Staff Gage	see Gage Ht & X	0.87	-0.65	5.02	1	n/a	Revised equation based on four measurements. Level sensor not installed.
RC3.2	$Q = P(G + X - e)^b$	Discharge (cfs)	Level on Staff Gage	see Gage Ht & X	24.14	0	0.41	0	n/a	
RC6.3	$Q = P(G + X - e)^b$	Discharge (cfs)	Level on Staff Gage	see Gage Ht & X	2.30	0	1.60	2	n/a	Rating accuracy suffers from excessive downstream aquatic vegetation growth
RC8.1 WED	$Q = P(G + X - e)^b$	Discharge (cfs)	Level on Staff Gage	see Gage Ht & X	23.2	2.4	1.52	0	2.81	Andy changed shift 2.59 to 2.82 on April 24. Scott M hard-coded shifts 2.82 on April 29, and 2.81 on May 13.
RC30.9	$Q = P(G + X - e)^b$	Discharge (cfs)	Level on Staff Gage	see Gage Ht & X	200	0.9	2.52	0	TBD	

Notes: Q is discharge in cfs; G is gate height (Ht) as read on staff gage plus X which is adjustment for negative gage readings (i.e., G = Ht + X); P, e and b are equation coefficients; Sensor Shift is the adjustment between sensor elevation and gage elevation.

Notes on Tables and Equations

1. The “Shift” value is used to shift the sensor level so that it matches the staff gage level.
2. Rating curves are based on the staff gage level, not on sensor level (except those stations that do not have staff gages).
3. Equation parameters (P, e, b, X) are independent of the sensor shift.
4. The parameter “X” is used for those sites where negative gage readings are possible (i.e. RC0.1).
5. In 2013 the adjustments to “sensor shift value” were required:
    - Adjusted the sensor shift value at WED from 2.59 to 2.82 on April 29, 2013, and to 2.81 on May 13, 2013.
    - Adjusted the sensor shift value at RC0.1 from -4.05 to -4.04 on June 7, 2013.

Rating Curves for Canal Locations

RC0.1 – Riverside Canal below Boise River Diversion

Description: This canal measuring location is an unlined canal reach located approximately 125 feet downstream of Boise River diversions gates (see cover photo). Two of the three diversion gates are motorized and can be controlled with the SCADA system. Level is measured with a float located in a stilling well on the right bank. The staff gage located on the left bank opposite the stilling well is sometimes difficult to read due to vegetation and is unusable at low flows.

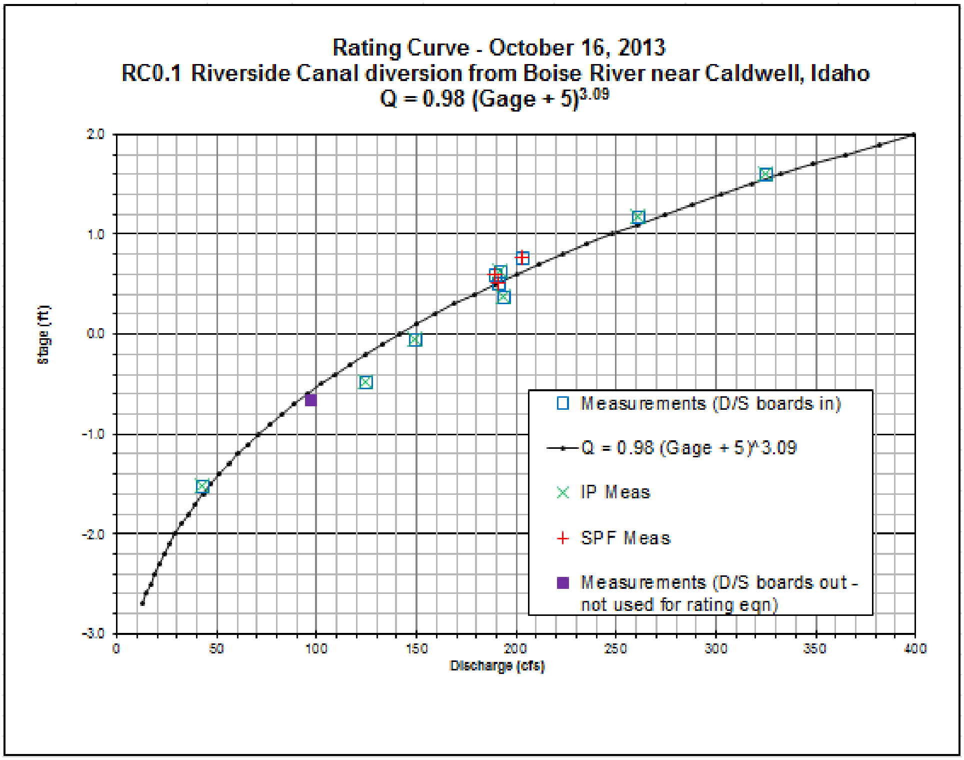
Table 3. Rating Equation for RC0.1.

$Q = 0.98 (\text{Gage} + 5)^{3.09}$

$Q = P (G - e)^{b}$

P (Q @ G-e+X=1)	0.98
e (gage ht @ Q=0)	0
b (slope of straight line)	3.09
X (adjustment for neg gage readings)	5

Figure 2. Rating Curve for RC0.1.



Notes:

Email by Mooney (5-13-13): canal flow computed with equation provided by King/SPF Water:

- OLD EQUATION: CFS=2.71828^((Canal_Hgt+8.6538)/1.7672)
- UPDATED 10-16-2013

RC2.3 – Canal at Water Master Gage

Description: This canal measuring location is a previously-rated concrete lined section. Level is measured with a level float located in a stilling well on the right bank with a staff gage located in the channel at the stilling well.

Table 4. Rating Equation for RC2.3.

Q = 38.4 (Gage)^1.63

Q = P (G - e)b

P (Q @ G-e=1)	38.4
e (gage ht @ Q=0)	0
b (slope of straight line)	1.63

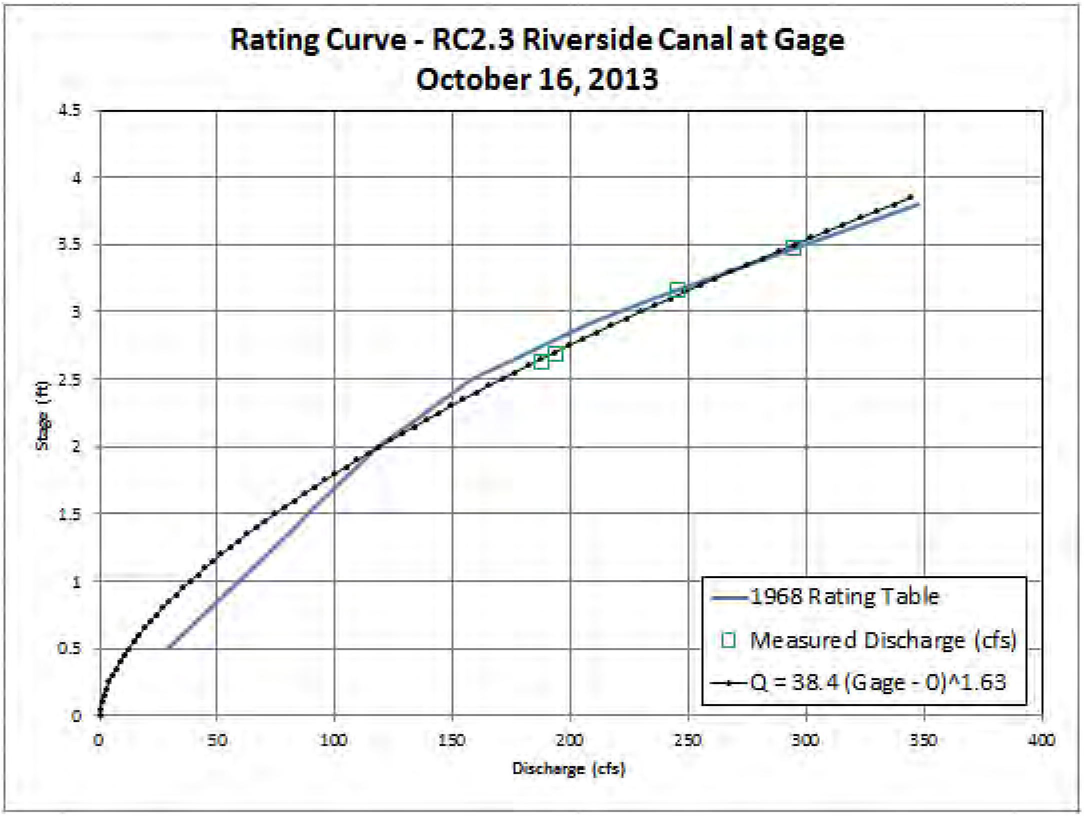


Figure 3. Rating Curve for RC2.3.

RC9.1 – Riverside Canal below Spill Gate#1 (Dixie)

Programed Equation for Canal Flow below Gate #1. The local program "calculated flow" below the "Canal gates" (downstream of the Spill Gate 1) uses the following equation:

> Gate_cfs = Cd * Area * [2 * g * (UP_canal_Hgt – (Gate_Hgt / 2))] ** 1/2
>
> Where:
>
> - Cd = 0.65
> - UP_Canal Hgt = water surface height upstream of gates
> - Gate_Hgt = gate opening (also used to calculate the Area)

Note that this is similar to the "differential head" equation below, but instead of the downstream head the ½ of the gate height (i.e., the center opening of the gate) is used.

Submerged Orifice Equations. USBR 2001 Excerpts:

> …the equation for computing the discharge of the standard submerged rectangular orifice … (using) … the difference between upstream and downstream heads or water surface elevations
>
> $$Q = C_d A (2g \Delta h)^{**}1/2$$
>
> where:
>
> $\Delta h = h_1 - h_2$, differential head
> $C_d = 0.61$, as determined experimentally
> A = the area of the orifice (ft^2)
> g = acceleration caused by gravity (ft/s^2)
> h_1 = upstream head (ft)
> h_2 = downstream head (ft)
>
> Notes: …the equation should not be used for heads less than 0.2 ft even with very precise head measuring devices..
>
> The effective discharge coefficient, Cd, is the product CcCvfCva, which has been determined experimentally to be 0.61 for rectangular irrigation weirs. The coefficient of contraction, Cc, accounts for the flow area reduction of the jet caused by the flow curving and springing from the orifice edges. The coefficient Cvf accounts for the velocity distribution and friction loss. The product, CcCvf, is sometimes called the coefficient of discharge, Cd. The coefficient Cva accounts for using the water head only and does not fully account for the velocity head of approach. This coefficient is near unity if all the requirements of section 4 are met.

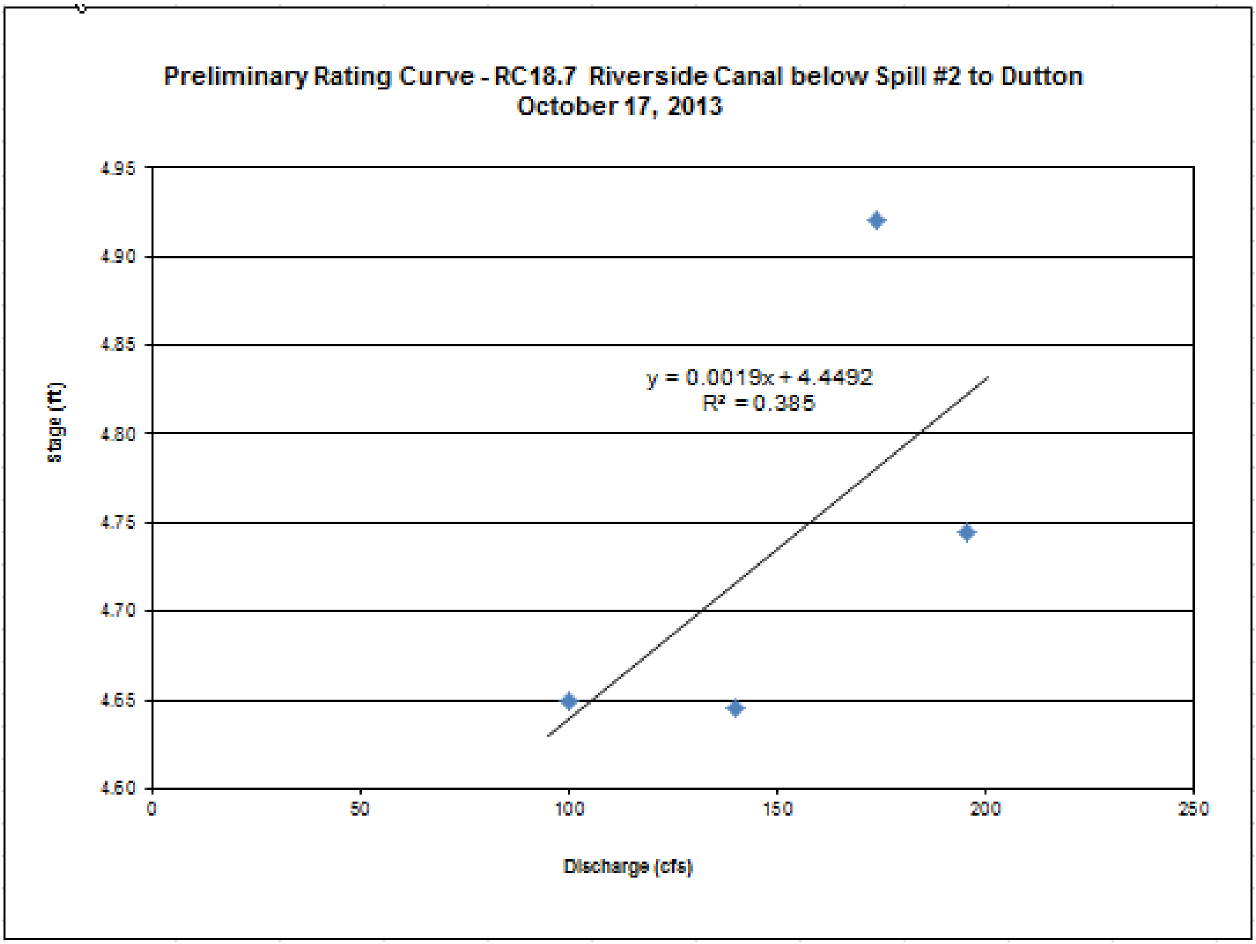
It should also be noted that the gates are not fully submerged, but that IPC flows measurements confirm use of the equation for the current operation of the gate and upstream spills.

RC18.7 – Canal below Spill Gate#2 (Dutton)

Description: An automated spill structure discharges excess flow to the East Alkali Drain system. Level floats in the canal upstream and downstream of the spill structure are used for automated control.

Spill discharge is based on the upstream canal height and gate opening per a BOR-developed equation. Two spot measurements indicate that calculated spill flow may range from 12% high to 10% low.

Canal discharge below the spill was measured four times. Sensor levels were recorded and used to prepare a preliminary rating, which does not appear satisfactory. This may be a poor location for a rated section. Installation of a staff gage at the stilling well location is recommended to monitor accurate operation of the level-float readings.



Preliminary Rating Curve - RC18.7 Riverside Canal below Spill #2 to Dutton
October 17, 2013

Figure 4. Preliminary Rating Curve for RC18.7.

RC19.4 – Canal at Opal Road (aka Allenders)

Description: This site is located downstream of Opal Road bridge canal crossing with a staff gage mounted to a concrete headwall on the right bank downstream of the bridge. Andy Bishop uses this site for managing the lower canal. One discharge measurement was made in 2013. Additional measurements are recommended to confirm sufficiency as a rated section. If rating is sufficient, a level logging device could be installed.

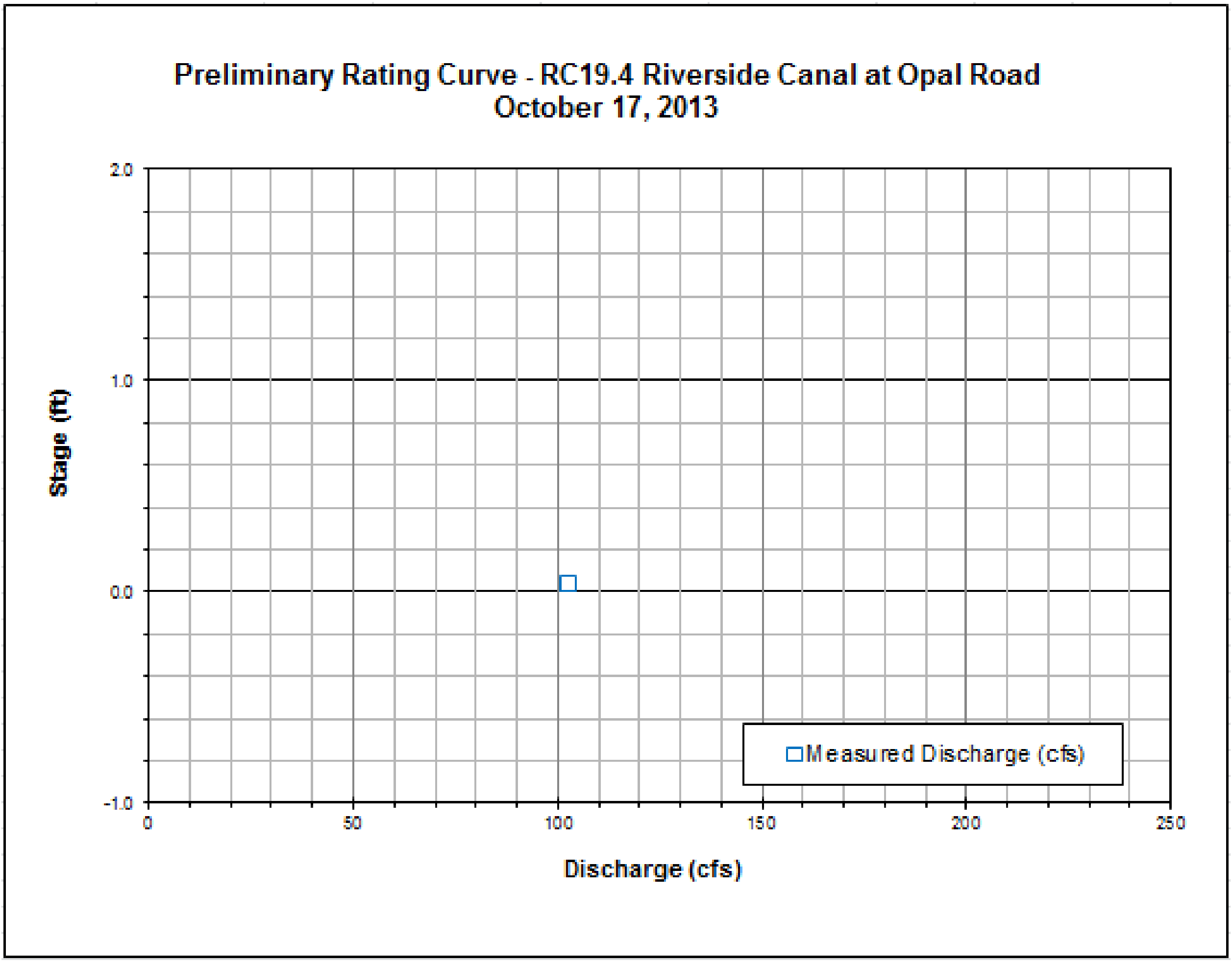


Figure 5. Preliminary Rating Curve for RC19.4.

RC23.9 – Canal below Spill Gate#3 (Holly)

Description: An automated spill structure discharges excess flow to the Holly/Singer Drain system. Level floats in the canal upstream and downstream of the spill structure are used for automated control.

Spill discharge is based on the upstream canal height and gate opening per a BOR-developed equation. One spot measurement indicates that calculated spill was approximately 5% low.

Canal discharge below the spill was measured four times. Sensor levels were recorded and used to prepare a preliminary rating, which does not appear satisfactory. This may be a poor location for a rated section. Installation of a staff gage at the stilling well location is recommended to monitor accurate operation of the level-float readings.

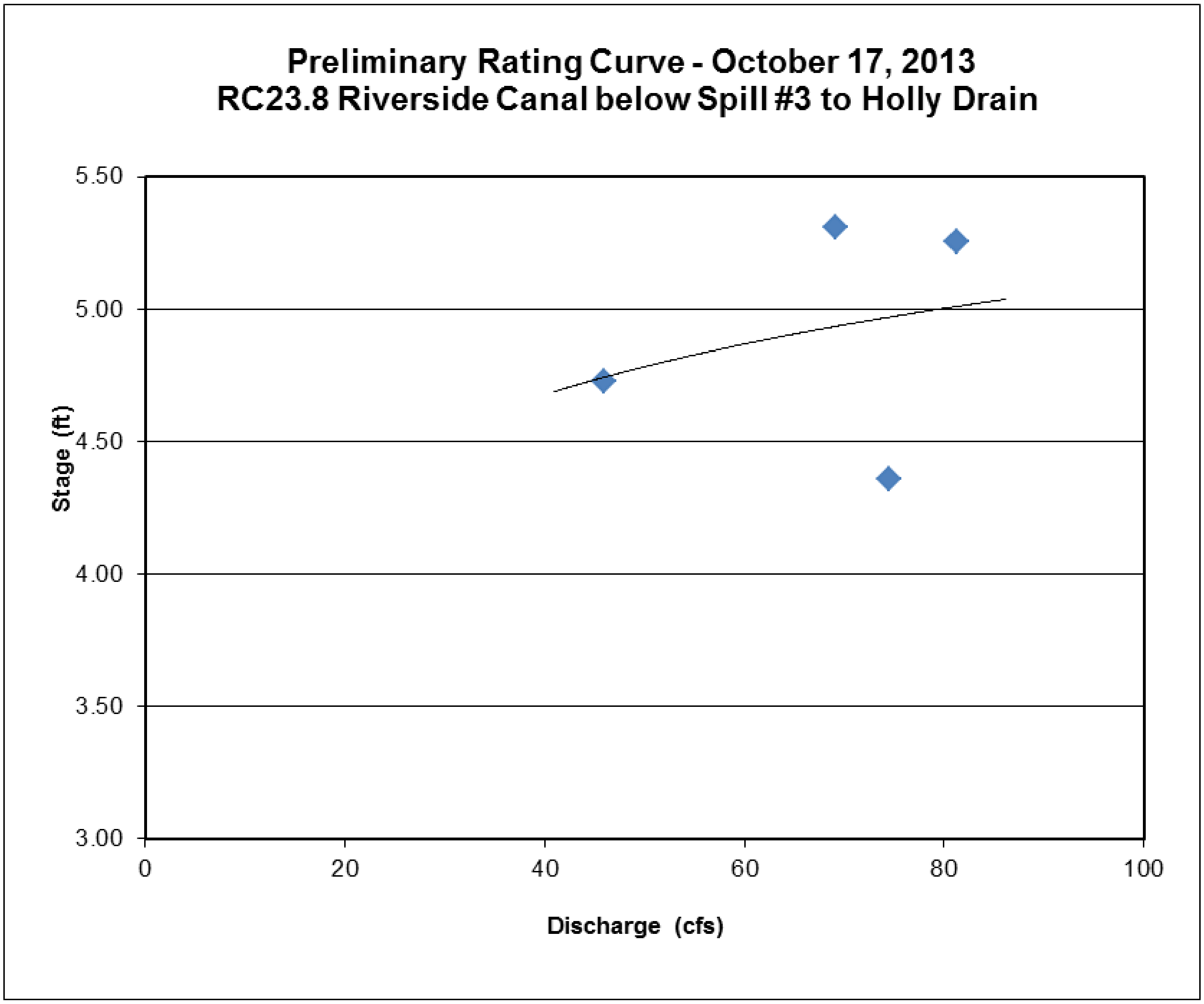


Figure 6. Preliminary Rating Curve for RC23.8.

RC30.8 – Canal End Spill

Description: This canal measuring location is an unlined canal reach located in a pool downstream of Pecham Road. A PVC stilling well is attached to a stake driven into the channel. The channel is susceptible to sediment deposition and vegetation growth and does not appear to be a satisfactory location for continued level monitoring. We recommend moving the measurement site approximately 0.6 miles upstream to the end spill check location.

Table 5. Rating Equation for RC30.8.

Q = 200 (Gage - 0.9)^2.52

$Q = P (G - e)^b$

P (Q @ G-e=1)	200
G (gage ht, ft)	
e (gage ht @ Q=0)	0.9
b (slope of straight line)	2.52

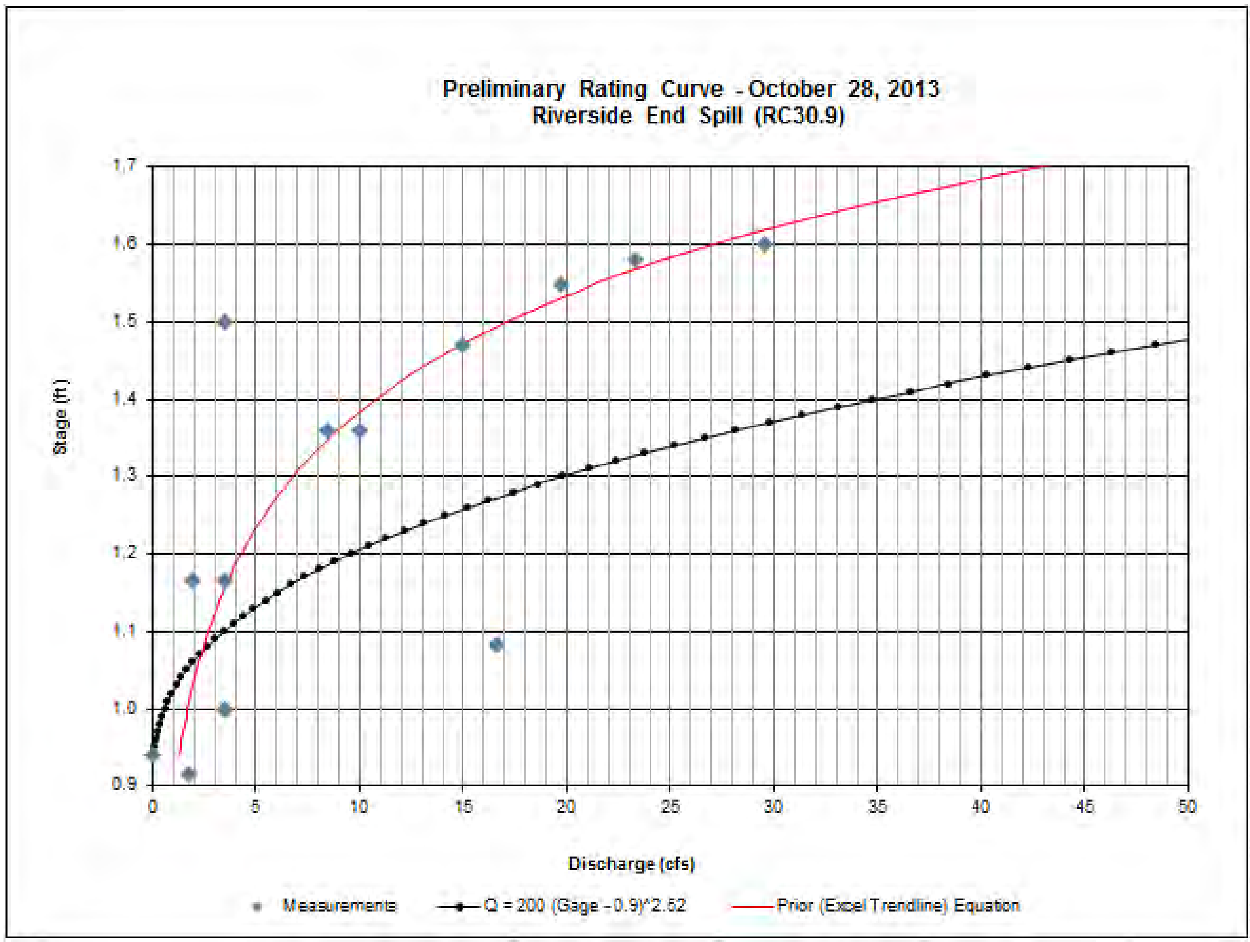


Figure 7. Preliminary Rating Curve for RC30.9.

Rating Curves for Tributaries

RC1.8 – Indian Creek at Kimball Rd (IC-1)

Description: This stream measuring location is Indian Creek at Kimball Road in downtown Caldwell. The site is equipped with a barometric-compensated submersible level sensor in a stilling well and staff gage on the right downstream bridge abutment.

Table 6. Rating Equation for RC1.8.

$$\boxed{Q = 11.13\ (\text{Gage} - 2)^{2.68}}$$

$Q = P\ (G - e)^{b}$

P (Q @ G-e=1)	11.13
G (gage ht + 5, ft)	
e (gage ht @ Q=0)	2
b (slope of straight line)	2.68

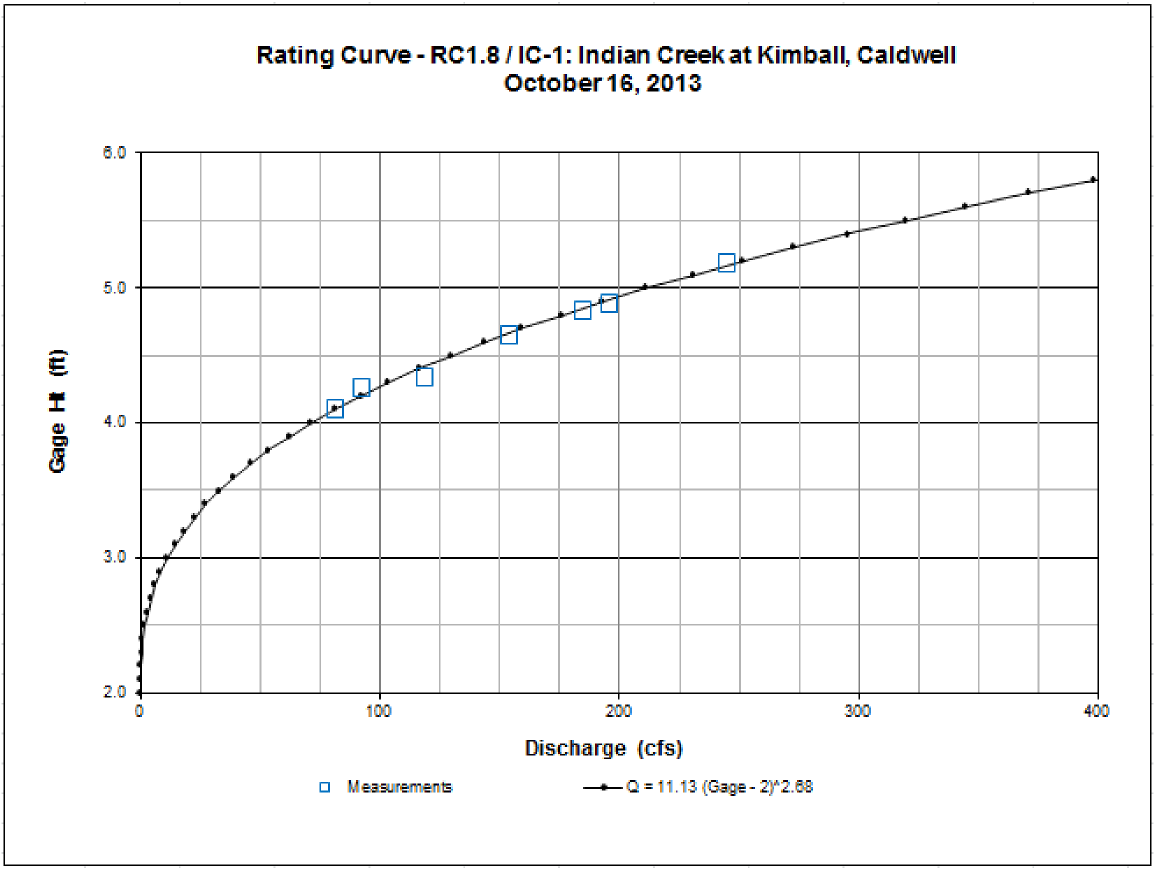


Figure 8. Rating Curve for RC1.8.

RC 8.1 – West End Drain (WED)

Description: This drain measuring location is upstream of the City of Greanleaf's treated wastewater outfall and approximately one mile upstream of the drain's discharge to Riverside Canal. The site is equipped with a barometric-compensated submersible level sensor and staff gage in a stilling well on the right channel bank.

Table 7. Rating Equation for RC8.1.

$Q = 23.2 (Gage - 2.4)^{1.52}$

$Q = P (G - e)^b$

P (Q @ G-e=1)	23.2
G (gage ht, ft)	
e (gage ht @ Q=0)	2.4
b (slope of straight line)	1.52

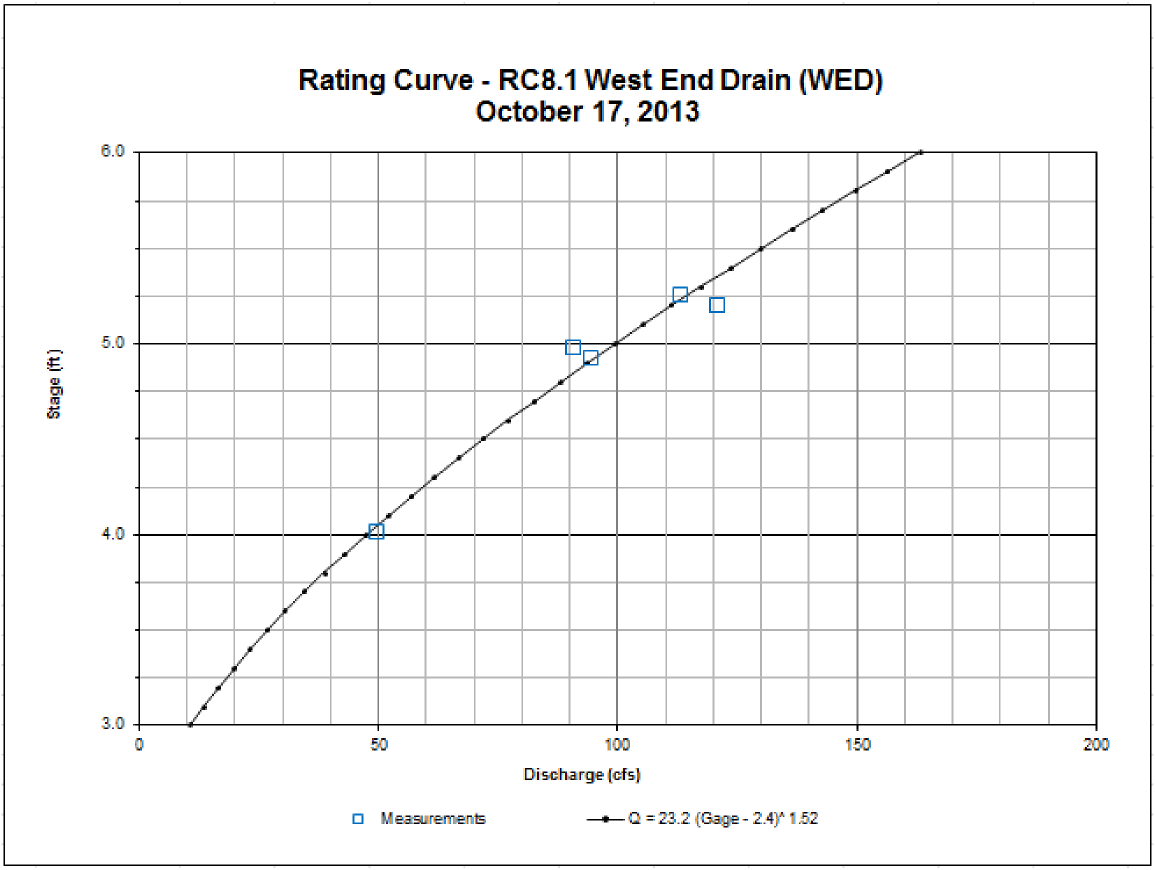


Figure 9. Rating Curve for RC8.1.

Rating Curves for Spills

RC 2.0 – Canal Spill#0 to Indian Creek

Description: This spill from Riverside Canal is automated. An existing staff gage located on the right bank below the spill is used for rating development. The prior 1972 rating no longer appears reliable and a revised rating is used.

Table 8. Rating Equation for RC2.0.

$$\mathbf{Q = 0.87\ (Gage + 1 + 0.65)^{5.02}}$$

$Q = P\ (G - e)^b$

P (Q @ G-e+X=1)	0.87
G (gage ht + X, ft)	
	-
e (gage ht @ Q=0)	0.65
b (slope of straight line)	5.02
X (adjustment for neg gage readings)	1

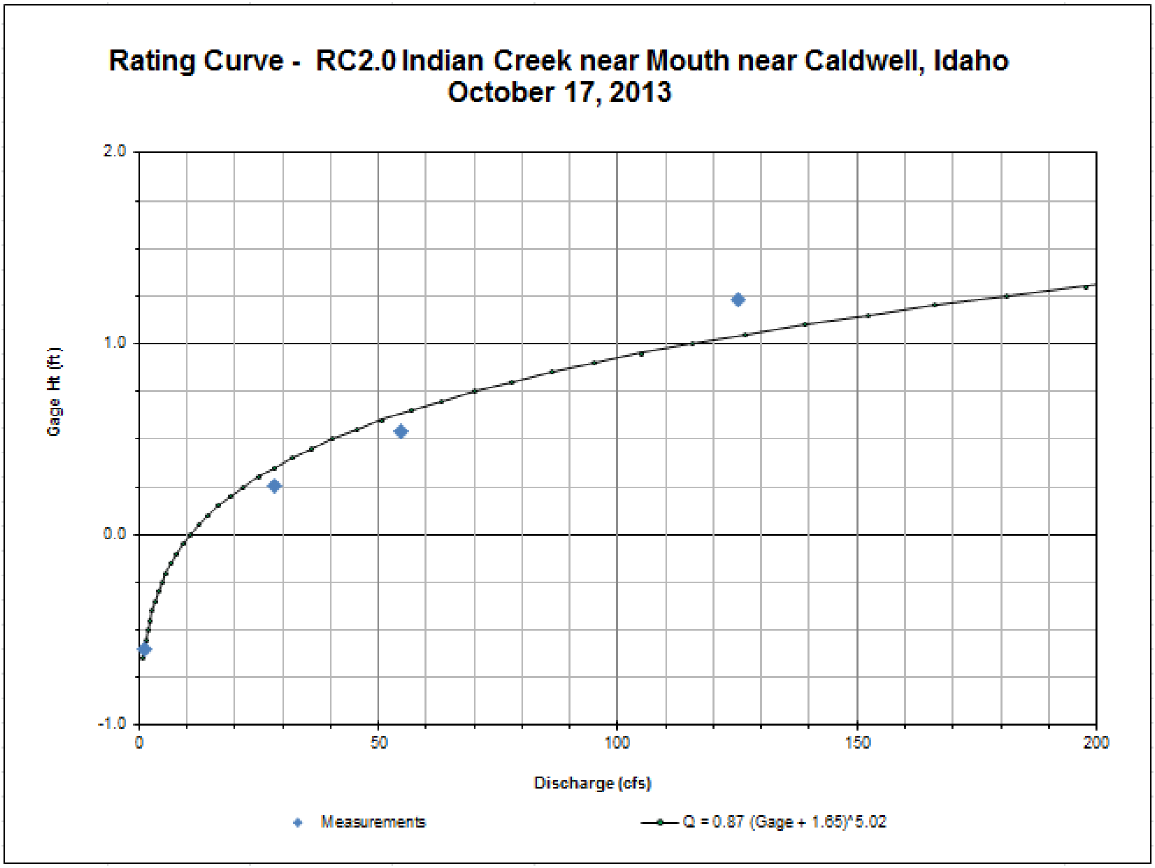


Figure 10. Rating Curve for RC2.0.

RC9.0 – Dixie Slough below Spill Gate#1

The USBR programed flow is adjusted using the linear relations shown on the graph. This indicates that an adjustment to the current flow calculations in needed.

Additional study of this measurement location and method is planned for 2014.

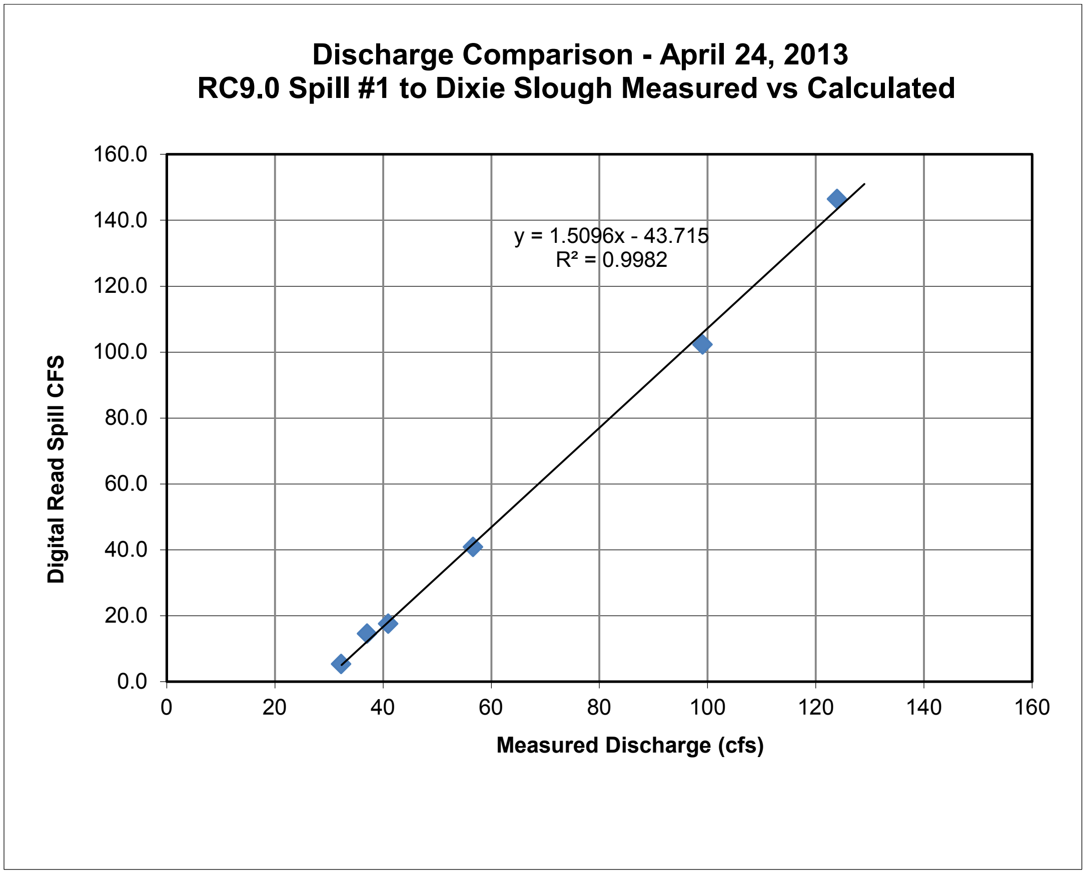


Figure 11. Discharge Comparison RC9.0 Spill #1 to Dixie Slough Measured vs Calculated.

Rating Curves for Upstream Diversions

RC1.6 Caldwell Residential Diversion

- No measurement set up; diversion is limited (< 5 cfs); requires "check" in canal.

RC3.2 Pioneer Dixie Diversion

Description: This diversion from Riverside Canal is measured in a rectangular concrete lined section about 125 feet below the headgate. A staff gage is mounted on the right wall. The section is heavily silted and vegetated; cleaning and re-calibration of the section is recommended. A PVC pipe stilling well is mounted to the left channel wall and equipped with level and atmospheric loggers.

Table 9. Rating Equation for RC3.2.

Q = 24.14 (Gage)^$^{0.41}$

$Q = P (G - e)^b$

P (Q @ G-e=1)	24.14
G (gage ht, ft)	
e (gage ht @ Q=0)	0
b (slope of straight line)	0.41

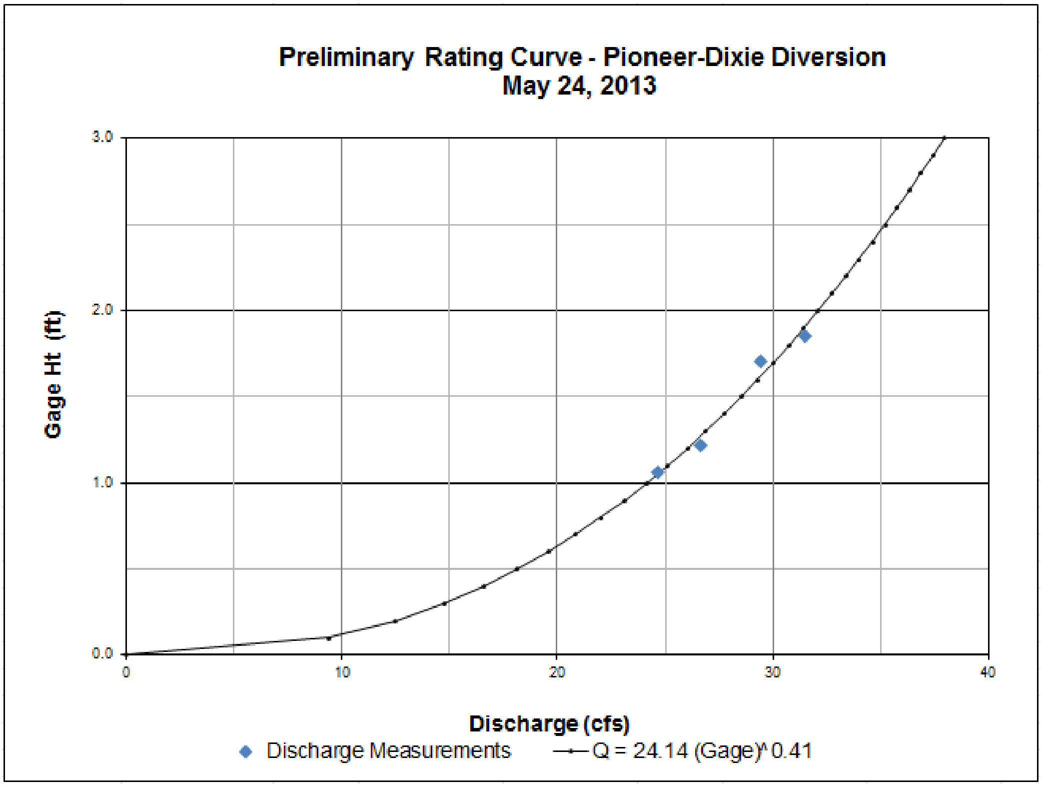


Figure 12. Preliminary Rating Curve for Pioneer-Dixie Diversion.

RC6.3 Cheney Diversion

Description: This diversion from Riverside Canal is measured in an unlined rated section about 100 feet below the headgate. A staff gage was set in the channel in 2013. The channel suffers from heavy vegetation growth and sediment deposition that appears to affect the rating as the season progresses.

Table 10. Rating Equation RC6.3.

$Q = 2.3\ (\text{Gage} + 2)\text{^}^{1.60}$

$Q = P\ (G - e)^b$

P (Q @ G-e+X=1)	2.3
G (gage ht + X, ft)	
e (gage ht @ Q=0)	0
b (slope of straight line)	1.60
X (adjustment for neg gage readings)	2

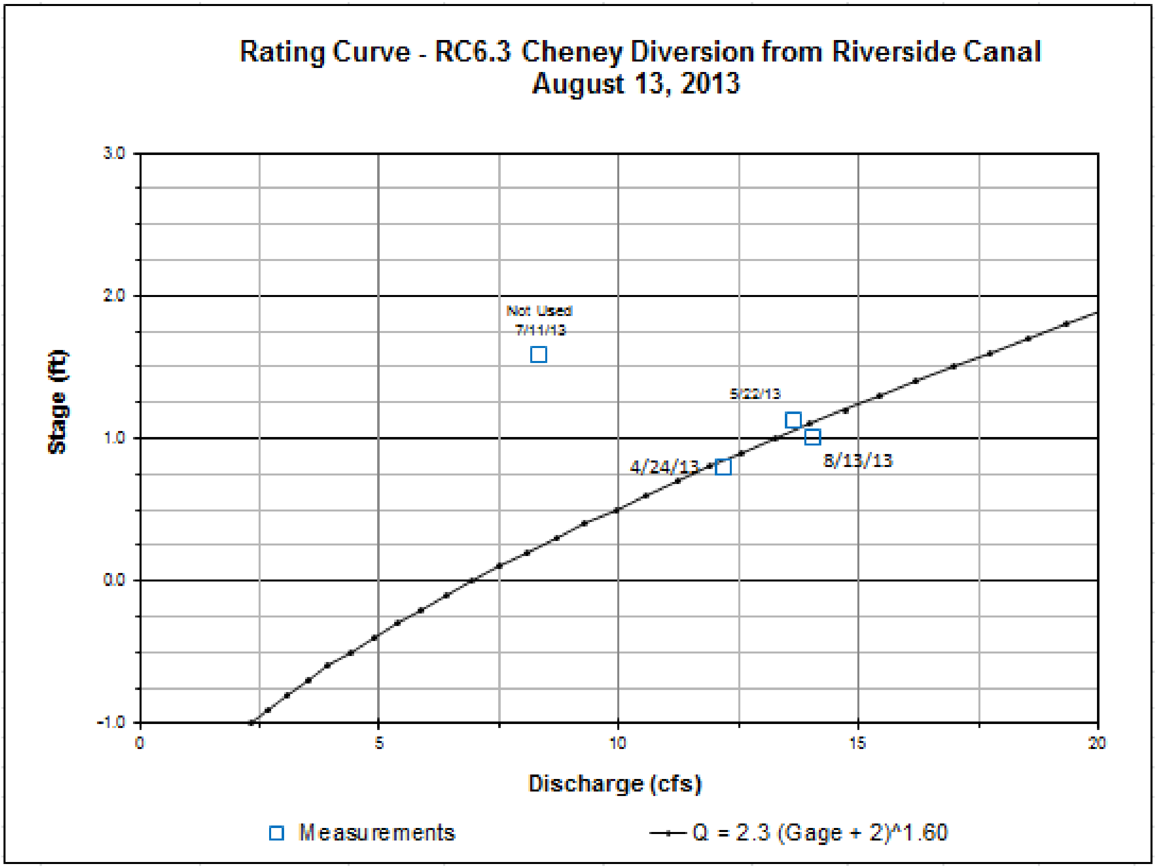


Figure 13. Rating Curve for RC6.3.

Exhibit 7.2-3

Oregon water quality trading rule provisions

The following comparative table includes all of the Oregon water quality trading rule provisions (left column), and an explanation of how the Riverside Operational Water-Quality Improvement Project (ROWQIP) addresses those provisions, where applicable. In the right column, references have been made to the overall 401 application (IPC 401 Application), section 7.2.1 and associated Exhibits 7.2-1 and 7.2-2 contained within the 401 application (ROWQIP), and the Snake River-Hells Canyon TMDL (SR-HC TMDL). Consistent with its stated purpose, the 2016 Oregon water quality trading Internal Management Directive (Trading IMD) has been used to supplement explanations where helpful.[1]

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340-039-0001 **Purpose and Policy** (1) Purpose. This rule implements ORS 468B.555 to allow entities regulated under the Clean Water Act to meet pollution control requirements through water quality trading. This rule establishes the requirements for water quality trading in Oregon. (2) Policy. The Oregon Department of Environmental Quality may approve water quality trading only if it promotes one or more of the following Environmental Quality Commission policies: (a) Achieves pollutant reductions and progress towards meeting water quality standards; (b) Reduces the cost of implementing Total Maximum Daily Loads (TMDLs); (c) Establishes incentives for voluntary pollutant reductions from point and nonpoint sources within a watershed; (d) Offsets new or increased discharges resulting from growth; (e) Secures long-term improvement in water quality; or (f) Results in demonstrable benefits to water quality or designated uses the water quality standards are intended to protect.	• (1): The purpose statement in the trading rules aligns with intent of Riverside Operational Water-Quality Improvement Project (ROWQIP) [IPC 401 Application, § 7.2, page 196]. • (2): The ROWQIP promotes at least one of the listed EQC policies, and is therefore with DEQ's discretion to approve consistent with these rules. Specifically, the ROWQIP helps achieve phosphorus loading reduction above the Hells Canyon Complex (HCC), to meet corresponding required loads in Brownlee Reservoir to meet the DO load allocation required in the SR-HC TMDL [IPC 401 Application, § 7.2.1.1.1. pg 198]. It also establishes incentives for voluntary pollutant reductions by the Riverside Irrigation District.
340-039-0003 **Water Quality Trading Objectives** Water quality trading authorized under this rule must: (1) Be consistent with anti-degradation policies; (2) Not cause or contribute to an exceedance of water quality standards; (4) Be designed to result in a net reduction of pollutants from participating sources	• (1, 2, 4, and 8): Oregon's antidegradation policy is found in OAR 340-041-0004. As stated in the Oregon trading IMD, Oregon's anti-degradation policy generally prohibits the lowering of existing

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[1] "DEQ expects the majority of trading activity to be driven by the need to comply with NPDES permit requirements developed to implement a total maximum daily load (TMDL).This IMD is, therefore, primarily focused on water quality trades between nonpoint sources and NPDES permittees to comply with the latter's water quality-based effluent limitations. To the extent it is relevant and helpful, this IMD may also be used by DEQ staff to evaluate trading proposals that are part of the water quality certification of a federal permit or other approval issued under Clean Water Act (CW A) section 401 and Oregon Administrative Rules (OAR) chapter 340, division 048 (referred to throughout this IMD as a "401 WQC")." ODEQ, Trading IMD, at 6.

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in the trading area; (8) Not create localized adverse impacts on water quality and existing and designated beneficial uses.	water quality. Trading IMD, at 9. In the 2003 federal Trading Policy, U.S. EPA states that it "does not believe that trades and trading programs will result in 'lower water quality' as that term is used in 40 CFR § 131.12(a)(2) ... when the trades or trading programs achieve a no net increase of the pollutant traded and do not result in any impairment of designated uses." Trading IMD, at 9. In line with EPA guidance, the Trading IMD instructs DEQ staff to ensure that trades are designed to result in a net reduction of pollutants in the trading area as required in OAR 340-039-0003(4), and that the proposed ROWQIP project does not create localized adverse impacts on water quality and existing and designated beneficial uses as required in OAR 340-039-0003(8). Trading IMD, at 9. The 401 Application has been designed to avoid localized DO impacts at the ROWQIP project location. The ROWQIP is designed to improve downstream water quality, and therefore conditions for beneficial uses, in waters that previously received highly degraded water. By minimizing the canal spill of water that is severely degraded, water quality conditions for beneficial uses in downstream waters—which were historically receiving this highly degraded water—should be improved. Prior to implementation, downstream water bodies received larger loading of pollutants and generally water of poor quality.
(3) Be consistent with local, state, and federal water quality laws; (4) [*excerpted and addressed above with explanation for subsection (1)*]	• (3): The ROWQIP has been designed by IPC, in cooperation with Riverside Irrigation District, to be consistent with all existing local, state, and federal water quality laws.
(5) Be designed to assist the state in attaining or maintaining water quality standards; (6) Be designed to assist in implementing TMDLs when applicable;	• (5,6): The ROWQIP has been designed to address IPC's DO allocation as defined in the SR-HC TMDL [IPC 401 Application, § 7.2; SR-HC TMDL, § 4.0.2.8]. IPC is proposing the ROWQIP to implement the DO load allocation assigned to IPC in the SR-HC TMDL. The RIDOWQIP is expected to fully address the 1,125 ton per year DO load allocation assigned to Brownlee Reservoir in the SR-HC TMDL.
(7) Be based on transparent and practical Best Management Practices (BMPs) quality standards to ensure that water quality benefits and credits are generated as planned; and	• (7): The ROWQIP is designed to be "consistent with generally accepted quality standards and guidelines for canal operations,"

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(8) [*excerpted and addressed above with explanation for subsection (1)*]	the detail provided on ROWQIP design and operations should provide a sufficient substitute for general quality standards which are designed to inform the implementation of multiple projects [IPC 401 Application, § 7.2.1.1.1; Canal Operating Guidelines Ex. 7.2-2, § 1].
340-039-0005 **Definitions** (1) Best Management Practices (BMPs): In-water or land-based conservation, enhancement or restoration actions that will reduce pollutant loading or create other water quality benefits. BMPs include, but are not limited to, structural and nonstructural controls and practices and flow augmentation. (2) BMP Quality Standards: Specifications for the design, implementation, maintenance and performance tracking of a particular BMP that ensure the estimated water quality benefits of a trading project are achieved, and that allow for verification that the BMP is performing as described in an approved trading plan. (3) Credit: A measured or estimated unit of trade for a specific pollutant that represents the water quality benefit a water quality trading project generates at a location over a specified period of time, above baseline requirements and after applying trade ratios or any other adjustments. (4) Public Conservation Funds: Public funds that are targeted to support voluntary natural resource protection or restoration. Examples of public conservation funds include United States Department of Agriculture (USDA) cost share programs, United States Environmental Protection Agency (EPA) section 319 grant funds, United States Fish and Wildlife Service Partners for Fish and Wildlife Program funds, State Wildlife Grants, and Oregon Watershed Enhancement Board restoration grants. Public funds that are not considered public conservation funds include: public loans intended to be used for water quality infrastructure projects, such as Clean Water State Revolving Funds, USDA Rural Development funds, and utility sewer storm water and surface water management fees.	• (1): The ROWQIP is an in-water action that involves the automated operation of the irrigation canal delivery system in order to reduce phosphorus loading the Boise and Snake rivers. Automation minimizes the withdrawal of higher quality water and maximizes the reuse of lower quality water. • (2): The ROWQIP proposal includes specifications for project designs, implementation actions, maintenance actions, monitoring, and performance tracking [IP 401 Application, Exhibit 7.2-2: Riverside Operational Water-Quality Improvement Project (ROWQIP)]. • (3): In the ROWQIP, the equivalent to a credit is a phosphorus "load reduction", in units of pounds per day, which will be estimated based on changes in canal operations [IPC 401 Application, § 7.2.1.1.3]. Reductions will be calculated annually from measured data and will continue to be evaluated based on monitoring as outlined in the proposal. Based on the results presented in the application, it is reasonable to assume that continued operation of the ROWQIP should meet DO obligations outlined in SR-HC TMDL [IPC 401 Application, § 7.2.1.1.2]. • (4): In the ROWQIP, IPC clearly states its intention to contract directly with Riverside Irrigation District. While not stated explicitly in the 401 Application, IPC will not use public conservation funds to support the ROWQIP [IPC 401 Application, § 7.2.1.1.8].

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(5) Trading Area: A watershed or other hydrologically-connected geographic area, as defined within a water quality management plan adopted for a TMDL, trading framework or trading plan. A trading area must encompass the location of the discharge to be offset, or its downstream point of impact, if applicable, and the trading project to be implemented.	• (5): While not stated explicitly in the 401 Application, the trading area for the ROWQIP is the “district boundary” for Riverside Canal [IPC 401 Application, § 7.2.1.1.1; page 197].
(6) Trading Baseline: Pollutant load reductions, BMP requirements, or site conditions that must be met under regulatory requirements in place at the time of trading project initiation.	• (6): The 401 Application does not explicitly address the regulatory baseline requirements in Idaho and Oregon that could apply to the ROWQIP. However, there are no current regulatory requirements that Riverside Irrigation District change its canal operations or reduce phosphorus loads.
(7) Trading Framework: A description contained in a TMDL water quality management plan, or water pollution control plan, adopted by rule or issued by order under ORS 468B.015 or 468B.110, that identifies trading elements applicable to one or more entities in a trading area.	• 7): No such framework exists for the ROWQIP.
(8) Trading Plan: A plan that describes the design, implementation, maintenance, monitoring, verification and reporting elements of a water quality trade.	• (8): The 401 Application description of the ROWQIP and its associated appendices include and address the elements of a trading plan definition included in the rules [IPC 401 Application, § 7.2, ROWQIP Exhibits 7.2-1 and 7.2-2].
(9) Trading Project: A site-specific implementation of a trading plan used to generate credits.	• (9): The ROWQIP is the equivalent of a trading project designed to address the DO load allocation assigned to IPC in the SR-HC TMDL [IPC 401 Application, § 7.2.1.1].
(10) Trading Ratio: A numeric value used to adjust the number of credits generated from a trading project, or to adjust the number of credits that a credit user needs to obtain.	• (10): While trading ratios are not specifically referenced in the ROWQIP, the concept is addressed through the Equivalent Phosphorus Load calculations for ROWQIP [IPC 401 Application, § 7.2.1.1.2], and the difference between the project benefit and compliance need [IPC 401 Application, §§ 7.2.1.1.2 (15,000 lbs phosphorus needed; Ex. 7.2-2 – Appendix 2; § 7.2.1.1.4.2 (31,920 lbs produced from project in 2014)]. Based on the information provided in the application exhibit document describing the movement and cycling of phosphorus within the Snake River and Brownlee Reservoir, no attenuation ratio is necessary [IPC 401 Application, 7.2-2 Exhibit].
(11) Verification: A process to confirm and document that a trading project is implemented and performing according to the approved trading plan and BMP quality standards, and to confirm the quantity of credits generated by the trading project.	• (11): The ROWQIP will include a process for third-party verification “if required” by HCC CWA §401 certification requirements [IPC 401 Application, § 7.2.1.1.5; Monitoring and Reporting].
(12) Water Quality Benefit: The quantifiable water quality improvement or net	

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pollutant reduction that can be reasonably attributed to BMPs at a trading project site. (13) Water Quality Trading or Trade: The use of water quality credits generated at one location in a trading area to comply with water quality-based requirements at another location within the trading area.	• (12): The ROWQIP defines "phosphorus reductions" similarly to and consistent with the definition of water quality benefits in the rule [IPC 401 Application, § 7.2.1.1.3, see Equation 2]. • (13): The ROWQIP is consistent with the definition of trading found in the OARs. The ROWQIP is also consistent with the potential implementation strategy specifically identified in the SR-HC TMDL, which specifically identifies upstream phosphorus reductions as a viable option for addressing the DO load allocation in Brownlee Reservoir [SR-HC TMDL, §4.0.2.8].
340-039-0015 **Eligibility** (1) An entity regulated by a National Pollutant Discharge Elimination System (NPDES) permit or a federal permit or license for which DEQ has issued a water quality certification pursuant to Clean Water Act section 401 and OAR chapter 340, division 048 (a "401 water quality certification") is eligible to enter into a trade. (2) Water quality parameters eligible for water quality trading: (a) DEQ may authorize water quality trading for the following water quality parameters: temperature, ammonia, sediment, total suspended solids, and nutrients and other oxygen-demanding substances, including biochemical oxygen demand. (b) Water quality trading for pollutants that are toxic and either persist in the environment or accumulate in the tissues of humans, fish, wildlife or plants is prohibited, except if trading is an element of a pollution reduction plan in a variance that has been issued by DEQ or the EQC and approved by EPA pursuant to OAR 340-041-0059. (c) Water quality trading authorized under this division may not be used to meet technology-based effluent limitations. (d) DEQ may authorize trading for other water quality parameters on a case-by-case basis provided it does not cause or contribute to an exceedance of a water quality standard. (3) Water bodies where trading may occur: (a) High quality waters. DEQ may authorize trading to maintain or improve water quality in water bodies that meet water quality standards, including but not limited to, trading projects designed to offset new or increased pollutant loads. (b) Water quality limited waters. DEQ may authorize trading where it is consistent with the water quality management plan in a TMDL or other water pollution control plan adopted by rule or issued by order under ORS 468B.015 or 468B.110,	• (1): As a licensee seeking a CWA section 401 certification from DEQ, IPC is eligible to enter into a trade. • (2a): The ROWQIP only addresses phosphorus [IPC 401 Application, § 7.2], which is an approved pollutant for trading under the rule. • (2b): The ROWQIP does not propose any actions that implicate pollutants described in Subsection (2)(b) of the rule. • (2c): This provision applies only to point sources and therefore does not apply to the HCC, a nonpoint source. • (2d): IPC is not seeking DEQ approval of any parameters that have not yet been approved in the rule. • (3): The SR-HC TMDL—which was established to address, among other things, dissolved oxygen impairment in Brownlee Reservoir from July 1-September 7—assigned a load allocation to IPC. The SR-HC TMDL water quality management plan (WQMP) from the state of Oregon [TMDL, § 6.1] describes the strategies that will be used to implement the SR-HC TMDL. Pursuant to WQMP,

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or in water bodies: (A) That are water quality limited but not subject to a TMDL; or (B) Where trading projects are designed to achieve progress towards meeting water quality standards before or while a TMDL is being developed. (4) BMPs eligible for credit generation must be quantifiable and have BMP quality standards.	designated management agencies (DMAs) then submit "implementation plans" (IPs) outlining their respective implementation strategies. In the WQMP, trading is noted as one strategy that can be pursued [TMDL, § 6.1, Ch. 1]. IPC is identified as a DMA, and is instructed to "comply with conditions of Section 401 WQ Certification." [TMDL, § 6.1, Ch. 5]. • (4): The ROWQIP includes a complete description of project design and implementation which serve as quality standards for the BMP from which phosphorus reductions will be measured [Ex. 7.2-2, Appendix 3]. Sediment reductions from these projects will be quantified in pounds of phosphorus per day, using a mass balance approach and measured data [IPC 401 Application, § 7.2.1.1.3].
340-039-0017 **Regulatory Mechanisms for Water Quality Trading** (1) NPDES Permitting: (a) Trading in Permits: DEQ may authorize water quality trading in an NPDES permit to meet water quality-based effluent requirements. (b) Compliance Schedules. Water quality trading may be included in an NPDES permit compliance schedule only if the trade is consistent with the requirements of OAR 340-041-0061 and any applicable regulations of the EPA. (c) Permit Variances. Water quality trading may be included as a component of the pollution reduction plan in a variance issued under OAR 340-041-0059. (2) 401 Water Quality Certifications. DEQ may condition a 401 water quality certification based on water quality trading consistent with this division. (3) Annual Reporting. The regulated entity must submit an annual report to DEQ that describes trading plan implementation and performance over the past year. The annual report must include information specific to each trading project implemented including: (a) The location of each trading project and BMPs implemented in the preceding year; (b) The trading project baseline; (c) The trading ratios used; (d) Trading project monitoring results; (e) Verification of trading plan performance including the quantity of credits acquired from each trading project, and the total quantity of credits generated under the trading plan to date;	• (1): The contents of this subsection are inapplicable because the ROWQIP is not related to NPDES permitting. • (2): ODEQ may condition a 401 certification upon consistency with the water quality trading rules. • (3a-f): The ROWQIP requires submission of annual monitoring reports to the DEQs [IPC 401 Application, § 7.2.1.1.5]. ROWQIP annual reports will be "consistent with regional and national trading programs" and of "sufficient quality to support ODEQ and IDEQ determination of compliance" [IPC 401 Application, § 7.2.1.1.5]. In order to meet Oregon Water Quality Trading Rule requirements, the elements required for Annual Reporting will be included in Annual ROWQIP reports.

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(f) A demonstration of compliance with OAR 340-039-0040(4), if applicable; and (g) Adaptive management measures implemented under the trading plan, if applicable.	- (3g): Adaptive management is a component of the ROWQIP [IPC 401 Application, § 7.2.1.1.7]. Specific elements of the monitoring plan, monitoring approach, and procedures are described in *Riverside Canal Water Quality Project Monitoring Status Report for 2011, 2012, and 2013* [IPC 401 Application, Exhibit 7.2-2] and *Riverside Operational Water-Quality Improvement Project (ROWQIP), 2014 annual report* [IPC 401 Application, Exhibit 7.2-1].
340-039-0020 **Trading Frameworks** (1) DEQ may establish one or more trading frameworks in a TMDL water quality management plan or water pollution control plan adopted by rule or issued by order under ORS 468B.015 or ORS 468B.110. If established, a trading framework must specify pollutants that are eligible for trading, the trading area, any priority areas, as well as regulations and applicable TMDL allocations and implementation schedules that will be used to derive trading baseline. (2) DEQ must provide an opportunity for public notice and comment before issuing a trading framework. (3) A trading framework is not required in order for DEQ to approve a water quality trading plan.	- (1): ODEQ has not established a trading framework for the Snake River-Hells Canyon TMDL. - (2): As no trading framework exists for this TMDL area, this provision does not apply. - (3): As noted in the rules, a trading framework is not required for DEQ to approve a trading plan.
340-039-0025 **Requirements of a Water Quality Trading Plan** (1) An eligible entity may not engage in water quality trading unless DEQ has reviewed and approved that entity's water quality trading plan. The use of credits will be authorized after all elements of a DEQ-approved trading plan required by subsection (5) of this rule are incorporated as enforceable conditions of an NPDES permit issued under OAR chapter 340 division 045 or a 401 water quality certification issued under OAR chapter 340 division 048. (2) For NPDES permittees trading may be proposed as part of a permittee's application for permit renewal or modification. (3) DEQ must provide an opportunity for public notice and comment on a trading plan before approving the trading plan. DEQ may amend the trading plan or require amendments to the trading plan prior to approval. Individual trading projects must be consistent with an approved trading plan. Individual trading projects do not require separate public notice and comment. (4) A trading plan must be consistent with an applicable DEQ-issued trading	- (1): ODEQ will review the proposed ROWQIP as part of the 401 certification process. Although the ROWQIP is not proposed as a trading program, it is fully consistent with the Oregon water quality trading rules. The NPDES permit specific language is inapplicable. - (2): This subsection is inapplicable because no NPDES permit. - (3): DEQ will provide a public comment opportunity on the draft 401 certification [OAR 340-048-0027], which will include reference to the ROWQIP. - (4): This subsection is inapplicable because no trading framework.

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framework if such a framework exists at the time DEQ approves the trading plan. (5) A trading plan must include all of the following elements and a description of how the elements were derived or calculated:	
(a) The parameter for which water quality trading is proposed;	• (5a): The ROWQIP is focused on phosphorus reductions, measured in pounds of phosphorus per day [IPC 401 Application, § 7.2].
(b) Trading baseline: A trading plan must identify any applicable regulatory requirements from OAR 340-039-0030(1) that apply within the trading area and that must be implemented to achieve baseline requirements;	• (5b): The 401 Application does not explicitly address the regulatory baseline requirements in Idaho and Oregon that could apply to the ROWQIP. However, there are no current regulatory requirements that Riverside Irrigation District change its canal operations or reduce phosphorus loads. The ROWQIP description focuses on the legal requirements of a water right and associated contractual agreements [IPC 401 Application, § 7.2.1.1.3.2].
(c) Trading area: A description of the trading area including identification of the location of the discharge to be offset, its downstream point of impact, if applicable, where trading projects are expected to be implemented, and the relationship of the trading projects to beneficial uses in the trading area;	• (5c): The ROWQIP is intended to address dissolved oxygen conditions in Brownlee Reservoir [IPC 401 Application, § 7.1.1]. The ROWQIP will be implemented in the Riverside Irrigation District and will redirect irrigation return flows to be re-used on agricultural fields instead of directly returning them to the Snake and Boise rivers. The Project Description includes a description of the project site location and the affected program area [IPC 401 Application, § 7.1.1]. The Riverside Irrigation District and the project location are both visible in the map in Figure 7.2-1 of the 401 Application. The ROWQIP is designed to improve downstream water quality, and therefore conditions for beneficial uses, in waters that previously received highly degraded water.
(d) BMPs: A description of the water quality benefits that will be generated, the BMPs that will be used to generate water quality benefits, and applicable BMP quality standards;	• (5d): The ROWQIP describes how "phosphorus reductions" will be generated [IPC 401 Application, § 7.2.1.1.1] and describes the improved canal management as the BMP that will be used to generate those reductions [IPC 401 Application, § 7.2.1.1.3]. The detailed project design and operation information, as well as maintenance effectively serve as quality standards for this project [IP 401 Application, Exhibit 7.2-2: Riverside Operational Water-Quality Improvement Project (ROWQIP) development report].
(e) Trading ratios: A description of applicable trading ratios, the basis for each applicable trading ratio, including underlying assumptions for the ratio, and a statement indicating whether those ratios increase or decrease the size of a credit	• (5e): No trading ratios are explicitly identified for the ROWQIP, however the project includes an equivalency ratio, and an unidentified, but significant, net pollution reduction ratio [IPC 401

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obligation or the number of credits generated from an individual trading project; (f) Credits: A description of the credits needed to meet water quality-based requirements of an NPDES permit or 401 water quality certification, including: (A) Quantity and timing: The number of credits needed and any credit generation milestones, including a schedule for credit generation; (B) Methods used: How credits will be quantified, including the assumptions and inputs used to derive the number of credits; and (C) Duration of credits: A description of the length of time credits are expected to be used.	Application, § 7.2.1.1.2; Ex. 7.2-2 – Appendix 2; § 7.2.1.1.4.2]. • (5f): The 401 Application calculates the "dissolved oxygen supplementation" (in tons) needed to address DO concerns in Brownlee Reservoir and calculates an equivalent seasonal phosphorus load reduction amount using stoichiometry [IPC 401 Application, § 7.2.1.1.2]. The mass balance quantification method used, including assumptions and details on inputs, is described in the Application [IPC 401 Application, § 7.2.1.1.3; Ex 7.2-2-Appendix 3]. The time period of credit generation (duration) is "183 days beginning April 15 and extending to October 15", which is twice the length of the DO critical period from July 1-September 7 [IPC 401 Application, § 7.2.1.1.2; Ex 7.2-2 Appendix 2]. Phosphorus reductions from the ROWQIP are counted daily and averaged over the irrigation season to generate an average annual load reduction. The time period of credit generation is "183 days beginning April 15 and extending to October 15" [IPC 401 Application, § 7.2.1.1.4.2]. Phosphorus reductions are generated during the irrigation season.
(g) Monitoring. The trading plan must include a description of the following: (A) Proposed methods and frequency of trading project BMP monitoring; and (B) Proposed methods and frequency of how water quality benefits generated by a trading project will be monitored;	• (5g): The 401 Application description of monitoring and reporting anticipates that "a detailed monitoring and reporting plan" will be submitted to ODEQ and IDEQ within 1 year of the new license issuance for the HCC" [IPC 401 Application, § 7.2.1.1.5]. This monitoring plan will include details on methods and frequency for monitoring the canal operations and for the phosphorus reductions that it generates. Exhibits 7.2-1 and 7.2-2 include information on monitoring, including methodologies, that has been completed in advance of the new license, and is expected to help form the basis of developing future monitoring documentation [IPC 401 Application, Exhibit 7.2-1: *Riverside Operational Water-Quality Improvement Project (ROWQIP), 2014 annual report*; IPC 401 Application, Exhibit 7.2-2: *Riverside Canal Water Quality Project Monitoring Status Report for 2011, 2012, and 2013*].
(h) Trading Plan Performance Verification: A description of how the entity will verify and document for each trading project that BMPs are conforming to applicable quality standards and credits are generated as planned; and	• (5h): The ROWQIP will include third party verification and associated reporting as required by ODEQ and IDEQ in the 401 certification [IPC 401 Application, § 7.2.1.1.5].

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(i) Tracking and Reporting: A description of how credit generation, acquisition and usage will be tracked and how this information will be made available to the public.	• (5i): The intent of the proposed ROWQIP is that annual reporting of credit generation, and how those credits relate to the compliance target, will be submitted to IDEQ and ODEQ on an annual basis. All documentation submitted to IDEQ and ODEQ would be available to the public. Further, the intent is that because there is an adaptive element inherent in the proposed project, reporting and tracking could be modified at the request of IDEQ or ODEQ as warranted by future project or national, state, or regional trading program developments. The current project proposal, which includes an adaptive element based on future developments, provides certainty that the ROWQIP will "ensure a level of quality consistency with regional and national nutrient trading programs" [IPC 401 Application, § 7.2.1.1.5].
(6) Adaptive Management: Trading plans must include a description of how monitoring and other information may be used over time to adjust trading projects and under what circumstances;	• (6): The ROWQIP acknowledges the multi-year timeframe of the contract and the variable nature of phosphorus load reductions. The ROWQIP therefore incorporates the ability to adaptively manage the program to reflect new knowledge and information as it emerges [IPC 401 Application, § 7.2.1.1.7].
(7) Trading Plan Revision: An approved trading plan must be revised during permit or 401 water quality certification renewal or if there is a change in circumstances that affects a trading plan element required by subsection (5) of this rule. Revised trading plans must be submitted to DEQ for review and approval and must be given an opportunity for public notice and comment. DEQ will reopen and modify the permit or 401 water quality certification for any revisions affecting an enforceable condition.	• (7): The ROWQIP contemplates that any proposed changes to canal operations (or other management to reduce phosphorus loads as well as to monitoring and reporting) would be subject to approval by the DEQs [IPC 401 Application, § 7.2.1.1.7].
340-039-0030 **Requirements for Trading Baselines** (1) Trading baseline must account for the following regulatory requirements applicable to the trading project at the time of trading project initiation:	• (1): In some instances, no baseline obligations exist: "If no regulatory requirements described in OAR 340-039-0030(1) exist or apply within the trading area, the trading plan may state that baseline is 'existing conditions.'" Trading IMD, § 5(II)(C). For the ROWQIP, the trading baseline is existing conditions—referred to here as the "Baseline Operations Flow" condition [IPC 401 Application, § 7.2.1.1.3.2]. Outside of the obligation to only withdraw water consistent with its water right, there is no current regulatory requirement for the operations or management of

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	Riverside Canal related to phosphorus or DO reductions.
(a) NPDES permit requirements;	• (1a): The 401 Application does not contemplate any interaction with a NPDES permit holder in the ROWQIP program area.
(b) Rules the Oregon Department of Agriculture issued for an agricultural water quality management area under OAR chapter 603 division 095;	• (1b): Oregon AgWQMP rules do not address irrigation canal operations.
(c) Rules the Oregon Board of Forestry issues under OAR chapter 629 divisions 610-680;	• (1c): Oregon BOF rules do not address irrigation canal operations.
(d) Requirements of a federal land management plan, or an agreement between a federal agency and the state;	• (1d): The ROWQIP project is based on a contract between two private parties, related to state law water right management.
(e) Requirements established in a Clean Water Act Section 401 water quality certification;	• (1e): The IMD notes that if a 401 license holder would like to generate credits, it would need to complete actions beyond mitigation conditions included in its 401 application [Trading IMD, § 5(I)(H)(iii)]. However, IPC will be generating phosphorus reductions to comply with its 401 obligation, so the baseline considerations that apply are those related to other nonpoint source generators of phosphorus reductions [Trading IMD, § § 5(I)(H)(iv)].
(f) Local ordinances;	(1f): No county and city regulations applicable to the ROWQIP trading area currently affirmatively require phosphorus reductions or improved canal operations.
(g) Tribal laws, rules, or permits; (h) Other applicable rules affecting nonpoint source requirements;	• (1g, h): The ROWQIP did not identify any tribal laws, rules or permits, or other currently applicable rules affecting nonpoint source requirements.
(i) Projects completed as part of compensatory mitigation, or projects required under a permit or approval issued under Clean Water Act section 404, or a supplemental environmental project used to settle a civil penalty imposed under OAR chapter 340 division 012 or the Clean Water Act; and	• (1i): IPC implemented ROWQIP; it was not planned or required for any other mitigation or permit.
(j) Regulatory requirements a designated management agency establishes to comply with a DEQ-issued TMDL, water quality management plan or another water pollution control plan adopted by rule or issued by order under ORS 468B.015 or 468B.110.	• (1j): Pursuant to the SR-HC TMDL, WQMP implementation plans can be issued by designated management agencies (DMAs). Relevant DMAs identified in the DEQ SR-HC TMDL WQMP include IPC, ODA, ODEQ, ODOF [SR-HC TMDL, § 6.1, Ch. 5]. The SR-HC TMDL “implementation plans” created by these DMAs incorporate and rely on existing regulatory mechanisms (e.g., AgWQMP area rules), but do not create stand-alone obligations for irrigation canal operations.

Oregon Water Quality Trading Rule	Explanation of How Riverside Addresses Oregon WQT Provision
(2) BMPs required to meet baseline requirements and BMPs used to generate additional water quality benefits and trade credits may be installed simultaneously.	• (2): The ROWQIP does not explicitly address this issue because since there are not baseline BMP requirements. As such, installation timing of BMPs for credit relative to baseline BMPs is not relevant.
340-039-0035 **Requirements for Trading Areas** (1) DEQ may establish trading areas in trading frameworks. (2) All trading areas must be consistent with any applicable TMDL water quality management plan, independent state water quality management plans, or trading framework.	• (1): inapplicable because no framework. • (2): The ROWQIP program area [IPC 401 Application, § 7.2.1.1.1] is consistent with Oregon's SR-HC TMDL water quality management plan (WQMP) [TMDL, § 6.1, Ch. 3]. The Oregon WQMP notes that one primary factor driving dissolved oxygen impacts in the Snake River is "oxygen demanding pollutants", which includes phosphorus.
340-039-0040 **Requirements for Credits** (1) Credits used for compliance with NPDES permit and 401 water quality certification requirements must be generated within the trading area of an approved trading plan. (2) A credit may not be used to meet a regulatory obligation by more than one entity at any given time. (3) Credits may be generated only from BMPs that result in water quality benefits above trading baseline requirements. (4) Credits generated under an approved trading plan may not include water quality benefits obtained with public conservation funds. Where public sources of funding are used for credit-generating activities, it is the entity's responsibility to demonstrate compliance with this requirement in its annual report. (5) Credits may be used for compliance with NPDES permit requirements and 401 water quality certifications once implementation of BMPs has been verified as consistent with applicable BMP quality standards according to OAR 340-039-0025(5)(h).	• (1): Only phosphorus reductions generated by the ROWQIP that contribute to phosphorus concentrations in agricultural drains will be eligible for use in the 401 [IPC 401 Application, § 7.2.1.1.7]. • (2): ROWQIP phosphorus reductions will only be used by IPC, and will be tracked accordingly [IPC 401 Application, § 7.2.1.1.5]. • (3): The ROWQIP is not currently subject to any regulatory baseline requirements. As noted above, baseline is equal to current conditions, and only credits generated above the Baseline Operations Flows condition can be used for compliance [IPC 401 Application, § 7.2.1.1.3.2]. • (4): ROWQIP operations associated with phosphorus reductions will not be funded via public conservation funds [IPC 401 Application, § 7.2.1.1.6]: "In 2014, IPC and Riverside signed a binding contract that identifies operational requirements for Riverside, and financial compensation by IPC to ensure the project is operated in a way that results in phosphorus load reductions." Additionally, IPC's intent is to demonstrate compliance with this requirement in its annual report. • (5): IPC expects that review and approval of its application, including all associated ROWQIP information and any required verification of the project, will serve to demonstrate consistency

Oregon Water Quality Trading Rule	Explanation of How Riverside Addresses Oregon WQT Provision
(6) Credits may be generated from BMPs installed before DEQ approves a trading plan if BMPs are verified as having been implemented consistent with BMP quality standards identified in a subsequently approved trading plan and are functioning effectively.	with BMP quality standards. • (6): The ROWQIP was implemented in 2014, in advance of 401 certification because "early implementation not only ensures that realization of benefits will begin immediately upon issuance of the HCC CWA § 401 certification, but also that long-term benefits can begin to accrue prior to § 401 issuance." [IPC 401 Application, § 7.2.1.1.6, Implementation Timeline]. Explicit quality standards for irrigation canal operations do not exist, however, monitoring data will be able to demonstrate that the equipment and operations are functioning effectively, and achieving expected reductions.
340-039-0043 **Requirements for Trading Ratios** (1) Water quality trades must include one or more trading ratios that apply to credits. Ratio components and underlying assumptions must be clearly documented in the trading plan.	• (1): The ROWQIP includes two ratio components, which affect the size of the offset obligation, and the value of benefits from the ROWQIP. The assumptions underlying these ratios are described in the 401 application [§ 7.2].
(2) Trading ratios may be used to account for variables associated with a trading project including the following: (a) Attenuation of a water quality benefit between the location where credit-generating BMPs occur and the point of use;	• (2a): The 401 Application explains in detail why the ROWQIP does not include an attenuation ratio between ROWQIP site and the point of use (Brownlee Reservoir) [IPC 401 Application, 7.2-2 Exhibit: IPC Equivalent Seasonal Phosphorus Load Reduction].
(b) Pollutant equivalency;	• (2b): The benefits from the ROWQIP project are measured in pounds of total phosphorus, which have been translated into an equivalent annual DO supplementation using stoichiometric ratios. IPC's oxygen allocation (1,125 tons of oxygen) equates to approximately 15,000 pounds of total phosphorus [IPC 401 Application, § 7.2.1.1.2; Exhibit 7.2-2-Appendix 2], and because phosphorus is a conservative constituent, the majority of upstream phosphorus reductions can be expected to have a direct effect on DO conditions in Brownlee Reservoir.
(c) Uncertainty of BMP performance or water quality benefit measurement or estimate; (d) Types of risk not associated with BMP performance;	• (2c, d): The modeled reductions from the ROWQIP are based on data measured in 2014 and other years [IPC 401 Application, § 7.2.1.1.3.2; 7.1.1.4], which limits uncertainty compared to BMP's without measured data. A 13% margin of safety was used in developing the load allocations and capacity for the TMDL,

Oregon Water Quality Trading Rule	**Explanation of How Riverside Addresses Oregon WQT Provision**
(e) Time lag after BMP installation before a BMP produces full water quality benefit;	including phosphorus allocations [SR-HC TMDL, §4.0.2.3]. • (2e): N/A. Anticipated compliance is expected immediately upon installation of ROWQIP; early implementation in 2014 further avoids any time lag in the production of phosphorus reductions. No time lag ratio required.
(f) Credit for trading projects located in priority areas; or	• (2f): N/A. IPC does not seek a ratio for implementing the ROWQIP in a priority area.
(g) Credit retirement to ensure a net reduction in water pollution.	• (2g): Load reductions above the compliance target, which have been demonstrated to potentially occur under this program, are implicitly part of the ROWRID. The SR-HC TMDL allocated IPC 1,125 tons of DO [SR-HC TMDL, §4.0.2.8]. After converting the DO load to phosphorus, IPC's load allocation is equivalent to approximately 15,000 lbs [IPC 401 Application, §§ 7.2.1.1.2; Ex. 7.2-2 – Appendix 2]. In comparison, the total phosphorus reduction associated with the ROWQIP in 2014 was 31,920 lbs [IPC 401 Application, §§ 7.2.1.1.4.2]. This extra benefit—which was more than 2:1 in 2014—is not being claimed by IPC, and is equivalent to retirement to ensure a net reduction in water pollution.

Exhibit 7.2-4

Additional supporting information for the Riverside Operational Water Quality Improvement Plan (ROWQIP)

Technical Memorandum

HyQual
Hydraulics
Hydrology
Water Quality

To: Ralph Myers, IPC

From: Jack Harrison, PhD, P.E. ID

Date: 5-18-18

Subject: Additional Supporting Information the Riverside Operational Water Quality Improvement Plan (ROWQIP)

The following additional supporting information was prepared in response to discussion that occurred during a meeting with Oregon and Idaho Departments of Environmental Quality (DEQs) on April 23, 2018. Much of the information below is based on information previously prepared for the Idaho Power Company (IPC) Hells Canyon Complex (HCC) 401 Certification Application (November 2017, updated February 2018) or in response to the DEQ's draft or proposed conditions.

Background Documents

O/I DEQ Documents:

1) ODEQ proposed Evaluation and Findings Report: 401 Water Quality Certification, public notice dated Jan 9, 2017.
2) IDEQ Draft 401 Water Quality Certification.

IPC Documents

3) Idaho Power Company (IPC) Hells Canyon Complex (HCC) 401 Certification Application (November 2017, updated February 2018)
4) Riverside Operational Water Quality Improvement Project (ROWQIP) in: Exhibit 7.2-2 of IPC's CWA Section 401 Water Quality Certification Application, November 2017 (updated Feb. 2018): Hells Canyon Hydroelectric Project. Idaho Power Company, Boise, ID.
5) IPC letter prepared by Sarah Higer to Idaho and Oregon DEQ dated Feb 28, 2017.
6) IPC's Responses to ODEQ's Evaluation and Findings Report (OE+F), Part II, February 2017 (includes IPC delineated OE+F).
7) IPC's Responses to IDEQ's Draft 401 Water-Quality Certification, February 2017.

Technical Memorandum

HyQual
Hydraulics
Hydrology
Water Quality

5029
5-18-18
JACK R. HARRISON

To: Ralph Myers, IPC

From: Jack Harrison, PhD, P.E. ID

Date: 5-18-18

Subject: Additional Supporting Information the Riverside Operational Water Quality Improvement Plan (ROWQIP)

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7) IPC's Responses to IDEQ's Draft 401 Water-Quality Certification, February 2017.

1. Equivalent Phosphorus Load Reduction: IPC 6818 kg/yr vs. ODEQ 9343 kg/yr

Question/Comment: *IPC has proposed a total phosphorus (TP) load reduction of 6818 kg/yr (15,000 lb/yr). ODEQ and IDEQ have proposed a TP load reduction 9,343 kg/yr (20,577 lb/yr)*

- ***Response:*** *6816 kg/yr is supported by best available science (i.e., include nitrogen oxygen demand and use Snake River ratios in calculation methods)*

The evaluation of the Riverside Operational Water Quality Improvement Project (ROWQIP) in ODEQ's Evaluation and Findings Report (OE+F) fails to use the best available science to establish the annual phosphorus load reduction target.

First, it relies solely on Redfield ratio stoichiometry that was derived for marine aquatic systems in the 1950s (Redfield 1958). While this may be considered a first approximation, contemporary literature for freshwater systems (e.g., Reynolds (1984), Hecky et al., (1993), Ekholm (2008), and Cole and Wells (1993)) and information more specific to the HCC (e.g., peer reviewed modeling used in the Snake River Hells Canyon TMDL) are more accurate. This available science that is ignored in the ODEQ evaluation supports the conclusion that IPC's proposed stoichiometry is more defensible than that proposed by ODEQ.

Second, and more importantly, despite acknowledging the presence of nitrogen in organic material (i.e., nitrogen is a major element in the Redfield and other ratios), ODEQ's methodology ignores the oxygen demand caused by the nitrogen component of the organic material. This approach is not consistent with the standard methodology used to assess oxygen demand in an aquatic system (Cole and Wells, 1993 and Chapra et. al. 2008). The practical consequence of this approach is that it does not consider a significant and real component of the oxygen demand associated with organic matter degradation.

In the discussion below, the ODEQ approach used to derive the target is compared to the approach used for the IPC proposed target. This comparison clearly demonstrates that the use of locally derived ratio, which is similar to the Redfield ratio, and inclusion of the oxygen demand related to nitrogen cycling, result in a defensible TP load reduction requirement of 6,818 kg/yr (15,000 lb/yr).

Fractions, Ratios and Calculations

Fractions, ratios, and calculation procedures used by DEQ and in the IPC application are shown in Table 1-A to allow comparison. Bold numbers are fractions and ratios based on literature and local data and analyses. The other values are calculated based on these numbers. The upper three rows show the fractions of carbon (C), nitrogen (N) and phosphorus (P) contained in organic matter (OM). The next two rows show the ratio of the oxygen demand (O2) caused by carbon and nitrogen.

ODEQ's fractions and calculations that produce the 9344 kg/yr value are shown in Column A of Table 1-A. While the IPC fractions simplified calculations (Column C) differs slightly, both fractions include the carbon and nitrogen elements (7.2% and 7.8%, respectively).

Table 1-A. Fractions, ratios, and calculations for phosphorus reduction based on TMDL allocation. Bold numbers are fractions and ratios based on literature and local data and analyses.

Column	**A**	**B**	**C**	**D**
	DEQs Draft Certification	**DEQs with OM**	**IPC Application**	**IPC with Ox Ratios**
Fractions of C, N and P in OM				
C/OM	**41%**	**41%**	**---**	**45%**
N/OM	**7.2%**	**7.2%**	**---**	**7.8%**
P/OM	**1.0%**	**1.0%**	**1.0%**	**1.0%**
Oxygen Demand Ratio				
O2/C	**2.663**	**2.663**	**---**	**2.663**
O2/N	**---**	**4.57**	**---**	**4.57**
O2/OM Calculated for C, N and OM				
O2/OM:C	1.09	1.09	---	1.20
O2/OM:N	---	0.33	---	0.35
O2/OM	---	1.43	1.5	1.55
O2/P calculated based on C only				
O2/P:C	109	---	---	120
P/02:C	0.0091	---	---	0.0083
P Reduction calculated based on C only (DEQs)				
kg/yr	9344	---	---	---
lb/yr	20557	---	---	---
O2/P calculated based on C and N				
O2/P:OM	---	143	150	155
P/02:OM	---	0.0070	0.0067	0.0064
P Reduction calculated based on OM (IPC)				
kg/yr	---	7176	6818	6588
lb/yr	---	15788	15000	14493

Nitrogen Oxygen Demand

In Column A, ODEQ uses a generic degradation ratio for carbon (O2/C) of 2.663 based on the simple stoichiometric “C to CO2” conversion, which assumes a pure carbon organic matter compound generates the oxygen demand. This calculation does not account for the oxygen needed to degrade the nitrogen fraction of the algal organic matter.

The oxygen needed for degradation of the nitrogen in algal organic matter is discussed in Cole and Wells 1993 and Chapra et. al. 2008, and described by many others. These processes are included in the water quality model (CE-QUAL-W2, Cole and Wells 1991), which was used to help determine the DO allocation during process TMDL development process. During decay of organic matter the oxygen demand for both carbon and nitrogen should be added together, as clearly evident in research data (Sullivan et al 2009). When a standard ratio of nitrogen oxygen demand is included in the calculations based on the Redfield ratio the resulting load reduction requirement is 7,176 kg/yr (Table 1-A, Column B), which is similar to IPC’s proposed requirement discussed next.

The ratios and calculation used in the IPC’s application are also shown in Columns C and D of Table 1-A for comparison. Column C is a simplified approach that was given in the application (Harrison 2014). Column D shows all steps and ratios. Note the ratios for oxygen demand in Column D, discussed further below.

Redfield Ratios

DEQ failed to use more recent literature from freshwater systems and specifically science developed during the SR-HC TMDL process.

Bloom 2016 states that "**the calculation is based on** the oxygen demand produced by the death and decay of algae and **fixed algal cell Redfield ratio stoichiometry**,…" (bold added) (See Table 1-A - Column A).

The Redfield ratio (used by ODEQ/Bloom) is based on studies conducted in the ocean (Redfield 1958). While the Redfield ratio is generally considered appropriate for many ocean studies, many researchers have reported that the ratios varies widely in fresh water systems. For example:

- Hecky 1993: "The C:P and N:P ratios are more variable for lake particles but generally higher than marine particles,…"
- Ekholm 2008: "…Redfield ratios are the exception rather than the rule in freshwater phytoplankton studies."
- Cole and Wells 1991: Model documentation provide "default ratios" based on years of experience modeling freshwater systems.

The site-specific fractions and ratios used to support the TMDL DO allocations and used in the IPC Application (Table 1-A Column C) were based on:

- Brownlee Reservoir modeling (2002 calibration) and on data collected in upper end of reservoir.
- Stoichiometric ratios optimized for the 1995 Brownlee model application.

These somewhat simplified ratios are based on the current science for freshwater systems and site-specific data. Calculations in a format similar to DEQ are shown in Table 1-A Column C. The more detailed calculations are shown in Table 1-A Column D.

In summary, and as stated above, the ODEQ approach used to derive the target is compared to the approach used for the IPC proposed target. This comparison (Table 1-A) clearly demonstrates that the use of a locally derived ratio, which is similar to the Redfield ratio, and inclusion of the oxygen demand related to nitrogen cycling, result in a defensible TP load reduction requirement of 6,818 kg/yr (15,000 lb/yr) (Table 1-A Column C).

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2. Period of Benefits: 183 days vs. 155 days

Question/Comment: *In ODEQ's Evaluations and Findings Report (OE+F), there are conflicting time periods for calculation of annual phosphorus load reduction. Also, in IDEQ's draft 401 Water-Quality Certification (February 2017) IDEQ uses the shorter ODEQ time period.*

- ***Response:*** *The 183-day period, as proposed by IPC and stated in the ODEQ Credits Subsection, is the appropriate time period from which phosphorus credits should be calculated; and it is a conservative canal operational period.*

In their 401 Application IPC proposes a 183-day time period for calculation of annual phosphorus load reduction generated by the ROWQIP. In the "Credits" subsection of the "Water Quality Trading" section (see IPC Delineated OE+F 25), ODEQ states that the time period of credit generation is 183 days beginning April 15 and extending through October 15, which is consistent with the annual period of Riverside canal operations. However, in the "ODEQ Evaluation" section (see IPC Delineated OE+F 24), immediately preceding the "Water Quality Trading" section, ODEQ indicated the period of reduction as a somewhat arbitrarily reduced period of 153 days.

IPC agrees that the 183-day period is the appropriate time period from which phosphorus credits should be calculated. IPC requests that ODEQ be consistent and explicitly state that the appropriate period for quantifying the phosphorus load reduction being required by the 401 certification is the 183 days. As discussed below, this time period is based on the annual time period of Riverside Canal operations during which load reductions occur and it provides the greatest environmental benefits to the Boise and Snake Rivers and Brownlee Reservoir.

The 183-day operational (and credit calculation) period is based on a defensible period of 183 days, which is justified by the actual period of canal operations. The actual period of canal operations (Table 2-A) exceeds the 183-day period. IPC selected the 183 days as the period that can consistently be met in the future. That stated, IPC recognizes that if this operational period is not met or exceeded, the credits allowed would need to be reduced.

Table 2-A. Riverside Canal operational periods for 2015 through 2017.

Year	Start	End	Duration (days)
2017	3/24/2017	10/16/2017	206
2016	3/24/2017	10/13/2017	203
2015	4/3/2015	10/16/2015	196

It should be noted that because actual operations (Table 2-A) exceed the 183 days, this is one example of a number of aspects that resulted in a conservative proposed reduction. Other examples include:

- The SR-Hells Canyon TMDL set a 13% margin of safety for phosphorus load allocations.
- Each year IPC plans to operate the ROWQIP to exceed the targeted TP reduction. This increases the actual load reduction that is provided.
- The phosphorus load reductions provide cumulative load reduction benefits over time because a fraction of the DO demand is due to phosphorus that recycled in the reservoir (Fish and Wagner 1950, Cole and Hannan 1990, Cole 1999, Myers et al. 2003, IODEQ 2004). By reducing inflow

phosphorus load the internally recycled phosphorus in Brownlee Reservoir (Harrison 2014) is reduced, and less organic demand is generated in the reservoir each year.

- IPC proceeded with early implementation. This has already provided benefits each year of the operation and has already reduced the internal recycling of phosphorus.

Regarding the reduced time period of 153 days, to which ODEQ associated a higher phosphorus reduction target, ODEQ implied that this would be inconsequential because early implementation of the project resulted in phosphorus reductions that exceed the higher target. While it is true that IPC's proposed mitigation measure has a high level of certainty that it will actually deliver more than the minimum required phosphorus reductions on the short-term, this may not be true for the duration of the new HCC license. For this reason, ODEQ should not assume that the shorter time period that was proposed would be inconsequential.

In summary, the 183-day period, as stated in the Credits Subsection, is the appropriate time period from which phosphorus credits should be calculated. Based on the annual time period of Riverside Canal operations during which load reductions can occur, this is an appropriate time period for quantifying the phosphorus load reduction needed to meet the HCC TMDL allocation, and will provide the greatest environmental benefits to the Snake River and Brownlee Reservoir.

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3. Riverside Canal Spills

Question/Comment: *A higher TP concentration in the Riverside Canal results in high phosphorus concentrations in irrigation spills (i.e., water in an irrigation canal to discharge back to a river, creek or drain without passing over agricultural land). If phosphorus concentration in the canal increases, then the spilled water can lead to higher phosphorus loads that discharged back to the rivers. IPC should not get credit for these loads that spill back to the rivers.*

- ***Response:*** *IPC has not claimed credits for canal water that spills back to the rivers; much of the supporting information below has been previously provided in the 401 Application.*

The Riverside Canal model is used to calculate deliveries for each Riverside Irrigation District (RID) agricultural area (Harrison King and Mooney 2014). The flow delivered to irrigated land is based on flow measured in the canal below the Dixie Spill at (Rc9_1). This is referred to as the RID demand, which is set by the RID superintendent on a daily basis. This measurement location is below two upper canal spills that discharge to the Boise River, Indian Creek spill, and Dixie Drain spills. Any increase in phosphorus concentration in these upper spills (and potentially higher phosphorus load) is the main focus of the modeling and is fully accounted for in the modeling.

Downstream of these spills, the irrigation water in the canal in excess of the water needed for delivery to irrigators is spilled back to either the Boise or Snake Rivers. Because these lower canal spills (and associated phosphorus load) are not delivered to the irrigators, they are subtracted from the RID demand flow. Thus, the flow delivered to RID agricultural area is equal to the measured RID demand (Rc9_1) minus the lower canal spills (i.e., Dutton, Holly and End Spills; numbered Rc18_8, Rc23_8 and Rc30_9 respectively).

For baseline operations, the Dutton and Holly spills are based on data collected during the 2011 through 2013 irrigation seasons (Tables 3-A and 3-B). The average daily values over the three year period are used in the baseline modeling (Harrison et al 2014).

Table 3-A. Flow Statistics for Dutton Spill (Rc18_7).

Rc 18_7	**Flow (cfs)**			
Year	2011	2012	2013	Avg
Average	35.3	41.4	31.6	36.2
Max	62.4	60.1	59.4	53.9
Min	17.1	20.1	8.7	21.2

Table 3-B. Flow statistics for Holly Spill (Rc23_8).

Rc23_8	**Flow (cfs)**			
Year	2011	2012	2013	Avg
Avg	29.6	31.7	26.3	28.9
Max	56.2	51.6	46.1	47.4
Min	8.1	7.0	6.8	10.3

In 2011, the End Spill at RC31.1 was measured when collecting water quality data (Harrison and King 2014). This location is just downstream of the current End Spill location (RC30.9). While the upstream canal spills were operated with locally controlled automation, the flows represent the earliest measurements available (Table 3-C).

Table 3-C. Flow Measurements for End Spill (Rc30_9).

Date	Flow (cfs)
4/19/2011	24
5/19/2011	40
7/8/2011	28
7/27/2011	32
8/17/2011	21
9/8/2011	31
10/6/2011	23
Average	28

For the operational year being modeled, the spilled flows are measured over the irrigation season. Then, at the end of the season, average daily values are calculated and used in that year's modeling. Under the current water quality focused operations, the spills are lower than in previous years (i.e., when baseline measured). For example, during the 2017 operations the lower canal spills (i.e., Dutton, Holly and End Spill) were about 30% lower than baseline operations (Table 3-D).

Table 3-D. Canal Spills as Measured in 2017 (average) and for Baseline Operations (Harrison 2018).

Flows (cfs)	RC18.7	RC23.8	RC30.9
2017 (average)	24	19	20
Baseline	36	29	28
2017-BL	-12	-10	-8

In summary, this shows how irrigation spills in the canal are accounted for in the model. And, while concentrations in spill water increase, the loads decrease due to the improved water management when compared to baseline operations.

References

Harrison, J. and S. King. 2014. Riverside Canal Water Quality Monitoring Status Report for 2011, 2012, and 2013. In: Exhibit 7.2-2 of IPC's CWA Section 401 Water Quality Certification Application, November 2017 (updated Feb. 2018): Hells Canyon Hydroelectric Project. Idaho Power Company, Boise, ID.

Harrison, J., S. King and S. Mooney. 2014. Riverside Operational Water Quality Improvement Project Load Reduction Calculation Methods. Prepared for Idaho Power Company. May, 2014.

Harrison, J. 2018. Riverside Operational Water Quality Improvement Project 2017 Annual Report. Prepared for Idaho Power Company. April 19, 2018.

4. Riverside Irrigation Runoff and BMPs

Question/Comment: *Higher TP concentration in Riverside Canal results in increased phosphorus runoff to rivers that IPC gets credit for.*

- ***Response:*** *IPC has not claimed credits for runoff that discharges to the rivers; much of the supporting information below has been previously provided in a letter to the DEQs from Sarah Higer dated February 2017 which was intended to address an EPA comment.*

In the methodology used to calculate the RID load reduction, the runoff load from agricultural land is assumed to remain unchanged between the water-quality focused operations and baseline. The basis for this assumption was a literature review and analysis by HyQual and IPC, a summary of which is included in Appendix 3 of Exhibit 7.2-2 of the 401 application. The conclusion of the review and analysis was that while an increase in runoff phosphorus loads is a hypothetical, potential scenario, IPC's intent is to include measures within the ROWQIP to provide reasonable assurance that the scenario will not become reality. In fact, the current ROWQIP agreement with Riverside includes incentives and landowner surveys for BMP implementation. Along with these incentives, there are a combination of factors that would tend to reduce, or at a minimum, not increase phosphorus levels in runoff and groundwater from agricultural land affected by the ROWQIP.

First, the change in phosphorus load in the inflow irrigation water is relatively low compared to phosphorus loading through crop fertilization. Second, soil characteristics that cause it to retain phosphorus make it unlikely that much of the relatively small additional phosphorus added to irrigation water by the ROWQIP will increase runoff phosphorus levels. Third, runoff controls and nutrient management by farmers is also increasing on land served with water from the ROWQIP through TMDL implementation and information on phosphorus levels in water delivered by the ROWQIP. Considering these three factors, the assumption that the runoff load would remain unchanged was very conservative. As such, runoff quality should improve and runoff quantity should decrease over the period of the ROWQIP. Technical details regarding the three factors that ensure phosphorus levels in runoff from ROWQIP served lands will not increase are provided below.

Change in Phosphorus Load

The actual change in the phosphorus load applied to the land as a result of implementing the ROWQIP is small relative to the amount of phosphorus needed to produce crops. The average increase in phosphorus concentration over baseline operations, resulting from ROWQIP implementation (as estimated in 2014), for irrigation water delivered to landowners was 0.13 mg/L on average (Table 4-A). Applying this change in phosphorus concentration to the 4 feet of water that is typically applied to crops over the course of the entire irrigation season results in the addition of 1.4 lbs of phosphorus per acre per year being applied to the crops over the baseline phosphorus loading from irrigation water of 4.5 lbs of phosphorus per acre per year (Table 4-A). In comparison, typical fertilization rates for crops that are grown within the Riverside Irrigation District averages 55 lbs per acre (Table 4-B). This small increase (1.4 lbs) represents about 3% of the 55 lbs of phosphorus needed to produce crops. In fact, the phosphorus loading from irrigation water in total would only be approximately 10% of the annual phosphorus load applied to the agricultural land for crop production. This very small potential increase in phosphorus loading to cropland under implementation of the ROWQIP supports the assumption that the ROWQIP will not increase phosphorus concentrations in irrigation runoff.

Table 4-A. Modeled phosphorus concentrations and loading rates based on the Riverside Canal Model concentrations at RC9_1.

RC9_1	Avg P Conc (mg/L)	P Load (lb/ac/yr)
Baseline	0.41	4.5
ROWQIP implemented	0.54	5.9
Difference	0.13	1.4

Table 4-B. Mid-range of recommended fertilization rates for selected crops based on University of Idaho Fertilization Guidelines (UI 2013).

Crop	Phosphorus (lb/ac)
Alfalfa hay	44
Sugar Beet	88
Pasture grass	53
Corn silage	26
Wheat (spring)	62
Average	55

Soils Can Retain Phosphorus

Research shows that soils typically have the capacity to retain a large percentage of the phosphorus applied (or delivered by source water). This indicates that a small increase in phosphorus load (e.g., 3%), delivered throughout the irrigation season, can easily be held by the soils for later use by the crops without contributing to runoff. Lentz and Westermann, (2001) assessed "percolation losses" for furrow irrigated soils in southern Idaho. They found mean TP concentrations in water moving below the crop root zone at levels of 0.15 mg/L and 1.1 mg/L, at upper and lower locations, respectively. With these concentrations, the TP losses due to subsurface seepage for the furrow irrigated fields were estimated to be less than 0.1 lb/acre/year. Again, this is a relatively small fraction of the total phosphorus applied for crop production (i.e. about 0.3%).

The ROWQIP is expected to cause a decrease in subsurface seepage loss of phosphorus to the groundwater system, which ultimately discharges to drains and the river. This positive benefit is caused by:

- The availability of nutrient data for the canal can be used to reduce fertilizer application. Previously, the fertilizer management planning did not account for the phosphorus in the water. Growers would estimate fertilizer requirement by subtracting the available soil phosphorus (rather than combined soil and water phosphorus) from the crop phosphorus requirement. Based on the example shown below (Table 4-C, Example A), this resulted in an "overloading" of about 5 lb/acre/year for Example A. Now, by accounting for the concentration in the water, this overloading is less likely to occur, even with the higher irrigation water phosphorus loading rates.

Table 4-C. Examples of Phosphorus Fertilizer Application Rates in lb/ac.

Example	A	B	C
Crop P required	30	30	30
Soil P available	10	10	10
Water P available	0	3	5
Fertilizer Needed	20	17	15

- The application of the irrigation-water portion of the fertilizer requirement on a more continuous basis can reduce leaching because the phosphorus will be applied at an even rate over the entire growing season when crops require nutrients instead of during “event” based applications (UI Extension 2014).

Under ROWQIP operations, Riverside Irrigation District will deliver irrigation water with a higher concentration of nutrients; these higher nutrient concentrations in canal water will now be available to irrigators on a regular basis. Thus, irrigators can adjust their fertilizer applications by accounting for nutrients supplied in the delivered irrigation water, minimizing their nutrient loading and lowering fertilizer costs.

Runoff Control and Nutrient Management is Increasing

Research shows that typically more than 90% of phosphorus runoff from “clean-tilled row-crop” fields is in particulate form (i.e., erosion of soil) (Bjorneberg, et al., 2006, Westermann et al., 2001). The primary focus of many agricultural BMPs is to control sediment runoff, which thereby reduces phosphorus runoff. Under existing Lower Boise River TMDLs, agriculture has, and is expected to continue to, reduce runoff of sediment and phosphorus. This will increase the likelihood that runoff phosphorus loads will be decreasing in the future.

Westermann et al., (2001) studied “Phosphorus Losses in Furrow Irrigation Runoff” and found that there was a linear relationship between total phosphorus (TP) and sediment concentrations in runoff. And, while the average dissolved reactive phosphorus (DRP) concentrations in runoff increased linearly as soil phosphorus concentrations increased, the average TP concentration of runoff was not related to soil phosphorus. Thus it appears, the DRP is such a minor fraction of the TP that it is insignificant when compared to the sediment fraction of TP.

This was further confirmed by Bjornberg et al., (2006) who showed that TP concentrations related directly to sediment concentrations because typically >90% of the phosphorus in runoff from “clean-tilled row-crop” fields was particulate phosphorus, emphasizing the need to control soil erosion to reduce phosphorus loss. They also showed that DRP concentrations tended to increase with distance down the furrow as contact time with soil and suspended sediment increased, but that there was a decrease in DRP during subsequent irrigations at a specific furrow site. They stated that their results indicated differences in flow hydraulics, suspended sediment loads, and the “non-equilibrium conditions” overshadowed the effects of soil phosphorus. The results of this research support the focus on efforts to improve irrigation return-flow water quality through reduction in sediment. The results of Westermann et al. (2001) also support that DRP concentrations in the runoff are more strongly related to soil phosphorus availability and equilibrium reactions as opposed to initial DRP concentration. Soil phosphorus availability, as previously discussed, is strongly related to fertilizer additions.

The research also shows water quality runoff from agricultural land can have sediment concentrations over 10,000 mg/L (Bjorneberg et al., 2002). Based on typical TP in sediment of 0.1% (Westermann et al. 2001), this would produce TP concentrations of 10 mg/L. Bjorneberg et al., (2002) reported on nutrient losses in surface irrigation runoff and showed that orthophosphorus (Ortho-P, equivalent to DRP) accounted for only about 3% of the total phosphorus in surface runoff.

On-farm water quality management has increased over last 10 years, and includes improved runoff control and nutrient management. Under nutrient management plan BMPs, phosphorus applications are balanced with crop needs. This BMP will increase and can utilize water quality information provided by IPC to reduce fertilizer loads.

As observed in other regions, many of the Riverside Irrigation District irrigators have been working to reduce runoff from their farms over the last 10 years (i.e., since the SR-HC TMDL was approved). These water quality improvement actions, which appear to be wide spread over the past decade, include conversion to sprinkler irrigation systems, installation of furrow end ponds and sediment basins, straw mulching and application of polyacrylamide (PAM). Sprinkler irrigation has increased substantially in the last 10 years and is now estimated to be used on greater than 30% of acreage in the Riverside Irrigation District. Also, during conversations with Riverside Irrigation District farmers, they estimated that:

- Approximately 20% of the land has been now been converted from furrow to sprinkler irrigation;
- PAM is applied to about 50% of the land still using furrow irrigation methods (personal communication with selected RID irrigators 2013); and
- All the hops and 50% of the onions are irrigated with drip systems. This would equate to about 6% overall and increased from near zero just a few years ago.

While these improvements reduce the potential for increased runoff resulting from the ROWQIP, they are not considered a part of the canal operational improvements. However, IPC intends to encourage BMP implementation and efforts to increase on farm BMPs using an incentive based approach. Efforts by the irrigators to decrease runoff and management of nutrients can easily result in a reduction in runoff phosphorus far in excess of the loads added by the ROWQIP.

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UI Extension. 2014. Best Management practices for nutrient management in the State of Idaho. Internet assess at http://www.extension.uidaho.edu/nutrient/nutrient_management_planning/codes.html

5. Swan Falls as part of Reasonable Assurance

Question/Comment: *Swan Falls organic matter removal was included as part of ROWQIP Reasonable Assurance but reductions could decline in future.*

- ***Response:*** *as stated in the 401 Application, annual implementation of Swan Falls vegetation removal will continue to be monitored and if declines are seen in the future this additional reasonable assurance can be reevaluated.*

Swan Falls is an ongoing voluntary effort by IPC that improves water quality in the Snake River through removal of phosphorus rich organic matter. This project removes a source of phosphorus-rich organic demanding materials that cause pH swings and anoxia. While it is hopeful that future organic matter levels in the Snake River will decrease, experience and data indicated that initial improvements in water quality related to sediment reduction can lead to increased levels of organic matter production, as has occurred in the Mid-Snake River.

Either way, the project was included in the Application to provide “additional” reasonable assurance beyond that provided by the Grandview Project. Data and information on the ROWQIP and these additional projects will be provided on an ongoing basis to assess compliance. In IPC’s Responses to the Draft 401 Water Quality Certification, February 2017 IPC noted that the DEQ states the DEQs can require implementation of Alternative Measures if it “determines the ROWQIP is currently not attaining the DO load allocation […] or is not reasonably likely to attain that DO load allocation in the future” (p. 11, of the Draft 401 Water Quality Certification).

Exhibit 7.2-5

Riverside Operational Water Quality Improvement Project 2015 Annual Report

Riverside Operational Water Quality Improvement Project

2015 Annual Report

Prepared for: Idaho Power Company

Riverside Irrigation District

Prepared by: Jack Harrison, PhD, P.E., HyQual, P.A.

Scott King, P.E., SPF Water Engineering, LLC

Scott Mooney, Control Engineers

6029

5/25/16

JACK R. HARRISON

Date: May 25, 2016

Riverside Operational Water Quality Improvement Project

2015 Annual Report

Prepared for: Idaho Power Company

Riverside Irrigation District

Prepared by: Jack Harrison, PhD, P.E., HyQual, P.A.

Scott King, P.E., SPF Water Engineering, LLC

Scott Mooney, Control Engineers

Date: May 25, 2016

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Acknowledgements: This report is the 2nd annual report for the Riverside Operational Water Quality Improvement Project (ROWQIP) and is intended to provide the supporting documentation to ensure the project is transparent, reliable, and verifiable. While this work is funded by Idaho Power Company (IPC), under the direction of Ralph Myers, it is the commitment by Riverside Irrigation District (RID), and their manager Andy Bishop, that leads to the substantial water quality improvement presented below. This report provides the water quality data collected by Scotts Hoskins along with canal operations controlled by RID staff, which relies on canal discharge verification data collected by IPC Water Management.

Photo on cover: Newly installed Rubicon Gate at Centennial Park located in canal about 1.7 miles downstream of Boise River diversion

Executive Summary

Idaho Power Company (IPC) is proposing to address its dissolved oxygen (DO) load allocation assigned to the transition zone and metalimnion of Brownlee Reservoir in the Snake River-Hells Canyon total maximum daily load (SR–HC TMDL) (IDEQ and ODEQ, 2004) by implementing the Riverside Operational Water-Quality Improvement Project (ROWQIP). Similar to 2014, the Riverside Irrigation District (RID) operated its primary delivery facility (Riverside Canal) in a way that reduced the loads of phosphorus and other pollutants discharged from the Riverside Canal to the Boise and Snake rivers throughout 2015.

As part of the ROWQIP, the Boise River diversion to the Riverside canal and four major spills from the canal have been automated and were controlled during the 2015 irrigation season by a supervisory control and data acquisition (SCADA) system. In addition to recording real-time flow data, the SCADA system monitored tributary inflows to the canal and automatically adjusted the Boise River diversion and spills to increase the phosphorus delivered to Riverside irrigators while decreasing phosphorus discharged to the Boise and Snake Rivers. In doing so, canal inflows from phosphorus-rich tributaries were preferentially utilized for irrigation, while canal diversion from the Boise River and canal spills to the Boise and Snake rivers were minimized. To assess changes in water quality, data were collected bi-monthly at seven canal and inflow locations.

Using the flow and water quality data collected in 2015, a Riverside Canal mass balance model was used to calculate the daily average load reductions occurring over the 183-day irrigation season. The model results show that the average load reduction was 86 lb/day, ranging from 34 to 155 lb/day over the season. The annual load reduction achieved by the ROWQIP over the season was just over 15,800 lbs. This model-calculated annual load reduction exceeds the equivalent Snake River phosphorus load reduction of 15,000 lb/yr, which is comparable to the dissolved oxygen allocation, and thus fulfills IPC’s DO requirements as identified in the SR-HC TMDL.

This supporting information provides details of the project and the load reduction calculation methods needed to support 401 Certification, along with the methods used to ensure the project performance is transparent, reliable, and verifiable. Additional information on the project and its development is provided in Harrison et al., 2014 and Harrison et al., 2015.

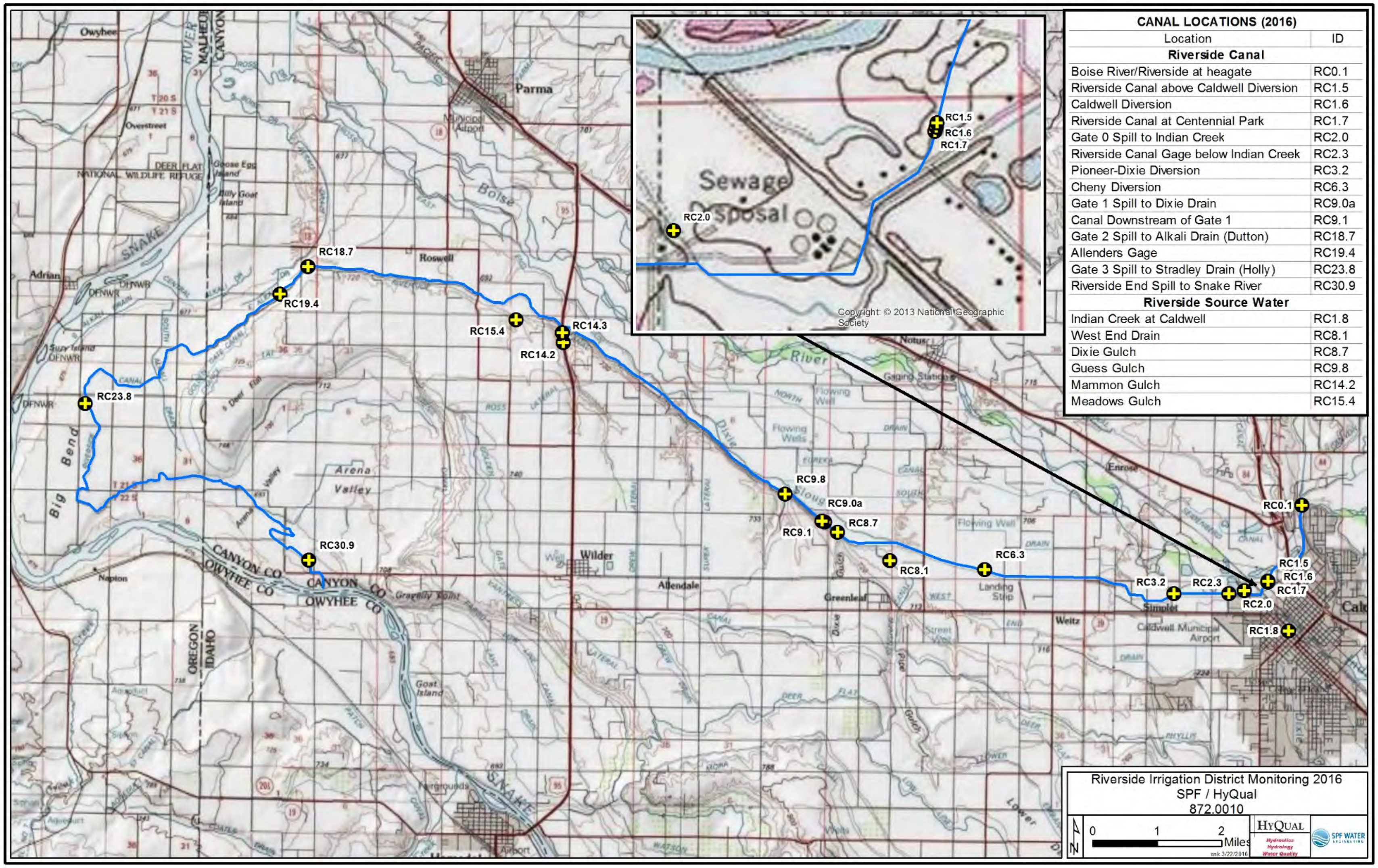
Riverside Irrigation District

The RID is located at the western end of the Boise River valley, near the confluence of the Boise and Snake rivers (Figure 1). The RID diverts water from the south bank of the Boise River near Caldwell (Figure 1: Rc0_1), and receives inflows from other tributary streams and drains along its length. The Riverside Canal (RC) flows northwesterly and crosses US Highway 95 approximately five miles southeast of Parma, Idaho. The canal turns westerly then southwesterly, crossing into Oregon approximately two miles southeast of Adrian, Oregon. The canal then flows south and east, re-crossing the state line into Idaho, before draining into the Snake River approximately four miles west of Wilder, Idaho (Figure 1: near Rc30_9).

The RID delivers water to approximately 230 water users for agricultural purposes, with principal crops being onions, sugar beets, wheat, potatoes, alfalfa, beans, and hops. According to Idaho Department of Water Resources records, the RID water rights authorize irrigation of 10,158 acres within a District boundary totaling 13,082 acres (the later estimated via GIS mapping). The RC is also used to deliver water for irrigation of 2,348 acres within the service area of the Pioneer Dixie Ditch Company, and for 454 acres at the Cheney Diversion (Figure 1: Rc3_2 and Rc6_3, respectively). Thus, the total irrigated acreage supplied by the canal is over 12,000 acres.

SCADA System

As a key part of the ROWQI project, an automated canal control system was designed, constructed, and implemented. The system includes automatic control of spill gates and real-time flow monitoring of the canal flows, tributary inflows, and spills. Cellular communications equipment and a centralized server are used to control the upper reach of the RC operations by a supervisory control and data acquisition (SCADA) system. With this equipment in place and operational as of 2014, RID can prioritize use of drainage water flowing into their canal and limit the amount of canal discharge (i.e., spill) that flows unused to the Boise and Snake Rivers.



CANAL LOCATIONS (2016)	
Location	ID
Riverside Canal	
Boise River/Riverside at heagate	RC0.1
Riverside Canal above Caldwell Diversion	RC1.5
Caldwell Diversion	RC1.6
Riverside Canal at Centennial Park	RC1.7
Gate 0 Spill to Indian Creek	RC2.0
Riverside Canal Gage below Indian Creek	RC2.3
Pioneer-Dixie Diversion	RC3.2
Cheny Diversion	RC6.3
Gate 1 Spill to Dixie Drain	RC9.0a
Canal Downstream of Gate 1	RC9.1
Gate 2 Spill to Alkali Drain (Dutton)	RC18.7
Allenders Gage	RC19.4
Gate 3 Spill to Stradley Drain (Holly)	RC23.8
Riverside End Spill to Snake River	RC30.9
Riverside Source Water	
Indian Creek at Caldwell	RC1.8
West End Drain	RC8.1
Dixie Gulch	RC8.7
Guess Gulch	RC9.8
Mammon Gulch	RC14.2
Meadows Gulch	RC15.4

Figure 1. Riverside Irrigation District irrigated acreages divided into general delivery areas and sampling locations.

Modeled Load Reductions

The RC model was developed to estimate the daily total phosphorus (TP) loads that are delivered to RID irrigators under different canal operations (Harrison et al. 2014). A simplified schematic diagram (Figure 2) shows conceptually how the canal is structured with water diverted from the Boise River and a tributary containing drainage water discharging into the canal. Any excess drain water then “spills” back to the river downstream of the diversion and tributary along with agricultural runoff. The change in TP load in the river is calculated using delivered water, which is adjusted for downstream spills and runoff. The use of delivered water, which is based on measured discharge and not modeled discharge, reduces the uncertainty of model load reductions by relying on the same measurements for canal inflows and agricultural water delivery.

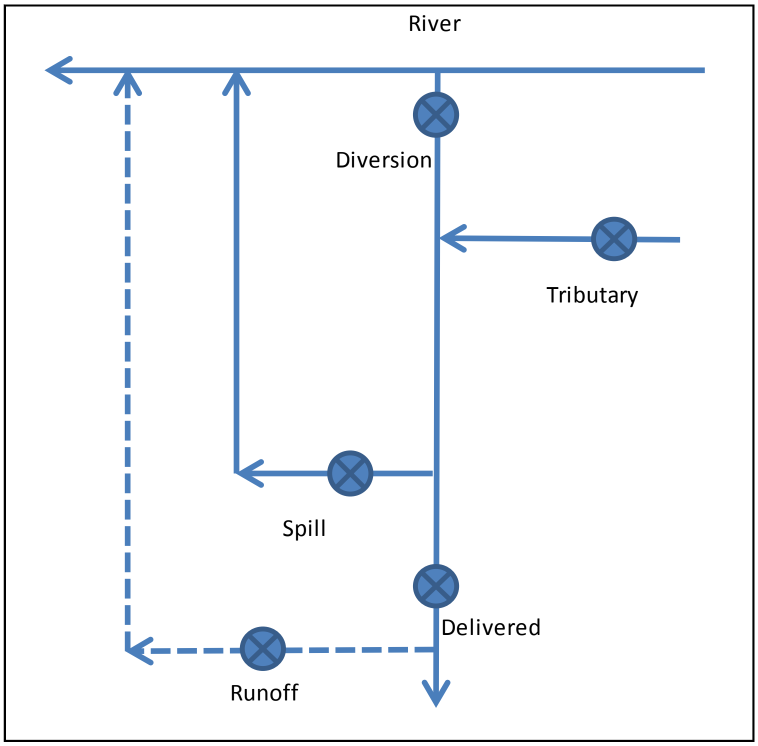


Figure 2. Simplified schematic of ROWQIP showing main components of the phosphorus-reduction calculation methodology.

The 2015 water-quality-focused canal operations were designed to maximize the use of high-nutrient agricultural and municipal drainage water on RID agricultural lands. This was accomplished by minimizing diversion of the comparatively higher-quality (lower phosphorus) Boise River, resulting in the greater utilization of the lower quality (higher phosphorus) water from the tributaries for delivery to irrigators.

To calculate annual phosphorous load reduction under 2015 operations, flow data collected at the Boise River diversion and other inflows locations (i.e., tributaries) are used to model the flow and phosphorus concentrations along the canal. Next, flows for "Baseline" operations were modeled with the Boise River diversion based on Riverside's decreed water rights from the river, totaling 271.5 cfs (http://www.idwr.idaho.gov). Then, the 2015 flow and Baseline flow models were used to calculate concentrations along the canal using a mass balance approach. Finally, the load reduction was calculated as the difference between operations (Table 1).

Table 1. Average annual loads for 2015 and Baseline operations, and TP reduction based average model results.

		Total Phosphorus	
	Flow	**Conc.**	**Load**
Yr 2015	(cfs)	(mg/L)	(lb/d)
Diversion	69	0.24	87
Tributary	295	0.43	684
Spill	115	0.38	233
Delivered	249	0.40	537
Baseline	(cfs)	(mg/L)	(lb/d)
Diversion	271	0.23	329
Tributary	295	0.43	684
Spill	318	0.33	562
Delivered	249	0.34	451
TP Reduction		0.06	86

The primary function of the Riverside Canal model was to calculate "comparable" concentrations for the water delivered under each of the operations (Table 1). The change in concentration of the water delivered to irrigators, which is the primary goal of the ROWQIP, was used directly to calculate the TP load reduction because quantity of water delivered for irrigation is the same for both operations (i.e., the change in TP load delivered can be calculated by multiplying 249 cfs by 0.06 mg/L and converting to 86 pounds per day).

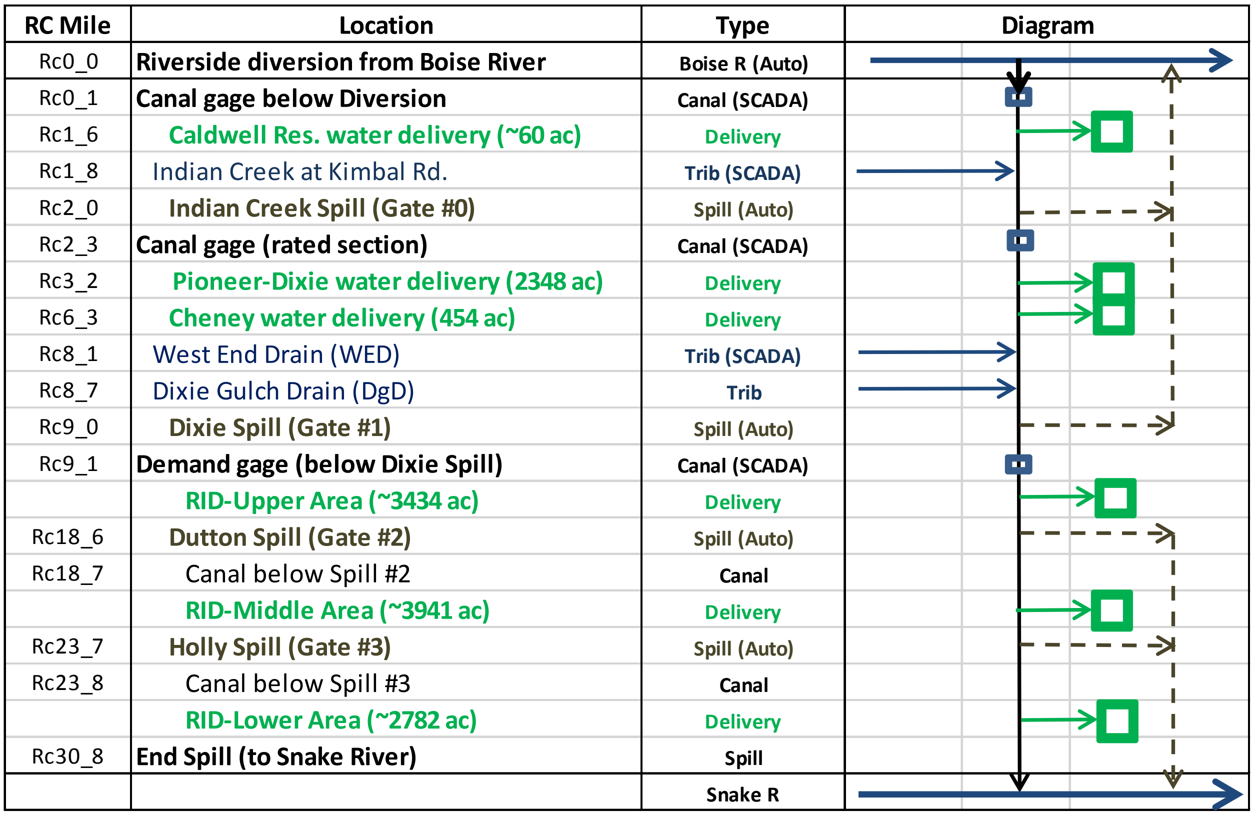
For comparison, the estimated load reductions for 2013 and 2014 were 164 and 174 pounds per day. These were based on delivered flows of 215 and 242 cfs, and changes in concentration of 0.14 and 0.13 mg/L, respectively. The 2013 load reduction is a "potential" load reduction because in 2013 the canal operations were not directed toward water quality improvements on a "full-time" basis. Beginning in 2014 (and continuing in 2015) water quality operations was a primary focus over the entire irrigation season. Note that the primary purpose of canal is delivery of water to the district irrigators, and water quality improvement operations are secondary to this.

While not shown in Table 1, runoff estimates (e.g., field losses and minor system spills) were included in the daily mass balance load model and reduced the delivery load for Year 2014 and 2015 operations compared to Baseline operations. This reflects the higher level of control under the current automated canal operations that were fully implemented beginning 2014 (continued in 2015), and discussed in more detail below.

2015 and Baseline Flows

As stated above, the 2015 water-quality-focused canal operations were designed to maximize the use of relatively high phosphorus tributary drainage water on the RID agricultural lands. The Boise River diversion and major spills are controlled by an automated SCADA system designed for real time monitoring of primary inflows and adjustment of the Boise River diversion and canal spills.

2015 operations flow data collected and recorded in the SCADA system for the Boise River diversion and other inflows locations (Figure 3) are used to model the flow (and phosphorus concentrations) along the canal. Next, Baseline operations flows were modeled with the Boise River diversion set at Riverside's legally established water right of 271.5 cfs. These daily flows and measured water quality data were then used to model the phosphorus load reductions, which were calculated by difference (Table 1).



RC Mile	Location	Type	Diagram
Rc0_0	**Riverside diversion from Boise River**	Boise R (Auto)	
Rc0_1	**Canal gage below Diversion**	Canal (SCADA)	
Rc1_6	**Caldwell Res. water delivery (~60 ac)**	Delivery	
Rc1_8	Indian Creek at Kimbal Rd.	Trib (SCADA)	
Rc2_0	**Indian Creek Spill (Gate #0)**	Spill (Auto)	
Rc2_3	**Canal gage (rated section)**	Canal (SCADA)	
Rc3_2	**Pioneer-Dixie water delivery (2348 ac)**	Delivery	
Rc6_3	**Cheney water delivery (454 ac)**	Delivery	
Rc8_1	West End Drain (WED)	Trib (SCADA)	
Rc8_7	Dixie Gulch Drain (DgD)	Trib	
Rc9_0	**Dixie Spill (Gate #1)**	Spill (Auto)	
Rc9_1	**Demand gage (below Dixie Spill)**	Canal (SCADA)	
	RID-Upper Area (~3434 ac)	Delivery	
Rc18_6	**Dutton Spill (Gate #2)**	Spill (Auto)	
Rc18_7	Canal below Spill #2	Canal	
	RID-Middle Area (~3941 ac)	Delivery	
Rc23_7	**Holly Spill (Gate #3)**	Spill (Auto)	
Rc23_8	Canal below Spill #3	Canal	
	RID-Lower Area (~2782 ac)	Delivery	
Rc30_8	**End Spill (to Snake River)**	Spill	
		Snake R	

Figure 3. Diagram of Riverside Canal showing RC mile, location (with sampling ID or estimated irrigated acreage in parentheses), and type (i.e., source and receiving waters, delivery in green, tributary (trib) creek or drain in blue, and spill in dashed line to receiving water). Also shown are automated gates (Auto) and gages linked into the SCADA system.

The raw 15-minute flow data were converted to average daily data and corrected to model the flows and concentrations. Examples of daily discharge for key locations are shown in Figures 4a and 4b. Most of the 15-minute discharge data from water-level measuring devices were recorded in the SCADA system and used on a real-time basis during the entire irrigation season to manage operations. Additionally, some flows were measured manually (e.g. using an acoustic Doppler device) or estimated at various locations to verify accuracy or make preliminary flow adjustments. After the irrigation season ended, the discharge measurements and flow estimates were used to correct the raw SCADA records for the major inflows (i.e., Boise River diversion and Indian Creek, Rc0.0 and Rc1_8, respectively) to reduce errors (Appendix A). Once corrected, daily average flow data were then used to model phosphorus concentrations in the Riverside Canal for both 2015 and Baseline loads. However, it should be noted, that while corrected flows are used to model concentrations, the delivery loads and the load reductions (as discussed in the Model 2015 Load Reduction section) are based on the uncorrected flow data.

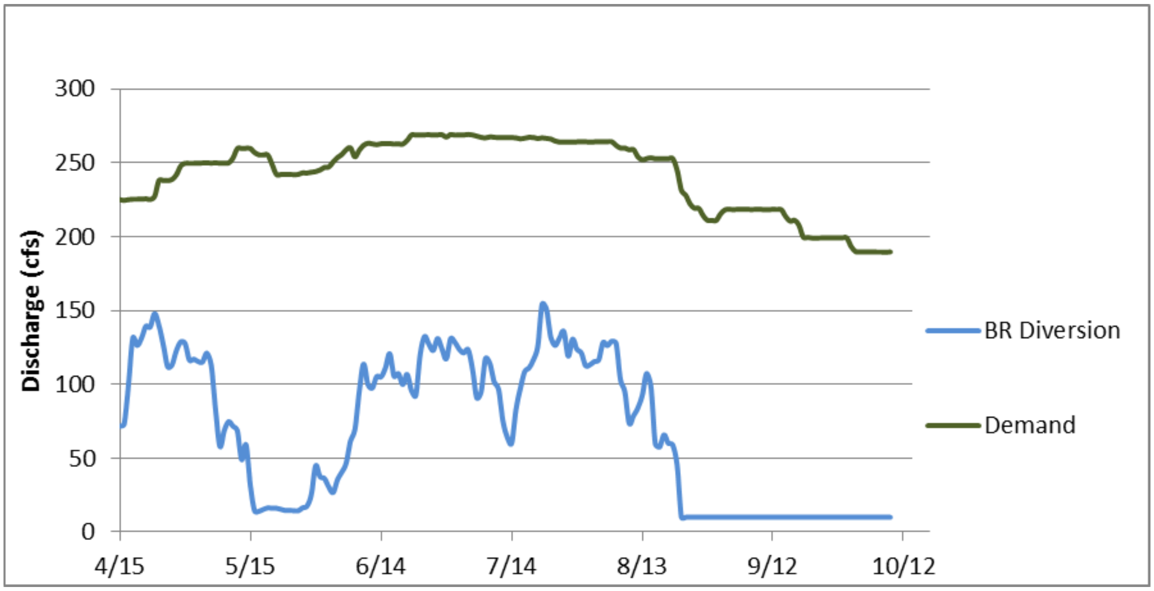


Figure 4a. Daily average flow data for Boise River diversion (Rc0_1c) and Demand (Rc9_1) for 2015 Operations.

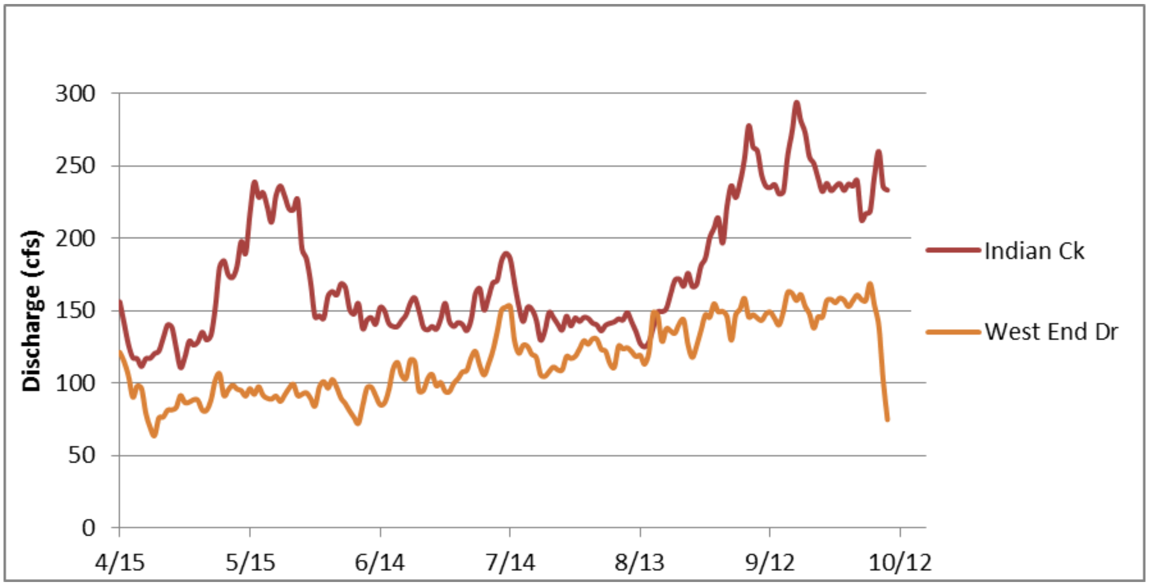


Figure 4b. 2015 Daily average Inflow data for Indian Creek at Kimball (Rc1_8c) and West End Drain (Rc8_1).

Delivered Flow

The daily delivery to RID irrigators is determined using measured Riverside Canal demand (Rc9_1) after subtraction of the lower canal spills (Figure 3). The demand (Rc9_1) is measured in the canal upstream of any RID deliveries, and is just below the Dixie Spill (Rc9_0). The lower spill locations used to calculate the RID delivery are the Dutton, Holly, and End Spills (Figure 3). The delivery calculated for 2015 operations is also used to model daily Baseline delivery loads, under the assumption that water delivery for either operation is the same. Total deliveries (Figure 5) are the sum of the RID and upper deliveries, which include deliveries to the Caldwell area, the Pioneer-Dixie, and Cheney (Figure 3). The upper delivery loads are calculated using the measured diversion rates.

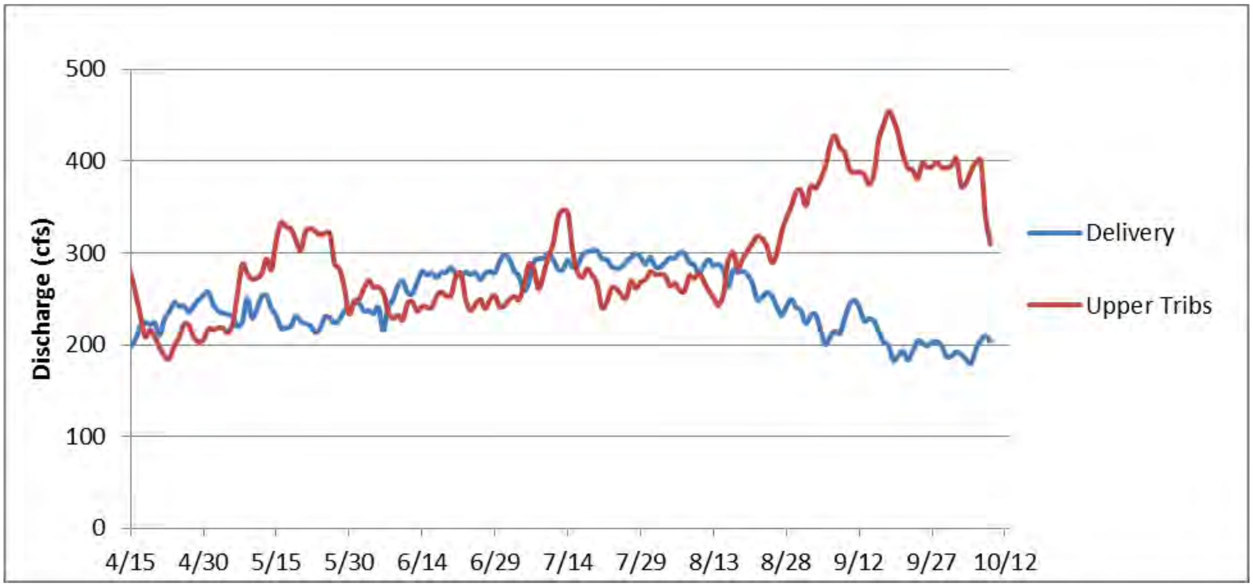


Figure 5. Daily modeled total delivery and upper tributaries (tribs) inflows as modeled for 2015.

Also shown in Figure 5 is the sum of the tributary inflows to the upper reaches of the canal (Figure 4b). This is the sum of Indian Creek, West End Drain, and Dixie Gulch. When the deliveries exceed the inflow from the upper tributaries, the SCADA system diverts water from Boise River (e.g., July through mid-August) to meet irrigation demands. When the upper tributary inflows exceed delivery, then the Boise River diversion is reduced, and upper spills (Indian Creek and Dixie Slough) will tend to increase (Figure 4c). During most of the 2015 irrigation season, the Boise River diversion gate was operated by the SCADA system, which was programed to minimize diversions from the Boise River (Figure 4a).

Baseline Diversion

Defining Baseline operations is necessary to determine the amount of phosphorus load reduction resulting from the ROWQIP. A definition of the baseline diversion is the critical parameter because it determines the flow along the canal, which will then be used to determine phosphorus concentration in the canal and delivery load for the Baseline operations. The ROWQIP is specifically designed to modify canal operations in a way that reduces phosphorus loading to the Snake and Boise rivers. However, the program does not include any actions to modify or redefine Riverside's overall irrigation requirements or the volume of water diverted as currently specified by adjudicated water rights. Therefore, the baseline relative to water diverted from the Boise River is 271.5 cfs, as legally established by Riverside's water rights.

Lower Spills and Runoff

In addition to changing Boise River diversion rates for the baseline model, the lower spills (i.e., Dutton, Holly and End Spill) used to model Baseline operations were the average of the spills measured during the 2010 through 2013 irrigations season (Harrison et al 2014). This baseline condition (Table 2) is used to model the benefits of reducing the lower spills and thereby offsetting any potential changes in runoff loads that could be caused by the slightly higher phosphorus concentration in the canal (Table 1).

Table 2. Lower canal spills as measured in 2015 (average) and for Baseline Operations.

Flows (cfs)	Rc18_7	Rc23_8	Rc31_1
2015 (average)	18	16	3
Baseline	36	29	28
2015-BL	-18	-13	-25

Corrected Flow and Quality Control

The daily average RID demand (i.e., the flow at Rc9_1), based on measured data and calculated using a water balance, are shown in Figure 6. The "Delta" is the difference between measured and calculated, which represents the model flow error. The causes of the error vary by measured location, canal reach, and season; and can include errors related to instruments, calculations, calibrations, channel conditions (i.e., weed growth and silting), and unknown inflow or outflow (i.e., unmeasured agricultural and stormwater drains, seepage to groundwater, and groundwater inflows).

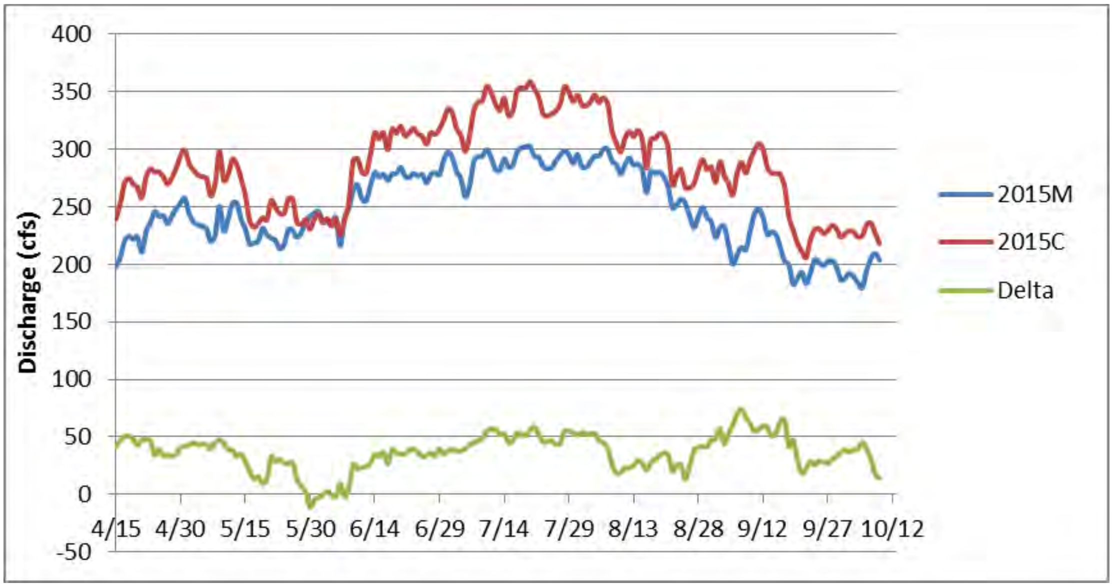


Figure 6. Year 2015 Measured (M) and calculated (C) demand flows, and the error.

During the irrigation season, preliminary raw discharge data from water-level measuring devices were recorded in the SCADA system and used to operate the canal diversion and spills in real time. Additionally, flows were measured manually (e.g. using acoustic Doppler and/or current meter devices) or estimated at various locations to verify accuracy or make preliminary flow adjustments.

After the irrigation season ended, the discharge measurements and RID flow estimates were used to correct the raw SCADA records for the major inflows (i.e., Boise River diversion and Indian Creek, Rc0.0 and Rc1_8, respectively) to reduce errors (Appendix A). Once corrected, the flow data are then used to model phosphorus concentrations in the Riverside Canal for both 2015 and Baseline operations. However, it should be noted, that while corrected flows are used to model concentrations, the delivery loads (and the load reductions) are based on the measured flow data at Rc9_1, which have not been corrected. This is done to link the calculated load reductions more directly to measured data and thereby reduce possible errors introduced during the correction and modeling procedures.

Water Quality

The 2015 total phosphorus concentration data used in the mass balance model (Table 3) were collected bi-monthly at Boise River diversion (Rc0_0), Indian Creek (Rc1_8), and West End Drain (Rc8_1). The water quality data were collected as part of a Riverside Canal monitoring program, and the monitoring procedures for collection of the data are presented in Harrison et al 2014. The other laboratory data reported for the 2015 irrigation season are summarized in Appendix B.

Table 3. Measured total phosphorus (mg/L) concentrations for inflow locations used in RC mass balance model.

	Total Phosphorus Concentration (mg/L)			
Sample Date	**Rc0_1**	**Rc1_8**	**Rc8_1**	**Rc9_1**
31-Mar	0.340	0.781	0.183	0.485
15-Apr	0.297	0.441	0.474	0.467
28-Apr	0.247	0.579	0.513	1.180
13-May	0.168	0.468	0.284	0.439
27-May	0.192	0.462	0.337	0.405
2-Jun	0.244	0.457	0.414	0.422
22-Jun	0.284	0.610	0.425	0.496
7-Jul	0.237	0.686	0.561	0.577
21-Jul	0.182	0.647	0.384	0.416
6-Aug	0.267	0.634	0.342	0.461
18-Aug	0.145	0.627	0.213	0.359
1-Sep	0.336	0.460	0.182	0.238
22-Sep	0.155	0.332	0.128	0.279
6-Oct	0.162	0.423	0.159	0.294
Average	**0.233**	**0.543**	**0.329**	**0.466**

As evident in Figure 7, the bi-monthly water quality data phosphorus concentration for the canal tributary inflows (Rc1_8 and Rc8_1) are consistently higher compared to the Boise River Diversion (Rc0_0). By optimizing the use of these higher phosphorus tributary waters, the concentration of phosphorus (and other pollutants) in the water delivered to the irrigators is higher (Table 1Table 2 and Figure 8). Coupled with reduced spills (achieved through SCADA-controlled automation) and the lower concentrations and loads of phosphorus (and other pollutants), overall phosphorus loads discharged to the Boise and Snake Rivers were reduced substantially (Table 1).

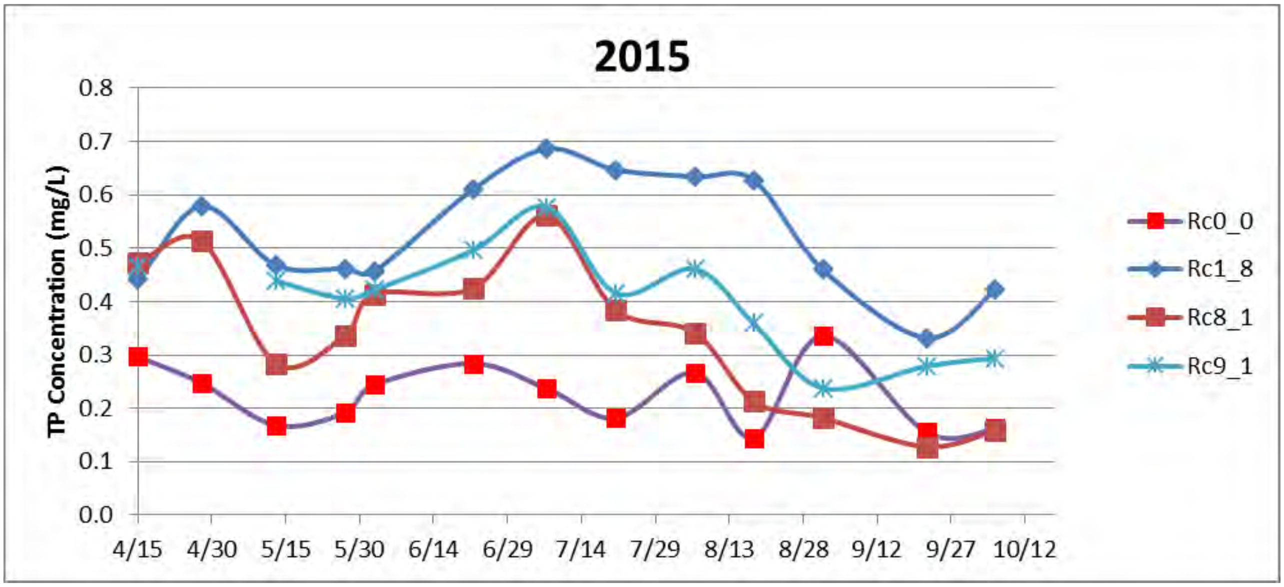


Figure 7. Graph of total phosphorus concentrations (TP) at modeled inflow locations and Riverside Canal at Dixie Spill (Rc9_1).

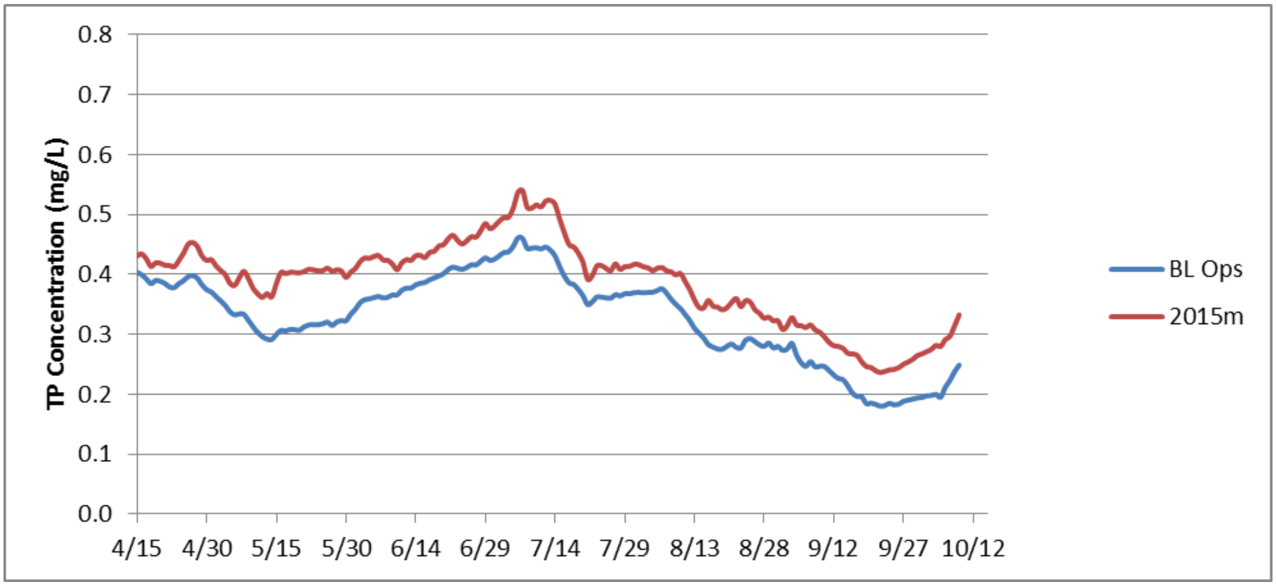


Figure 8. Modeled daily TP concentration of canal water delivered to RID irrigators for baseline and 2015 operations.

As discussed below, the mass balance approach is used to calculate total phosphorus loads delivered to irrigators on a daily basis. To calculate the loads in the canal on a given day, total phosphorus concentration data reported by the laboratory for the three primary inflows were first interpolated. These interpolated daily concentrations are then used with the modeled average daily flows to calculate daily loads along the canal using a simple mass balance equation often used by others (e.g., Etheridge, 2014).

Modeled 2015 Load Reduction

During the 2015 irrigation season, the Riverside Canal was operated to reduce the discharge of phosphorus loads to the Boise and Snake Rivers while ensuring consistent delivery of irrigation water. Using a mass balance water quality model of Riverside Canal (Harrison et al 2014), the daily TP reduction for the irrigation season (Figure 9) was calculated using bi-monthly water quality data, and corrected flow data.

The daily TP loads delivered to RID irrigators for 2015 water-quality focused operations were modeled using corrected 2015 daily average flow and interpolated water quality data (Figure 9 – 2015m). The Baseline canal operations was also modeled (Figure 9 – BL Ops) using the same inflow data and assuming Boise River diversions at the permitted rate. The “TP Reduction” line in Figure 9 represents the daily load reduction and was calculated as the difference between lines “2015m” and BL Ops (representing modeled 2015 and Baseline operations, respectively). When summed over the 183 day irrigations, this reduction is the total daily load reduction in the Boise and Snake Rivers for the irrigation season.

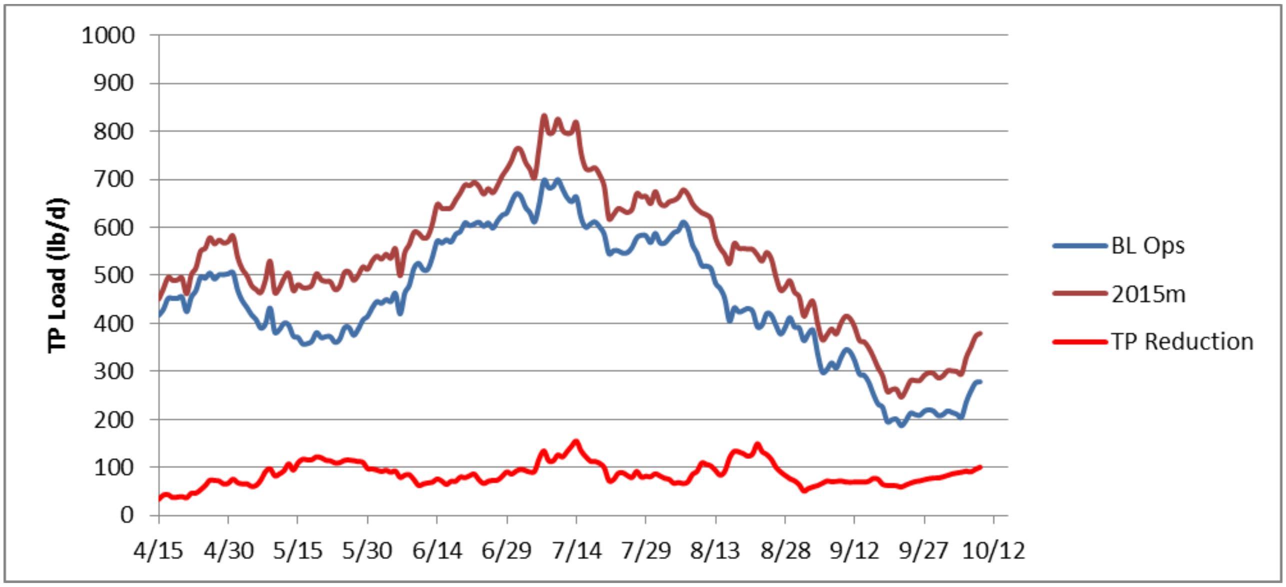


Figure 9. Modeled daily average load reductions with lower spills set at Baseline (BL) rates.

Based on these model results, the 2015 annual TP load reduction exceeded 15,000 lbs (Table 4). This annual phosphorus load reduction represent the change in phosphorus load in the Boise and Snake rivers (e.g., Figure 2) which would occur over a 183-day irrigation season under the water-quality focus operations of the ROWQIP.

Table 4. Preliminary total phosphorus load reductions for 2015.

TP Load Reduction (2015 - BL)		
(lb/d)	Days	lb/yr
86	183	15826

Conclusions

During the 2015 irrigation season, RID operated the Riverside Canal with the intent of reducing the discharge of phosphorus loads to the Boise and Snake rivers. The phosphorus originated from upstream urban and agricultural sources, and previously discharged into the canal as tributary drains and discharged from the canal as canal “spills”, which then discharge into downstream receiving waters. The canal spills and Boise River diversion were controlled with a SCADA system designed to automatically adjust the Boise River diversion rate as drainage inflows change while meeting irrigation deliveries.

The flow and water quality data were collected in 2015 to model the phosphorus load reduction of the ROWQIP for the irrigation season. The modeling results show that with current implementation, the ROWQIP phosphorus load reduction can exceed 15,000 lb/year. The 2015 load reduction was about one-half the potential load reduction calculated for 2013 and 2014 (Harrison et. al., 2014 and Harrison et. al., 2015). Based on a review of available data, the decrease appears to be due to a lower Indian Creek TP levels.

The modeled load reduction represents phosphorus from upstream sources that was applied to RID and other farm land via the Riverside Canal, and is thereby removed from the Snake River. The modeled load reductions occurring over the 183-day irrigation season exceeds the equivalent phosphorus load reduction of 15,000 lb/yr, which is comparable to the SR-HC TMDL dissolved oxygen allocation.

The information provided in this report documents the methods used to ensure the project performance is transparent, reliable, and verifiable. Laboratory data reports, raw flow measurement data, and other data are available upon request.

References

Etheridge, A. 2013. Evaluation of Total Phosphorus Mass Balance in the Lower Boise River, Southwestern Idaho. USGS SIR 2013-5220.Appendices

Harrison, J. S. King and S. Mooney. 2014. Riverside Operational Water Quality Improvement Project Development Report. Prepared for Idaho Power Company. May, 2014.

Harrison, J., S. King and S. Mooney. 2015. Riverside Operational Water Quality Improvement Project 2014 Annual Report. Prepared for Idaho Power Company. February 6, 2015.

Idaho and Oregon Departments of Environmental Quality (IDEQ and ODEQ). 2004. Snake River–Hells Canyon total maximum daily load (TMDL). IDEQ, Boise Regional Office, Boise, ID, and ODEQ, Pendleton Office, Pendleton, OR.

Appendices

Appendix A – Corrected 2015 Flow Data

2015 Corrected (c) and Uncorrected Flows (cfs)

2015Cf	Rc0_1c	Rc1_6	Rc1_8	Rc2_0	Rc2_3	Rc3_2	Rc6_3	Rc8_1	Rc8_7	Rc9_0	Rc9_1	Rc18_	Rc23_8	Rc30_9
4/15/2015	71.70	5.00	156.08	12.09	183.73	17.04	5.23	121.25	1.35	44.34	225.03	16.48	30.77	7.28
4/16/2015	73.03	5.00	141.08	9.22	171.66	18.75	5.87	114.63	1.00	19.52	224.56	20.27	19.75	8.27
4/17/2015	99.44	5.00	126.39	14.20	179.85	21.97	6.69	104.83	1.00	8.34	225.04	16.10	15.12	7.10
4/18/2015	131.40	5.00	117.49	17.60	197.57	21.03	7.45	90.30	1.00	13.17	225.30	18.47	10.25	5.78
4/19/2015	126.33	5.00	116.86	10.19	200.02	19.87	8.19	97.90	1.00	25.54	225.31	21.82	9.88	4.93
4/20/2015	131.23	5.00	111.48	6.22	201.57	19.86	8.86	96.36	1.00	31.97	225.30	20.49	8.61	6.03
4/21/2015	139.36	4.66	116.87	15.49	209.80	20.40	8.81	79.19	1.00	14.05	225.60	29.38	14.39	5.02
4/22/2015	138.80	5.00	117.10	6.10	218.01	21.98	8.62	69.35	1.00	11.97	225.15	17.38	12.93	1.89
4/23/2015	147.86	5.00	120.34	8.56	227.57	23.01	8.44	63.71	1.00	13.81	227.20	11.31	12.74	3.65
4/24/2015	139.83	5.00	122.02	2.04	229.65	23.64	8.26	75.92	1.00	27.72	237.97	12.96	13.05	2.85
4/25/2015	126.82	5.00	130.93	0.58	225.46	20.93	8.08	76.51	1.00	23.87	237.94	14.27	12.13	4.06
4/26/2015	111.93	5.00	140.03	0.18	222.41	17.17	7.90	81.27	1.00	32.51	237.90	12.02	6.96	6.70
4/27/2015	113.11	5.00	138.50	0.30	219.28	17.06	7.70	81.52	1.00	31.06	238.64	9.11	15.44	8.31
4/28/2015	122.86	5.00	124.07	0.30	215.79	16.88	7.49	83.16	1.01	26.34	241.81	8.65	15.00	4.98
4/29/2015	128.77	3.85	110.67	0.00	209.66	18.14	7.20	91.37	1.12	19.88	247.77	14.00	13.78	0.56
4/30/2015	127.75	3.00	117.80	0.01	214.24	19.54	6.92	86.61	1.23	13.34	249.56	15.08	9.44	0.86
5/1/2015	116.36	3.00	128.87	0.00	213.40	19.88	6.62	86.81	1.35	12.43	249.56	10.01	11.58	0.13
5/2/2015	117.01	3.00	126.26	0.00	210.67	19.81	6.30	88.51	1.48	11.19	249.58	12.74	19.28	2.73
5/3/2015	115.43	3.00	128.40	0.00	211.44	19.91	5.97	88.10	1.61	10.08	249.57	18.61	20.55	2.28
5/4/2015	115.18	3.00	135.06	0.00	215.96	20.10	5.65	81.39	1.74	11.41	249.83	15.78	26.66	1.71
5/5/2015	121.10	3.00	129.81	0.00	216.12	20.20	5.33	81.27	1.87	12.32	250.00	12.63	31.21	1.64
5/6/2015	113.02	3.00	132.89	0.00	212.84	20.10	5.04	88.14	1.97	14.33	249.73	14.08	29.38	3.64

2015Cf	Rc0_1c	Rc1_6	Rc1_8	Rc2_0	Rc2_3	Rc3_2	Rc6_3	Rc8_1	Rc8_7	Rc9_0	Rc9_1	Rc18_	Rc23_8	Rc30_9
5/7/2015	83.00	3.00	151.84	0.00	206.10	20.11	5.00	101.87	1.86	20.81	249.97	24.02	28.85	5.32
5/8/2015	57.99	3.00	179.68	0.00	205.24	19.80	5.00	106.37	1.72	23.24	249.69	28.20	17.83	6.53
5/9/2015	68.72	3.00	184.45	0.00	216.18	20.63	5.00	91.48	1.57	20.32	249.81	17.13	4.20	6.64
5/10/2015	74.70	3.00	174.76	0.00	212.87	20.61	5.00	95.26	1.43	23.32	249.87	23.94	18.80	6.76
5/11/2015	71.68	3.00	172.80	0.00	209.33	20.42	5.00	98.52	1.29	23.74	253.14	15.08	19.48	7.74
5/12/2015	68.70	3.00	180.33	0.00	211.33	21.67	5.00	95.93	1.14	18.49	259.62	10.38	19.41	6.63
5/13/2015	49.03	3.00	197.71	0.00	210.54	21.50	5.02	94.77	1.07	20.03	259.67	9.19	19.89	6.80
5/14/2015	58.99	3.00	189.46	0.00	209.70	17.62	5.20	91.07	1.40	20.25	259.76	17.47	22.13	6.65
5/15/2015	31.45	3.00	216.48	0.43	213.30	16.23	5.40	96.09	1.80	31.84	259.65	21.82	22.53	8.90
5/16/2015	14.12	3.00	238.69	0.69	224.10	15.31	5.60	92.27	2.20	45.62	256.82	27.89	25.33	9.71
5/17/2015	14.14	3.00	228.25	0.06	218.08	14.22	5.80	97.48	2.59	50.53	255.34	24.79	25.68	9.07
5/18/2015	15.38	3.00	231.48	0.18	220.97	14.36	6.00	91.70	2.95	47.22	255.25	23.00	27.67	7.76
5/19/2015	16.34	3.00	221.72	0.23	215.91	15.75	6.22	89.54	3.00	40.90	255.24	22.99	20.89	5.07
5/20/2015	16.14	3.00	211.06	0.00	208.34	16.76	6.44	88.93	3.00	30.94	248.81	24.38	21.99	2.97
5/21/2015	16.15	3.00	229.26	0.19	217.49	17.23	6.67	91.02	3.00	37.65	242.01	25.03	19.90	1.20
5/22/2015	15.39	3.00	235.98	0.70	220.74	17.42	6.89	87.38	3.00	42.90	242.07	25.15	22.53	1.18
5/23/2015	14.64	3.00	229.07	0.00	214.45	17.39	7.11	91.70	3.00	38.16	242.08	28.37	24.53	3.16
5/24/2015	14.65	3.00	220.29	0.00	209.42	17.21	7.33	96.30	3.00	37.65	242.12	22.73	26.21	3.14
5/25/2015	14.51	3.00	219.57	0.00	208.49	17.51	7.55	99.26	3.00	39.44	241.93	18.17	19.40	2.08
5/26/2015	14.43	3.00	226.58	0.40	213.81	18.05	7.78	91.43	3.00	36.72	242.11	9.11	26.22	6.76
5/27/2015	16.45	3.00	192.80	0.00	192.84	18.61	7.95	92.25	3.02	19.37	243.11	15.92	21.23	11.81
5/28/2015	17.52	3.00	186.11	0.00	189.14	21.12	7.80	93.29	3.20	17.86	243.04	16.78	18.86	11.76
5/29/2015	25.37	3.00	169.48	0.00	186.08	22.05	7.60	89.41	3.40	9.52	243.59	13.23	16.29	9.90
5/30/2015	44.91	3.00	145.61	0.00	190.84	23.46	7.40	84.19	3.60	11.47	244.02	11.58	15.97	8.49
5/31/2015	37.52	3.00	146.44	0.00	180.37	23.81	7.20	97.13	3.80	10.54	245.07	10.81	15.12	8.78
6/1/2015	36.34	3.00	144.70	0.00	173.61	24.06	7.00	101.06	4.00	8.01	246.79	10.80	15.44	8.78
6/2/2015	30.57	3.00	159.84	0.00	179.33	25.32	6.80	96.56	4.20	9.12	247.13	12.08	22.04	11.44
6/3/2015	26.78	3.00	163.17	0.00	174.60	26.00	6.60	102.40	4.40	8.15	250.54	11.71	25.61	11.60
6/4/2015	35.38	3.00	160.82	0.00	183.14	26.73	6.40	97.06	4.60	8.99	253.47	18.37	24.74	12.51

2015Cf	Rc0_1c	Rc1_6	Rc1_8	Rc2_0	Rc2_3	Rc3_2	Rc6_3	Rc8_1	Rc8_7	Rc9_0	Rc9_1	Rc18_	Rc23_8	Rc30_9
6/5/2015	40.54	3.00	168.54	0.00	195.92	25.23	6.20	89.60	4.80	15.01	255.55	22.09	18.12	8.95
6/6/2015	46.69	3.00	166.08	0.00	199.58	2.16	6.08	85.76	4.97	24.11	258.78	26.95	16.27	10.56
6/7/2015	61.63	3.00	150.85	0.00	202.31	16.80	6.40	80.68	4.94	13.84	260.05	18.50	17.33	9.71
6/8/2015	69.32	3.00	147.61	0.00	204.08	25.18	6.81	76.28	4.88	3.72	254.02	16.10	20.14	4.02
6/9/2015	94.90	3.00	154.92	1.25	226.96	27.29	7.22	72.28	4.81	3.83	258.41	10.15	21.00	0.65
6/10/2015	113.76	3.00	137.58	1.41	235.10	27.13	7.62	84.60	4.75	17.30	261.76	7.90	19.26	2.97
6/11/2015	99.94	3.00	143.52	0.00	227.61	23.05	8.03	96.70	4.69	24.26	263.14	17.02	18.55	4.46
6/12/2015	97.44	3.00	145.04	0.00	226.38	24.12	8.44	97.15	4.63	21.96	262.77	19.12	20.70	3.19
6/13/2015	105.22	3.00	140.64	0.00	227.42	29.34	8.84	91.24	4.56	10.93	262.29	15.63	17.15	2.58
6/14/2015	105.01	3.00	152.04	0.30	233.20	31.90	9.25	85.08	4.50	4.77	262.82	10.07	13.61	3.44
6/15/2015	110.82	3.00	150.03	0.43	233.64	29.82	9.66	86.18	4.44	12.43	262.93	11.03	14.12	4.33
6/16/2015	120.73	3.00	141.30	0.10	234.28	28.12	10.06	94.89	4.37	20.65	263.04	11.41	12.18	2.34
6/17/2015	105.53	3.00	139.04	0.00	227.19	29.37	10.47	109.52	4.31	26.34	262.59	18.83	11.12	2.34
6/18/2015	107.24	3.00	139.06	3.13	219.45	30.14	10.88	114.29	4.25	15.96	262.82	19.27	6.52	2.49
6/19/2015	99.90	3.00	143.24	0.00	219.76	30.31	11.28	105.26	4.19	9.97	262.57	19.09	7.43	1.80
6/20/2015	106.74	3.00	147.11	0.00	229.93	31.72	11.68	103.23	4.13	14.05	265.02	17.67	5.79	3.72
6/21/2015	95.80	3.00	155.36	0.00	226.73	32.11	12.09	115.98	4.06	20.16	268.79	21.81	14.12	3.30
6/22/2015	92.45	3.00	158.83	0.00	221.46	32.05	12.48	114.78	4.01	14.95	268.70	22.33	14.38	4.03
6/23/2015	120.17	3.00	149.65	0.00	239.90	33.21	12.79	94.43	4.03	11.03	268.86	17.40	18.28	3.36
6/24/2015	132.32	3.00	138.46	1.90	241.90	33.57	13.08	94.88	4.07	12.99	268.82	18.90	21.17	1.74
6/25/2015	127.21	3.00	136.71	0.00	238.21	35.21	13.38	103.13	4.10	17.46	269.00	16.62	25.42	0.27
6/26/2015	123.0	3.0	139.0	0.0	234.7	35.2	13.7	106.0	4.1	17.9	268.7	20.1	28.6	0.92
6/27/2015	131.0	3.0	137.2	0.0	237.9	35.5	14.0	98.1	4.2	12.9	268.8	24.1	17.8	1.45
6/28/2015	123.9	3.0	144.3	0.0	235.7	35.6	14.3	100.4	4.2	17.7	268.9	23.4	17.7	1.16
6/29/2015	117.3	3.0	155.1	0.0	238.3	35.5	14.6	94.3	4.2	11.0	267.4	23.6	17.9	0.79
6/30/2015	130.8	3.0	142.5	0.0	241.5	34.8	14.8	94.2	4.3	14.9	269.1	20.6	9.5	0.89
7/1/2015	128.3	3.0	139.1	0.0	233.6	35.9	15.1	99.8	4.3	11.2	268.7	12.9	12.0	0.23
7/2/2015	123.7	3.0	141.7	0.0	231.5	38.1	15.4	103.1	4.3	8.7	268.9	13.8	18.8	0.22
7/3/2015	121.3	3.0	140.4	0.0	228.5	38.6	15.7	107.6	4.4	10.1	268.8	20.9	24.7	0.32

2015Cf	Rc0_1c	Rc1_6	Rc1_8	Rc2_0	Rc2_3	Rc3_2	Rc6_3	Rc8_1	Rc8_7	Rc9_0	Rc9_1	Rc18_	Rc23_8	Rc30_9
7/4/2015	123.5	3.0	136.2	0.0	226.8	31.2	16.0	108.7	4.4	15.4	269.1	19.7	24.9	0.67
7/5/2015	110.6	3.0	143.9	0.0	221.1	10.8	16.3	117.5	4.4	38.0	268.8	18.7	20.4	1.09
7/6/2015	90.8	3.0	161.6	0.0	219.4	28.8	16.6	121.8	4.5	18.9	268.0	25.3	20.4	2.02
7/7/2015	94.9	3.0	165.2	0.0	228.4	39.1	16.9	112.2	4.5	5.9	267.2	16.0	18.2	2.05
7/8/2015	117.3	3.0	150.5	0.0	233.9	39.4	17.2	105.6	4.6	4.4	266.9	14.3	17.1	1.35
7/9/2015	114.1	3.0	159.1	0.0	241.2	39.1	17.5	113.1	4.6	15.3	267.4	17.0	14.8	1.08
7/10/2015	101.7	3.0	169.1	0.0	238.5	38.5	17.8	122.3	4.6	16.1	267.2	12.3	14.5	0.00
7/11/2015	96.6	3.0	170.8	0.0	236.9	35.0	18.1	135.2	4.7	27.5	267.0	12.5	18.1	0.00
7/12/2015	75.3	3.0	184.2	0.0	231.8	32.8	18.4	150.1	4.7	36.5	267.0	14.7	23.8	0.10
7/13/2015	64.3	3.0	189.5	0.0	228.3	33.0	18.7	152.4	4.7	37.2	267.0	17.5	21.1	1.18
7/14/2015	60.1	3.0	185.9	0.0	217.7	32.2	18.9	153.0	4.8	30.0	266.9	15.4	12.6	1.25
7/15/2015	82.7	3.0	169.0	0.0	221.1	32.0	19.2	129.2	4.8	19.8	266.8	22.3	13.7	0.56
7/16/2015	97.1	3.0	153.1	0.0	219.0	33.4	19.5	120.6	4.8	6.8	266.2	13.6	22.4	0.10
7/17/2015	108.6	3.0	142.5	0.0	217.9	35.1	19.8	126.1	4.9	3.9	266.6	8.6	16.8	1.36
7/18/2015	111.1	3.0	152.2	0.0	231.5	35.7	20.1	125.3	4.9	15.4	267.2	5.4	16.5	2.85
7/19/2015	116.5	3.0	150.8	0.0	234.0	35.5	20.4	119.9	4.9	14.9	267.1	7.6	13.6	2.63
7/20/2015	125.3	3.0	143.6	0.0	233.8	35.3	20.7	117.8	5.0	10.3	266.4	12.8	7.9	2.19
7/21/2015	154.2	3.0	129.7	0.0	245.0	35.8	21.0	105.9	5.0	9.6	266.9	21.8	10.6	0.21
7/22/2015	150.8	3.0	136.0	0.0	252.0	36.2	21.1	104.6	5.0	17.4	266.5	18.1	14.7	1.06
7/23/2015	132.0	3.0	148.7	0.0	249.8	36.3	21.2	108.0	5.0	21.7	266.0	19.0	19.0	3.04
7/24/2015	126.4	3.0	145.1	0.0	238.1	35.9	21.3	111.1	5.0	16.7	264.7	16.8	20.0	5.00
7/25/2015	131.4	3.0	140.5	0.0	234.6	35.9	21.4	109.0	5.0	15.2	264.0	19.0	18.0	2.99
7/26/2015	135.6	3.0	136.7	0.0	233.0	35.0	21.5	109.1	5.0	19.5	264.0	14.2	19.1	0.04
7/27/2015	119.0	3.0	146.2	0.0	229.8	35.1	21.6	118.3	5.0	20.4	263.9	14.3	14.2	0.07
7/28/2015	130.6	3.0	139.5	0.0	221.9	34.8	21.7	117.0	5.0	13.3	264.0	14.0	9.6	0.75
7/29/2015	123.8	3.0	144.9	0.0	217.3	34.8	21.8	118.5	5.0	13.4	264.1	11.8	12.6	4.22
7/30/2015	121.3	3.0	142.6	0.0	224.3	35.0	21.9	123.6	5.0	14.9	264.1	17.1	16.4	2.58
7/31/2015	112.6	3.0	145.3	0.0	221.1	35.1	22.0	129.2	5.0	16.2	264.2	10.9	16.9	0.99
8/1/2015	113.2	3.0	144.6	0.0	219.6	35.1	22.0	126.8	5.0	11.8	264.0	14.7	21.4	3.14

2015Cf	Rc0_1c	Rc1_6	Rc1_8	Rc2_0	Rc2_3	Rc3_2	Rc6_3	Rc8_1	Rc8_7	Rc9_0	Rc9_1	Rc18_	Rc23_8	Rc30_9
8/2/2015	115.4	3.0	141.4	0.0	216.8	35.4	22.1	130.5	5.0	14.6	264.1	14.1	19.5	6.33
8/3/2015	116.5	3.0	140.0	0.0	213.9	35.5	22.2	130.1	5.0	14.6	264.2	15.7	14.2	5.91
8/4/2015	128.3	3.0	136.0	0.0	218.9	35.9	22.3	123.3	5.0	14.2	264.4	13.9	14.5	2.76
8/5/2015	126.3	3.1	139.9	0.0	225.6	36.4	22.4	122.0	5.0	20.4	264.2	14.0	17.1	0.75
8/6/2015	129.2	3.0	141.2	0.0	226.5	36.8	22.5	113.5	5.0	17.7	264.3	11.7	13.9	0.76
8/7/2015	127.8	3.0	142.1	0.0	228.4	37.1	22.3	111.0	5.0	22.2	261.8	11.6	11.5	1.21
8/8/2015	103.2	3.0	144.3	0.0	214.0	36.5	22.1	125.5	5.0	30.5	259.9	18.9	11.8	1.04
8/9/2015	95.0	3.0	143.5	0.0	204.6	36.0	21.9	123.6	5.0	27.7	260.0	17.5	15.1	1.25
8/10/2015	73.8	3.0	148.6	0.0	191.4	36.1	21.7	124.3	5.0	13.2	258.8	18.3	20.6	1.84
8/11/2015	78.7	3.0	142.3	0.0	186.7	37.2	21.5	121.8	5.0	4.3	258.9	15.3	18.7	0.20
8/12/2015	84.0	3.0	135.5	0.0	182.6	37.3	21.3	118.4	5.0	4.5	254.0	12.1	9.9	0.97
8/13/2015	92.5	3.0	127.3	0.0	179.9	37.6	21.0	119.1	5.0	5.3	252.0	13.7	10.2	3.59
8/14/2015	107.3	3.0	125.0	0.0	186.3	38.6	20.8	113.0	5.0	5.7	252.7	13.6	11.1	3.23
8/15/2015	98.6	3.0	128.2	0.0	186.8	29.2	20.6	121.2	5.0	19.9	253.3	9.2	12.5	2.60
8/16/2015	59.7	3.0	138.3	0.0	169.2	12.4	20.4	148.4	5.0	41.7	252.6	10.9	13.1	1.77
8/17/2015	57.6	3.0	149.0	0.0	175.4	33.6	20.2	146.8	5.0	21.3	252.6	12.1	14.2	2.23
8/18/2015	65.8	3.0	149.2	0.0	182.6	35.1	20.0	128.7	5.0	7.1	252.8	14.7	15.0	2.34
8/19/2015	60.1	3.0	151.3	0.0	181.1	36.5	20.2	137.5	5.0	7.8	252.7	14.7	17.1	0.63
8/20/2015	59.1	3.0	161.3	0.0	187.7	37.6	20.4	135.9	5.0	11.5	252.9	17.2	19.2	1.28
8/21/2015	45.7	3.0	171.0	0.0	188.0	37.4	20.5	134.4	5.0	15.7	245.1	18.1	18.8	1.93
8/22/2015	10.0	3.0	171.7	0.0	168.1	36.2	20.7	141.1	5.0	16.2	231.4	22.3	18.4	1.54
8/23/2015	10.0	3.0	166.9	0.0	160.4	35.9	20.9	143.6	5.0	12.1	227.9	17.2	18.2	0.58
8/24/2015	10.0	3.0	175.8	0.0	167.6	36.3	21.1	126.5	5.0	9.4	222.1	12.3	13.1	0.29
8/25/2015	10.0	3.0	166.7	0.0	165.6	36.0	21.2	117.8	5.0	6.3	219.2	13.4	12.1	1.06
8/26/2015	10.0	3.0	168.1	0.0	162.5	34.5	21.4	125.7	5.0	6.2	219.1	17.2	17.0	1.85
8/27/2015	10.0	3.0	180.8	0.0	169.6	33.3	21.6	136.3	5.0	22.1	214.2	18.6	19.2	2.23
8/28/2015	10.0	3.0	186.1	0.0	175.2	33.7	21.8	147.1	5.0	37.8	211.0	8.8	17.6	1.54
8/29/2015	10.0	3.0	200.0	0.0	187.5	34.3	22.0	145.4	5.0	48.7	211.0	9.3	10.2	1.19
8/30/2015	10.0	3.0	206.8	0.0	196.1	34.6	22.1	154.7	5.0	64.3	211.0	17.3	11.9	0.55

2015Cf	Rc0_1c	Rc1_6	Rc1_8	Rc2_0	Rc2_3	Rc3_2	Rc6_3	Rc8_1	Rc8_7	Rc9_0	Rc9_1	Rc18_	Rc23_8	Rc30_9
8/31/2015	10.0	3.0	213.9	0.0	204.5	35.0	22.3	149.2	5.0	54.9	215.4	25.1	12.3	1.30
9/1/2015	10.0	3.0	196.6	0.0	188.2	34.3	22.4	149.5	5.0	35.1	218.1	39.0	14.6	0.83
9/2/2015	10.0	3.0	222.0	0.0	209.0	35.5	22.2	145.8	4.9	45.8	218.5	35.6	11.7	0.26
9/3/2015	10.0	3.0	236.2	0.0	229.5	33.0	21.9	129.6	4.8	60.4	218.3	31.3	10.3	1.39
9/4/2015	10.0	3.0	228.0	0.0	221.2	24.1	21.6	146.9	4.7	69.3	218.5	31.6	15.8	2.55
9/5/2015	10.0	3.0	238.4	0.0	232.4	21.9	21.4	150.9	4.7	79.3	218.5	40.2	18.9	5.33
9/6/2015	10.0	3.0	254.1	0.0	246.1	22.4	21.1	158.5	4.6	91.9	218.5	39.2	13.3	3.81
9/7/2015	10.0	3.0	277.6	4.8	257.8	22.8	20.8	145.6	4.5	94.0	218.3	35.7	13.0	1.43
9/8/2015	10.0	3.0	262.9	0.3	251.6	26.8	20.5	147.1	4.4	88.3	218.4	34.6	18.6	2.94
9/9/2015	10.0	3.0	260.2	0.0	253.7	29.6	20.2	144.9	4.3	86.7	218.4	29.3	11.2	1.99
9/10/2015	10.0	3.0	243.5	0.0	240.3	29.1	19.9	143.2	4.2	75.7	218.3	20.1	5.1	1.32
9/11/2015	10.0	3.0	235.8	0.0	231.3	28.9	19.6	147.8	4.1	71.3	218.2	15.4	6.2	0.00
9/12/2015	10.0	3.0	235.0	0.0	229.5	28.9	19.4	148.9	4.1	68.8	218.5	17.3	10.6	0.95
9/13/2015	10.0	3.0	236.9	0.0	231.3	26.3	19.1	144.4	4.0	70.3	218.4	25.5	12.6	2.64
9/14/2015	10.0	3.0	230.5	0.0	227.7	24.6	18.8	140.2	3.9	69.0	218.1	22.7	10.1	3.37
9/15/2015	10.0	3.0	232.1	0.0	228.7	25.2	18.5	149.4	3.8	82.3	213.4	15.1	14.7	4.42
9/16/2015	10.0	3.0	257.2	0.0	254.9	24.1	18.2	162.7	3.7	114.5	210.4	15.6	21.0	4.32
9/17/2015	10.0	3.0	273.6	7.1	259.4	21.2	17.9	162.0	3.6	123.9	211.1	23.6	22.4	4.30
9/18/2015	10.0	3.0	293.7	67.9	224.2	17.6	17.6	157.0	3.5	108.4	207.6	18.8	23.3	4.20
9/19/2015	10.0	3.0	281.2	74.4	213.9	14.4	17.4	161.1	3.5	100.0	199.6	22.1	25.2	4.18
9/20/2015	10.0	3.0	272.9	73.9	214.4	14.4	17.1	153.1	3.4	101.4	199.5	18.2	23.5	4.10
9/21/2015	10.0	3.0	256.1	70.7	205.1	14.1	16.8	147.7	3.3	95.1	199.1	13.9	22.2	4.10
9/22/2015	10.0	3.0	251.6	73.3	198.4	14.0	16.5	137.9	3.2	74.2	198.9	24.6	20.6	4.03
9/23/2015	10.0	3.0	241.4	64.3	198.6	13.8	16.2	145.7	3.1	75.5	199.1	24.5	10.7	3.92
9/24/2015	10.0	3.0	232.2	58.3	196.1	17.5	15.9	145.5	3.0	71.1	199.1	22.6	4.9	3.85
9/25/2015	10.0	3.0	237.8	58.0	199.6	20.8	15.6	156.9	2.9	81.8	199.2	27.6	5.5	3.78
9/26/2015	10.0	3.0	232.8	55.1	196.6	21.1	15.4	157.7	2.9	81.5	199.1	28.5	7.5	3.71
9/27/2015	10.0	3.0	235.6	54.7	198.4	21.2	15.1	155.5	2.8	83.8	199.2	21.5	10.8	3.63
9/28/2015	10.0	3.0	237.6	55.4	199.4	21.3	14.8	158.6	2.7	84.8	199.2	20.5	11.0	3.56

2015Cf	Rc0_1c	Rc1_6	Rc1_8	Rc2_0	Rc2_3	Rc3_2	Rc6_3	Rc8_1	Rc8_7	Rc9_0	Rc9_1	Rc18_	Rc23_8	Rc30_9
9/29/2015	10.0	3.0	233.0	50.8	198.0	21.3	14.5	157.2	2.6	81.2	199.0	25.9	10.1	3.49
9/30/2015	10.0	3.0	237.3	52.2	199.8	21.7	14.2	152.8	2.5	81.6	193.2	32.2	9.6	3.42
10/1/2015	10.0	3.0	235.9	51.7	199.2	22.0	13.9	156.8	2.4	86.0	189.9	26.5	11.2	3.35
10/2/2015	10.0	3.0	239.7	52.7	201.5	22.3	13.6	160.7	2.3	94.6	189.6	19.7	13.4	3.28
10/3/2015	10.0	3.0	212.6	26.8	197.4	22.2	13.4	157.6	2.3	88.7	189.7	19.6	16.0	3.20
10/4/2015	10.0	3.0	217.0	25.2	203.0	22.4	13.1	157.0	2.2	92.9	189.7	21.1	19.8	3.13
10/5/2015	10.0	3.00	218.4	26.7	200.8	25.3	12.8	168.7	2.1	96.5	189.7	25.3	22.8	3.06
10/6/2015	10.0	3.00	243.0	48.5	204.1	26.7	12.5	153.5	2.0	88.5	189.5	19.3	15.0	3.01
10/7/2015	10.0	3.00	259.9	69.7	202.0	26.5	12.5	139.5	2.0	79.1	189.5	12.2	11.3	3.00
10/8/2015	10.0	3.00	235.6	49.4	198.2	26.3	12.5	102.3	2.0	51.6	189.4	10.9	7.8	3.00
10/9/2015	10.0	3.00	233.1	43.1	199.8	26.3	12.5	74.7	2.0	31.0	189.6	15.3	9.3	3.00

2015 Flow Correction Summary

During the 2015 irrigation season preliminary canal, tributary and diversion flows are calculated or estimated using rating curves and estimates generated from data, observations, and measurements collected in earlier years (i.e., 2014 and earlier). The preliminary SCADA flow data are then corrected for modeling daily phosphorus load reductions. The correction process relies on flow measurements and observations collected during the 2015 irrigation season to revise, adjust, and replace the preliminary recorded SCADA flows.

In 2015 only the Boise River diversion (Rc0_1) flow data were substantially corrected at the end of the year. Below are graphs and other information used to correct the discharge record for the Riverside Canal Diversion at the Boise River (Rc0_1). In the beginning of the year, dual rating equations (e.g., high and low flow) developed in 2014 were used. In mid-year, IPC flow measurements made during 2015 were used to revise the rating equation, which were applied to the SCADA flow reporting beginning on July 29 (Figure 1) on a preliminary basis.

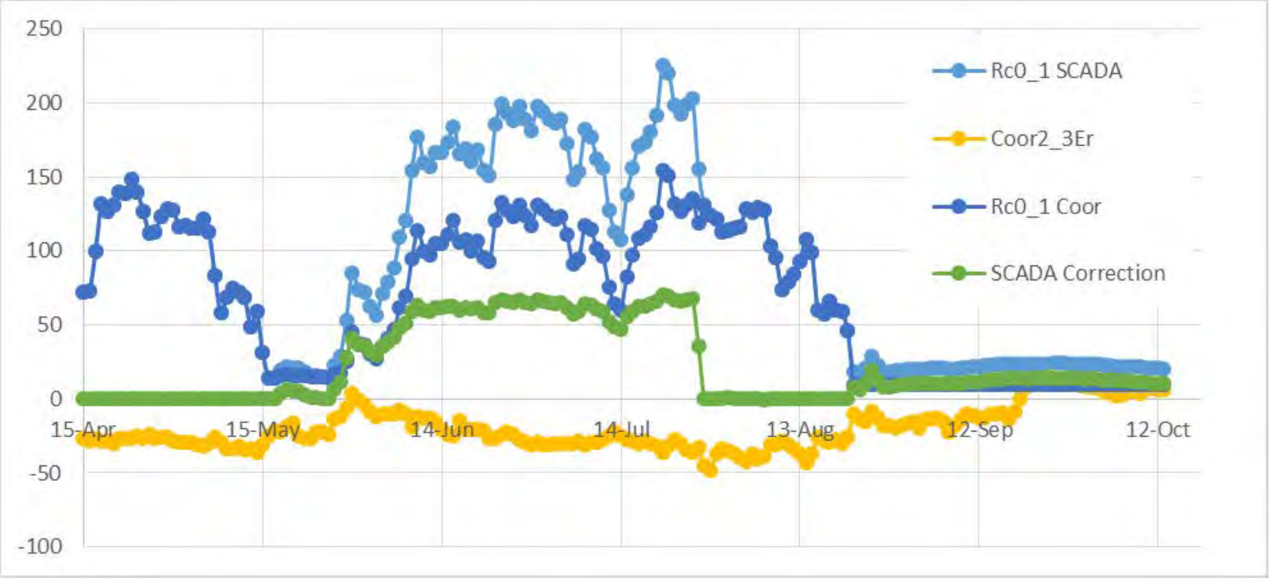


Figure A-1. Raw SCADA data (Rc0_1 SCADA), "corrected" SCADA including manual changes, calculated error at Rc3_3 (Coor2_3Er), and SCADA correction.

After the end of the season, the rating curves were reviewed and finalized for the 2015 irrigation season (Figure 2). The SCADA recorded flows (preliminary SCADA record) were then corrected based on all available information. The following list summarizes the SCADA corrections as shown in Figure A-1:

1. The raw SCADA record uses the 2014 rating curves and was not changed from April 15 through May 15 per recommendations based on the IPC measurements and error estimated at Rc2_3 (Figure A-1: Coor2_3Er).
2. Based on flow measurements by IPC during 2015, a 2015 single rating curve was developed and first applied July 29. This rating was then extended back to May 15 and used through August 22.

3. In late summer, around August 22, the diversion dropped below reliable rating measurements. At this time the flow was set at 10 cfs based on IPC measurements upstream of Rc1_7 (Table A-1)

Table A-1. End of season changes for Rc0_1 when flow was near 10 cfs.

IPC Measurements		**Flow (cfs)**
(Upstream 1_6)	3-Sep	13.90
	29-Sep	11.10
	Average	**12.5**
Caldwell Div (1_6)	Estimate	3
Flow into RID (1_7)	**Estimate**	**10**

While the Boise River diversion was the only flow data that were corrected using an improved rating equation, other flow data were revised based on observations recorded during the irrigation season by RID staff. The preliminary minor diversion and inflow data (Rc6_3 and Rc8_7, respectively) were first compared with RID staff observations (Figure A-2) general consistency, and then final flow data were estimated using observation data.

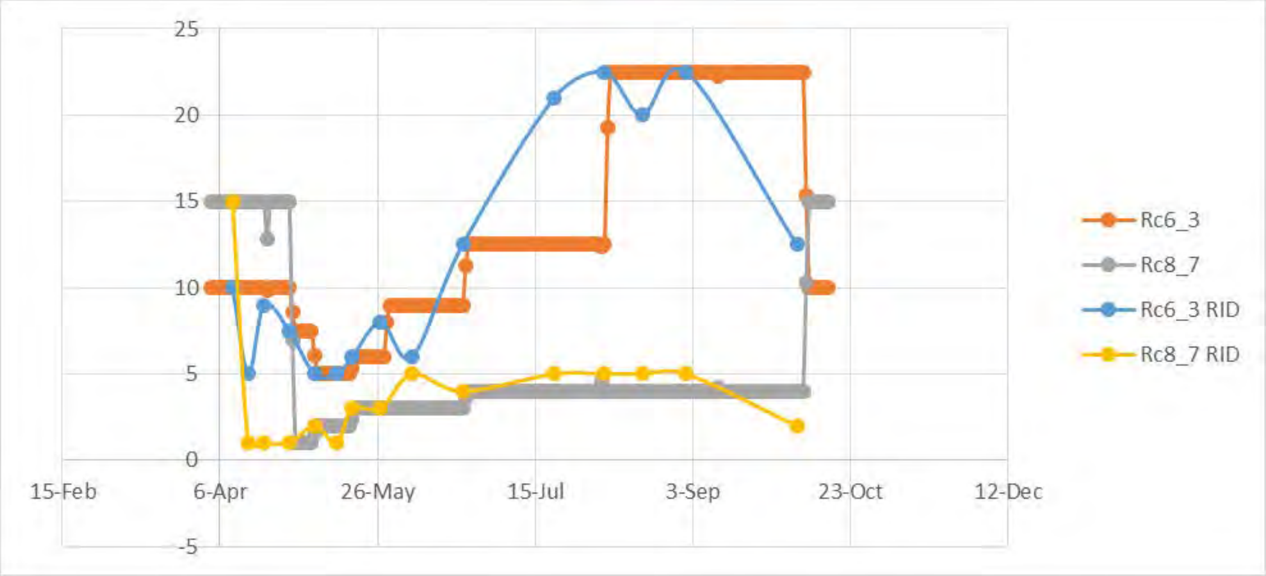


Figure A-2. Preliminary minor diversion and inflow data (Rc6_3 and Rc8_7, respectively) compared with RID staff observations (Rc6_3 RID and Rc8_7 RID, respectively).

Appendix B – Water Quality Data and QC

2015 Water Quality Data

Riverside Canal at Boise River Diversion (Rc0_1)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/31/2015	10:00		119	0.220	0.340	41
4/15/2015	13:05		66	0.197	0.297	38
4/28/2015	11:15		106	0.140	0.247	45
5/13/2015	11:20		54	0.100	0.168	39
5/27/2015	11:00		25	0.119	0.192	31
6/2/2015	11:10		58	0.154	0.244	47
6/2/2015	11:10			0.165	0.228	43
6/22/2015	11:50		130	0.180	0.284	47
7/7/2015	12:10		142	0.133	0.237	51
7/21/2015	11:00		144	0.107	0.182	31
8/6/2015	10:20		112	0.171	0.267	28
8/18/2015	11:05		57	0.151	0.145	17
9/1/2015	10:40		19	0.129	0.336	43
9/22/2015	13:00		23	0.106	0.155	5
9/22/2015	13:00			0.111	0.144	9
10/6/2015	11:45		21	0.118	0.162	7

Indian Creek at Kimball Rd (Rc1_8)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/31/2015	9:30		92	0.687	0.781	31
4/15/2015	12:40		154	0.382	0.441	25
4/28/2015	10:30		128	0.527	0.579	44
4/28/2015	10:30		128	0.507	0.568	96
5/13/2015	11:00		190	0.379	0.468	56
5/27/2015	10:15		187	0.394	0.462	1060
6/2/2015	10:40		160	0.426	0.457	28
6/22/2015	11:30		161	0.461	0.610	58
7/7/2015	11:40		168	0.411	0.686	105
7/21/2015	10:30		135	0.429	0.647	61
8/6/2015	10:00		147	0.502	0.634	41
8/6/2015	10:00			0.486	0.627	33
8/18/2015	10:50		154	0.474	0.627	22
9/1/2015	11:00		199	0.420	0.460	17
9/22/2015	12:40		261	0.283	0.332	21
10/6/2015	11:30		245	0.323	0.423	19

West End Drain above Riverside Canal (Rc8_1)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/31/2015	9:00		23	0.088	0.183	76
4/15/2015	11:00		123	0.114	0.474	215
4/28/2015	9:40		89	0.152	0.513	268
5/13/2015	10:00		94	0.097	0.284	145
5/27/2015	9:30		94	0.109	0.337	173
6/2/2015	9:40		98	0.116	0.414	234
6/22/2015	10:30		134	0.130	0.425	186
7/7/2015	10:45		119	0.113	0.561	263

West End Drain above Riverside Canal (Rc8_1)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
7/7/2015	10:45			0.113	0.533	253
7/21/2015	9:30		112	0.131	0.384	206
8/6/2015	9:08		122	0.130	0.342	129
8/18/2015	9:54		135	0.108	0.213	56
9/1/2015	9:50		152	0.110	0.182	37
9/22/2015	12:00		139	0.072	0.128	33
10/6/2015	10:20		148	0.083	0.159	44

Riverside Canal at Gate 1 and Spill to Dixie Slough (Rc9_1 and Rc9_0)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
4/15/2015	10:30	55	226	0.271	0.485	95
4/15/2015	10:30	55	226	0.270	0.467	117
4/28/2015	9:10	38	240	0.279	1.180	128
5/13/2015	9:30	18	258	0.287	0.439	100
5/27/2015	8:40	28	241	0.246	0.405	96
6/2/2015	9:20	8	247	0.292	0.422	125
6/22/2015	10:15	23	267	0.284	0.496	79
7/7/2015	10:20	17	267	0.277	0.577	163
7/21/2015	9:10	13	266	0.242	0.416	110
8/6/2015	8:00	29	261	0.288	0.461	83
8/18/2015	9:20	10		0.279	0.359	38
8/18/2015	9:20			0.282	0.252	40
9/1/2015	9:02	38		0.264	0.238	27
9/22/2015	11:35	73	199	0.206	0.279	24
10/6/2015	9:50	91		0.218	0.294	22

Riverside Canal at Gate 2 and Spill to Dutton Drain (Rc18_7)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
4/15/2015	9:30	12		0.245	0.422	103
4/28/2015	8:10	10		0.269	0.460	124
5/13/2015	8:40	8		0.255	0.418	124
5/27/2015	8:05	14		0.219	0.394	137
6/2/2015	8:00	12		0.250	0.428	173
6/22/2015	9:20	30		0.263	0.480	165
6/22/2015	9:20			0.265	0.518	161
7/7/2015	9:21	8		0.243	0.573	183
7/21/2015	8:20	31		0.210	0.447	160
8/6/2015	7:11	13		0.221	0.396	99
8/18/2015	8:35	17		0.212	0.349	53
9/1/2015	8:30	37		0.221	0.299	45
9/1/2015	8:30			0.226	0.306	50
9/22/2015	10:50	22		0.177	0.239	25
10/6/2015	9:00	19		0.196	0.268	30

Riverside Canal at Gate 3 and Spill to Holly Drain (Rc23_8)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
4/15/2015	8:30			0.209	0.419	110
4/28/2015	7:50	18		0.236	0.391	124
5/13/2015	8:05	19		0.221	0.411	150
5/13/2015	8:05	19		0.226	0.430	141
5/27/2015	7:40	29		0.189	0.366	138
6/2/2015	8:00	21		0.221	0.339	116
6/22/2015	8:30	16		0.224	0.484	163
7/7/2015	8:45	17		0.174	0.492	145
7/21/2015	7:50	5.5		0.189	0.408	113
8/6/2015	7:00	12		0.213	0.392	105
8/18/2015	8:06	20		0.197	0.332	67

Riverside Canal at Gate 3 and Spill to Holly Drain (Rc23_8)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
9/1/2015	8:06	16		0.214	0.307	48
9/22/2015	10:35	20		0.162	0.229	38
10/6/2015	8:30	19		0.174	0.242	26

Riverside Canal at End Spill to Snake River (Rc30_9)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
4/15/2015	7:30	9.9		0.211	0.313	33
4/28/2015	7:20	21		0.222	0.271	30
5/13/2015		5.4		0.244	0.343	58
5/27/2015	7:40	12.4		0.234	0.305	40
5/27/2015	7:40			0.230	0.316	42
6/2/2015	7:20	7.5		0.191	0.215	18
6/22/2015	7:30	2		0.165	0.236	21
7/7/2015	7:00	3.5		0.172	0.279	32
7/21/2015	7:30	2		0.170	0.243	25
8/6/2015	6:30	3		0.205	0.278	23
8/18/2015	7:45	1.5		0.189	0.257	30
9/1/2015	7:00	2		0.166	0.218	16
9/22/2015	10:10	4		0.166	0.214	19
10/6/2015	8:00	3		0.135	0.183	36

Mammon Gulch above Riverside Canal (Rc14_2)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
7/7/2015	10:00		12	0.059	0.188	46
7/21/2015	8:50		12	0.078	0.302	97
8/6/2015	7:30		12	0.044	0.177	49
8/18/2015	9:00		8	0.062	0.139	74

Mammon Gulch above Riverside Canal (Rc14_2)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
9/1/2015	8:50		8	0.058	0.133	24
9/22/2015	11:10		14	0.052	0.096	16
10/6/2015	9:25		2	0.056	0.144	57

2015 Quality Control Data

Riverside Canal at Boise River Diversion (Rc01_1)

Date	Time	Lab Analysis			Difference (Duplicate - Original)/Original		
		Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
6/2/2015	11:10	0.154	0.244	47			
6/2/2015	11:10	0.165	0.228	43	7%	-7%	-9%
9/22/2015	13:00	0.106	0.155	5			
9/22/2015	13:00	0.111	0.144	9	5%	-7%	80%

Indian Creek at Kimball Rd (Rc1_8)

Date	Time	Lab Analysis			Difference (Duplicate - Original)/Original		
		Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
4/28/2015	10:30	0.527	0.579	44			
4/28/2015	10:30	0.507	0.568	96	-4%	-2%	118%
8/6/2015	10:00	0.502	0.634	41			
8/6/2015	10:00	0.486	0.627	33	-3%	-1%	-20%

West End Drain above Riverside Canal (Rc8_1)

Date	Time	Lab Analysis			Difference (Duplicate - Original)/Original		
		Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
7/7/2015	10:45	0.113	0.561	263			
7/7/2015	10:45	0.113	0.533	253	0%	-5%	-4%

Riverside Canal at Gate 1 and Spill to Dixie Slough (Rc9_1 and Rc9_0)

Date	Time	Lab Analysis			Difference (Duplicate - Original)/Original		
		Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
4/15/2015	10:30	0.271	0.485	95			
4/15/2015	10:30	0.270	0.467	117	0%	-4%	23%
8/18/2015	9:20	0.279	0.359	38			
8/18/2015	9:20	0.282	0.252	40	1%	-30%	5%

Riverside Canal at End Spill to Snake River (Rc30_9)

Date	Time	Lab Analysis			Difference (Duplicate - Original)/Original		
		Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
5/27/2015	7:40	0.234	0.305	40			
5/27/2015	7:40	0.230	0.316	42	-2%	4%	5%

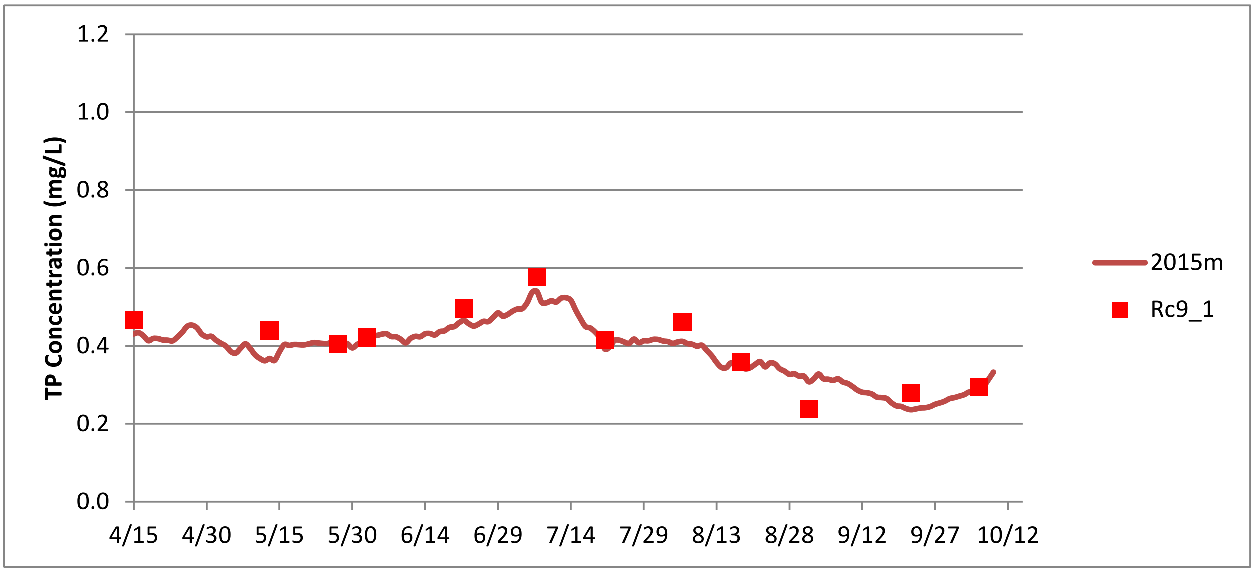
Riverside Canal at Gate 2 and Spill to Dutton Drain (Rc18_7)

Date	Time	Lab Analysis			Difference (Duplicate - Original)/Original		
		Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
6/22/2015	9:20	0.263	0.480	165			
6/22/2015	9:20	0.265	0.518	161	1%	8%	-2%
9/1/2015	8:30	0.221	0.299	45			
9/1/2015	8:30	0.226	0.306	50	2%	2%	11%

Riverside Canal at Gate 3 and Spill to Holly Drain (Rc23_8)

Date	Time	Lab Analysis			Difference (Duplicate - Original)/Original		
		Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
5/13/2015	8:05	0.221	0.411	150			
5/13/2015	8:05	0.226	0.430	141	2%	5%	-6%

Total Phosphorus Concentration Data (modeled and measured) and Error



	Mean Error	
	Arithmetic	**Absolute**
4/15/2015	-0.036	0.036
4/28/2015	0.430	0.430
5/13/2015	-0.054	0.054
5/27/2015	0.003	0.003
6/2/2015	-0.003	0.003
6/22/2015	-0.020	0.020
7/7/2015	-0.061	0.061
7/21/2015	-0.018	0.018
8/6/2015	-0.086	0.086
8/18/2015	-0.018	0.018
9/1/2015	0.077	0.077
9/22/2015	-0.014	0.014
10/6/2015	-0.003	0.003
Average	**0.0152**	**0.0633**

Exhibit 7.2-6

Riverside Operational Water Quality Improvement Project 2016 Annual Report

Riverside Operational Water Quality Improvement Project

2016 Annual Report

Prepared for: Idaho Power Company

Riverside Irrigation District

Prepared by: Jack Harrison, PhD, P.E.,

HyQual, P.A.

PROFESSIONAL ENGINEER
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6-27-17
STATE OF IDAHO
JACK R. HARRISON

Date: June 27, 2017

Riverside Operational Water Quality Improvement Project

2016 Annual Report

Prepared for:	Idaho Power Company Riverside Irrigation District
Prepared by:	Jack Harrison, PhD, P.E., HyQual, P.A.
Date:	June 27, 2017

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Acknowledgements: This is the 3nd annual report for the Riverside Operational Water Quality Improvement Project (ROWQIP) and is intended to provide the supporting documentation to ensure the project is transparent, reliable, and verifiable. While this work is funded by Idaho Power Company (IPC), under the direction of Ralph Myers, it is the commitment by Riverside Irrigation District (RID), and their manager Andy Bishop, that leads to the substantial water quality improvement presented below. This report provides the water quality data collected by Scotts Hoskins along with canal operations as controlled by RID staff, with assistance from HyQual, Scott Mooney with Control Engineers (who oversees SCADA system), and Scott King with SPF Water Engineering. Additionally, IPC Water Management collects canal and tributary discharge verification data.

Photo on cover: Rubicon Gate install in 2016 at Centennial Park located in canal about 1.7 miles downstream of Boise River diversion.

Executive Summary

Idaho Power Company (IPC) is proposing to address its dissolved oxygen (DO) load allocation assigned to the transition zone and metalimnion of Brownlee Reservoir in the Snake River-Hells Canyon total maximum daily load (SR–HC TMDL) (IDEQ and ODEQ, 2004) by implementing the Riverside Operational Water-Quality Improvement Project (ROWQIP). Similar to 2014 and 2015, the Riverside Irrigation District (RID) operated its primary water delivery facility (Riverside Canal) in a way that delivers more drain water from upstream sources onto Riverside agricultural lands. Through these automated canal operations additional phosphorus and other pollutants were applied to agricultural lands and removed from drains that under historical operations would have discharged to the Boise and Snake rivers.

As part of the ROWQIP, the Boise River diversion to the Riverside canal and four major spills from the canal have been automated and were controlled during the 2016 irrigation season by a supervisory control and data acquisition (SCADA) system. In addition to recording real-time flow data, the SCADA system monitored tributary inflows to the canal and automatically adjusted the Boise River diversion and spills to increase the phosphorus delivered to Riverside irrigators while decreasing phosphorus discharged to the Boise and Snake Rivers. In doing so, canal inflows from phosphorus-rich tributaries were preferentially utilized for irrigation, while canal diversion from the Boise River and canal spills to the Boise and Snake rivers were minimized. To assess changes in water quality, data were collected bi-monthly at seven canal and inflow locations.

Using the flow and water quality data collected in 2016, a Riverside Canal mass balance model was used to calculate the daily average load reductions occurring over the 183-day irrigation season. The model results show that the average load reduction was 147 lb/day, ranging from 61 to 209 lb/day over the season. The annual load reduction achieved by the ROWQIP over the season was over 26,000 lbs. This model-calculated annual load reduction exceeds the equivalent Snake River phosphorus load reduction of 15,000 lb/yr, which is comparable to the dissolved oxygen allocation as identified in the SR-HC TMDL (ref Harrison 2014).

This supporting information provides details of the project and the load reduction calculation methods needed to support 401 Certification, along with the methods used to ensure the project performance is transparent, reliable, and verifiable. Additional information on the project and its development is provided in Harrison et al., 2014, Harrison et al., 2015 and Harrison et al., 2016.

Riverside Irrigation District

The RID is located at the western end of the Boise River valley, near the confluence of the Boise and Snake rivers (Figure 1). The RID diverts water from the south bank of the Boise River near Caldwell (Figure 1: Rc0_1), and receives inflows from other tributary streams and drains along its length. The Riverside Canal (RC) flows northwesterly and crosses US Highway 95 approximately five miles southeast of Parma, Idaho. The canal turns westerly then southwesterly, crossing into Oregon approximately two miles southeast of Adrian, Oregon. The canal then flows south and east, re-crossing the state line into Idaho, before draining into the Snake River approximately four miles west of Wilder, Idaho (Figure 1: near Rc30_9).

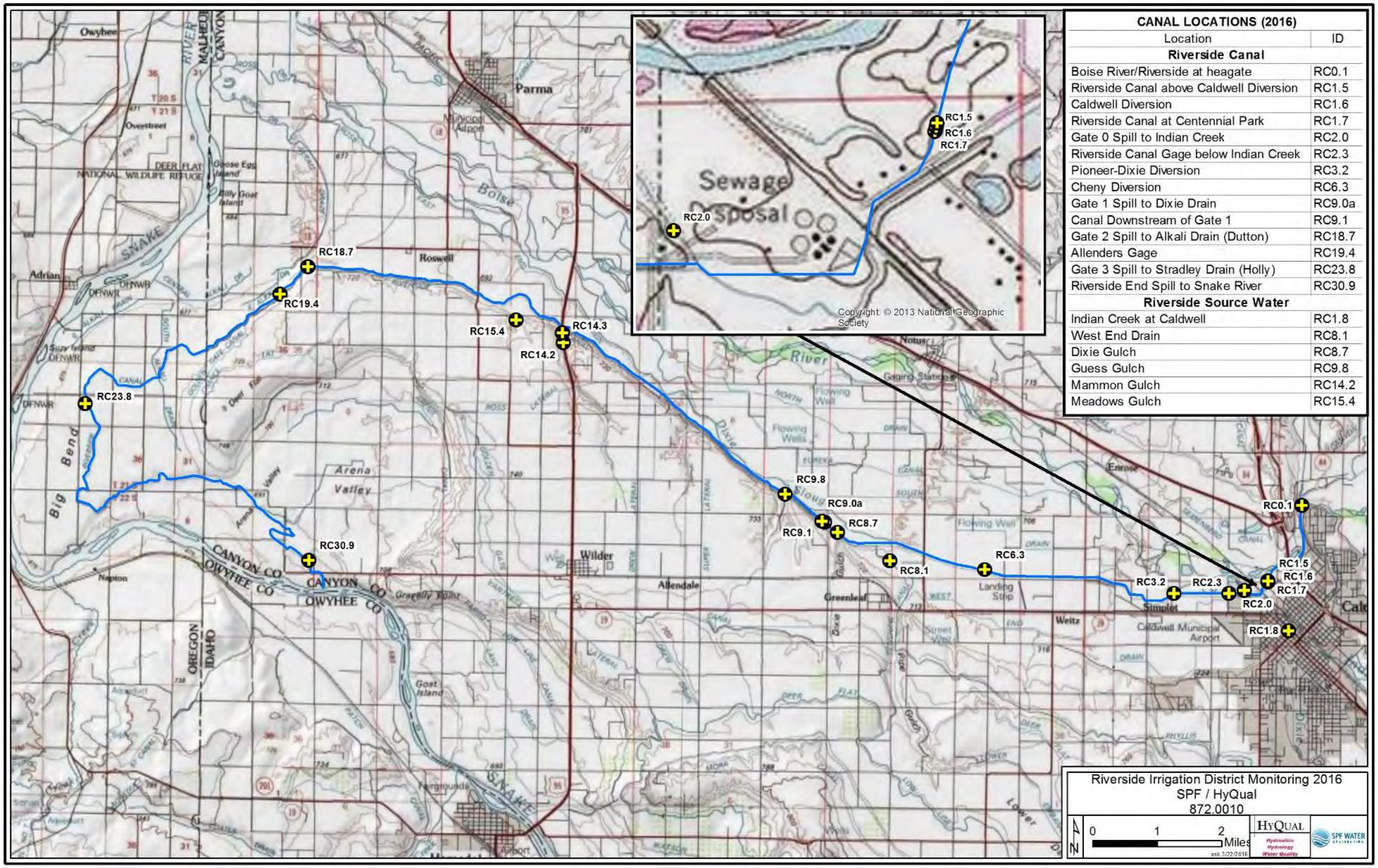
The RID delivers water to approximately 230 water users for agricultural purposes, with principal crops being onions, sugar beets, wheat, potatoes, alfalfa, beans, and hops. According to Idaho Department of Water Resources records, the RID water rights authorize irrigation of 10,158 acres within a District boundary totaling 13,082 acres (the later estimated via GIS mapping). The RC is also used to deliver water for irrigation of 2,348 acres within the service area of the Pioneer Dixie Ditch Company, and for 454 acres at the Cheney Diversion (Figure 1: Rc3_2 and Rc6_3, respectively). Thus, the total irrigated acreage supplied by the canal is over 12,000 acres.

SCADA System

As a key part of the ROWQIP, an automated canal control system was designed, constructed, and implemented. The system includes automatic control of spill gates and real-time flow monitoring of the canal flows, tributary inflows, and spills. Cellular communications equipment and a centralized server are used to control the upper reach of the RC operations by a supervisory control and data acquisition (SCADA) system. With this equipment in place and operational as of 2014, RID can prioritize use of drainage water flowing into their canal and limit the amount of canal discharge (i.e., spill) that flows unused to the Boise and Snake Rivers.

Since 2014 there have been a number of improvements to the ROWQIP. These include:

- Installed a Doppler current meter at Centennial Park location (Rc1_5)
- Installed a Rubicon gate at Centennial Park location (Rc1_7)
- Replaced the rated section at Rc8_1 with a weir located upstream about 100 feet at Greenleaf Bridge



CANAL LOCATIONS (2016)	
Location	ID
Riverside Canal	
Boise River/Riverside at heagate	RC0.1
Riverside Canal above Caldwell Diversion	RC1.5
Caldwell Diversion	RC1.6
Riverside Canal at Centennial Park	RC1.7
Gate 0 Spill to Indian Creek	RC2.0
Riverside Canal Gage below Indian Creek	RC2.3
Pioneer-Dixie Diversion	RC3.2
Cheny Diversion	RC6.3
Gate 1 Spill to Dixie Drain	RC9.0a
Canal Downstream of Gate 1	RC9.1
Gate 2 Spill to Alkali Drain (Dutton)	RC18.7
Allenders Gage	RC19.4
Gate 3 Spill to Stradley Drain (Holly)	RC23.8
Riverside End Spill to Snake River	RC30.9
Riverside Source Water	
Indian Creek at Caldwell	RC1.8
West End Drain	RC8.1
Dixie Gulch	RC8.7
Guess Gulch	RC9.8
Mammon Gulch	RC14.2
Meadows Gulch	RC15.4

Figure 1. Riverside Irrigation District irrigated acreages divided into general delivery areas and sampling locations.

Modeled Load Reductions

The RC model was developed to estimate the daily total phosphorus (TP) loads that are delivered to RID irrigators under different canal operations (Harrison et al. 2014). A simplified schematic diagram (Figure 2) shows conceptually how the canal is structured with water diverted from the Boise River and a tributary containing drainage water discharging into the canal. Any excess drain water then "spills" back to the river downstream of the diversion and tributary along with agricultural runoff. The change in TP load in the river is calculated using delivered water, which is adjusted for downstream spills and runoff. The use of delivered water, which is based on measured discharge and not modeled discharge, reduces the uncertainty of model load reductions by relying on the same measurements for canal inflows and agricultural water delivery.

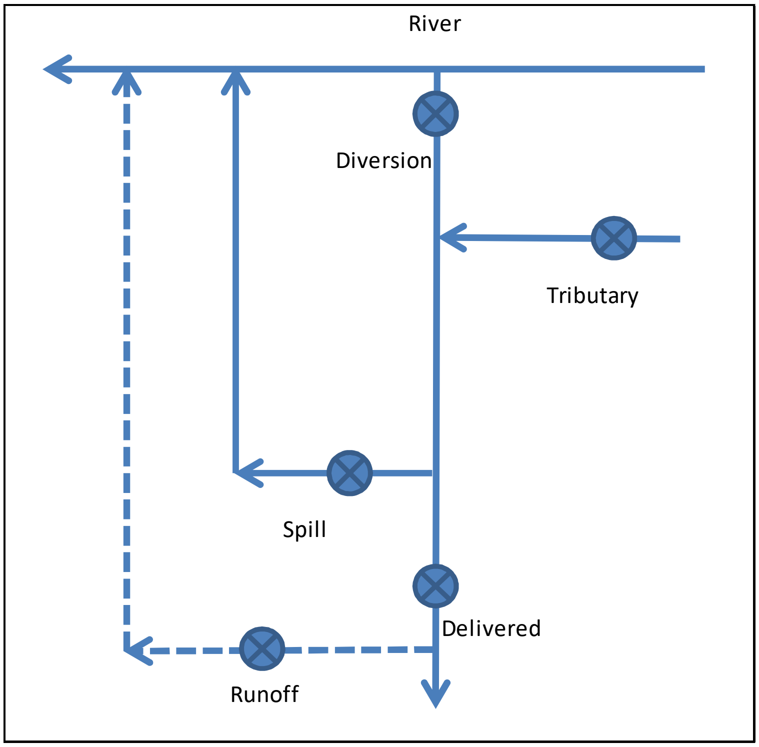


Figure 2. Simplified schematic of ROWQIP showing main components of the phosphorus-reduction calculation methodology.

The 2016 water-quality-focused canal operations were designed to maximize the use of high-nutrient agricultural and municipal drainage water on RID agricultural lands. This was accomplished by minimizing diversion of the comparatively higher-quality (lower phosphorus) Boise River, resulting in the greater utilization of the lower quality (higher phosphorus) water from the tributaries for delivery to irrigators.

To calculate annual phosphorous load reduction under 2016 operations, flow data collected at the Boise River diversion and other inflow locations (i.e., tributaries) are used to model the flow and phosphorus concentrations along the canal. Next, flows for "Baseline" operations were modeled with the Boise River diversion based on Riverside's decreed water rights from the river, totaling 271.5 cfs (http://www.idwr.idaho.gov). Then, the 2016 flow and Baseline flow models were used to calculate concentrations along the canal using a mass balance approach. Finally, the load reduction was calculated as the difference between operations (Table 1).

Table 1. Average annual loads for 2016 and Baseline operations, and TP reduction based average model results.

		Total Phosphorus	
	Flow	**Conc.**	**Load**
Yr 2016	(cfs)	(mg/L)	(lb/d)
Diversion	43	0.18	42
Tributary	316	0.52	886
Spill	92	0.46	226
Delivered	267	0.49	702
Baseline	(cfs)	(mg/L)	(lb/d)
Diversion	271	0.18	261
Tributary	316	0.52	886
Spill	320	0.34	591
Delivered	267	0.39	556
TP Reduction		0.10	147

The primary function of the Riverside Canal model was to calculate "comparable" concentrations for the water delivered under each of the operations (Table 1). The change in concentration of the water delivered to irrigators, which is the primary goal of the ROWQIP, was used directly to calculate the TP load reduction because quantity of water delivered for irrigation is the same for both operations (i.e., the change in TP load delivered can be calculated by multiplying 267 cfs by 0.1 mg/L and converting to average daily reduction of 147 pounds per day).

For comparison, the estimated load reductions for 2013, 2014 and 2015 were 164, 174 and 86 pounds per day, respectively. These were based on delivered flows of 215, 242 and 249 cfs, and changes in concentration of 0.14, 0.13 and 0.06 mg/L, respectively. The 2013 load reduction was calculated as a "potential" load reduction because in 2013 the canal operations were not directed toward water quality improvements on a "full-time" basis. Beginning in 2014 (and continuing through 2016) water quality operations were a primary consideration over the entire irrigation season. Note that the primary purpose of the RID canal is delivery of water to the district irrigators, and water quality improvement operations are secondary to this.

While not shown in Table 1, lower canal spills, which add to downstream runoff (Figure 2), were included in the daily mass balance load model and reduced the delivery load for the water quality improvement operations compared to the Baseline operations. This reflects the higher level of automated control under the current canal operations that were fully implemented beginning 2014, and discussed in more detail below.

2016 and Baseline Flows

As stated above, the 2016 water-quality-focused canal operations were designed to maximize the use of relatively high phosphorus tributary drainage water on the RID agricultural lands. The Boise River diversion and major spills are controlled by an automated SCADA system designed for real time monitoring of primary inflows and adjustment of the Boise River diversion and canal spills.

The 2016 operations flow data collected and recorded for the Boise River diversion and other inflows locations (Figure 3) are used to model the flow (and phosphorus concentrations) along the canal. Next, Baseline operations flows were modeled with the Boise River diversion set at Riverside's legally established water right of 271.5 cfs. These daily flows and measured water quality data were then used to model the phosphorus load reductions, which were calculated by difference (Table 1).

RC Mile	Location	Type	Diagram
Rc0_0	**Riverside diversion from Boise River**	**Boise R (Auto)**	
Rc0_1	**Canal gage below Diversion**	**Canal (SCADA)**	
Rc1_6	**Caldwell Res. water delivery (~60 ac)**	**Delivery**	
Rc1_8	Indian Creek at Kimbal Rd.	**Trib (SCADA)**	
Rc2_0	**Indian Creek Spill (Gate #0)**	**Spill (Auto)**	
Rc2_3	**Canal gage (rated section)**	**Canal (SCADA)**	
Rc3_2	**Pioneer-Dixie water delivery (2348 ac)**	**Delivery**	
Rc6_3	**Cheney water delivery (454 ac)**	**Delivery**	
Rc8_1	West End Drain (WED)	**Trib (SCADA)**	
Rc8_7	Dixie Gulch Drain (DgD)	**Trib**	
Rc9_0	**Dixie Spill (Gate #1)**	**Spill (Auto)**	
Rc9_1	**Demand gage (below Dixie Spill)**	**Canal (SCADA)**	
	RID-Upper Area (~3434 ac)	**Delivery**	
Rc18_6	**Dutton Spill (Gate #2)**	**Spill (Auto)**	
Rc18_7	Canal below Spill #2	**Canal**	
	RID-Middle Area (~3941 ac)	**Delivery**	
Rc23_7	**Holly Spill (Gate #3)**	**Spill (Auto)**	
Rc23_8	Canal below Spill #3	**Canal**	
	RID-Lower Area (~2782 ac)	**Delivery**	
Rc30_8	**End Spill (to Snake River)**	**Spill**	
		Snake R	

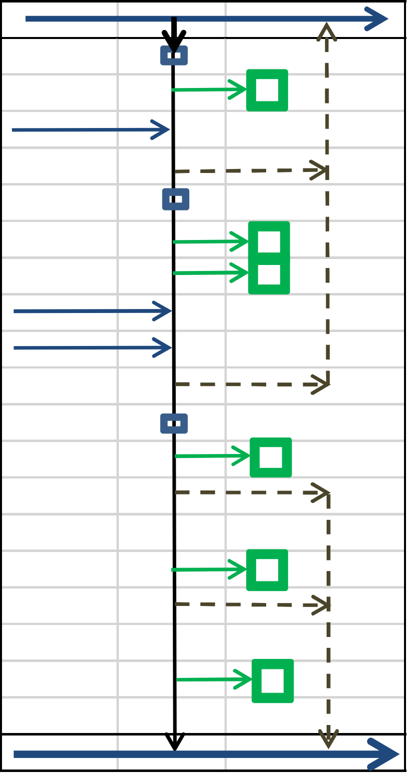


Figure 3. Diagram of Riverside Canal showing RC mile, location (with sampling ID or estimated irrigated acreage in parentheses), and type (i.e., source and receiving waters, delivery in green, tributary (trib) creek or drain in blue, and spill in dashed line to receiving water). Also shown are automated gates (Auto) and gages linked into the SCADA system.

The raw 15-minute flow data were converted to average daily data to model the flows and phosphorus concentrations along the canal. Most of the 15-minute discharge data from water-level measuring devices were recorded in the SCADA system and used on a real-time basis during the entire irrigation season to manage operations. Additionally, some minor flows were measured manually or visually estimated at various locations to provide preliminary flow data.

Corrected Flow and Quality Control

After the irrigation season, the flow (and water quality) data are used as boundary conditions (input files) for modeling the phosphorus load reductions. Prior to use, the data were reviewed, corrected or sometimes adjusted to produce more defensible phosphorus load reduction estimates, which can then be used to support HCC permitting and, in the future, compliance reporting.

The general process for finalizing the boundary condition files includes:

- **Review:** during the irrigation season data are graphed, compared with quality control data (i.e., measured flow) and water balances are calculated.
- **Correction**: Prior to use in the model relatively minor changes to the raw flow data are made to eliminate data collection and reporting errors caused by short term electrical or communication problems.
- **Adjustment:** sometimes a more substantial change to flow (or water quality) data are justified based on water balance analyses, flow measurements, QC review and other analyses. Often these changes are based on best professional judgement.

For most locations where IPC measured flow (i.e., Rc0_1, Rc1_8, Rc2_3 and Rc 8_1), IPC corrected flows were used for the final model flow boundary condition files (designated “F” for Final). The other flow boundary condition files were based on reviewed and corrected SCADA data (designated “c” for corrected). Flow boundary condition files used in the final model are given Appendix A.

Inflow and Demand

The 2016 daily discharge for major inflows and irrigation demand are shown in Figures 4a and 4b. The two major inflows of Indian Creek (Rc1_8) and West End Drain (Rc8_1) have a combined flow near or above 300 cfs (Figure 4a). This creek and drain contain elevated levels of sediment, nutrients and other pollutants from upstream agricultural and urban sources. The total of the inflows shown in Figure 4a often exceeds the RID irrigation demand, as measured at Rc9_1 (Figure 4b). The canal spill gates at Rc2_0 and Rc9_0, along with Boise River diversion gate at Rc0_1, are controlled by the SCADA system to minimize the diversions from the Boise River (Figure 4b). The RID demand is generally over 250 cfs during much of the irrigation season, while the Boise River diversion averages about 50 cfs. It is evident that the two major inflows (Figure 4a) provide most of the irrigation water under the water quality focused operations.

Figure 4a. 2016 daily average inflow data for Indian Creek at Kimball (Rc1_8) and West End Drain (Rc8_1).

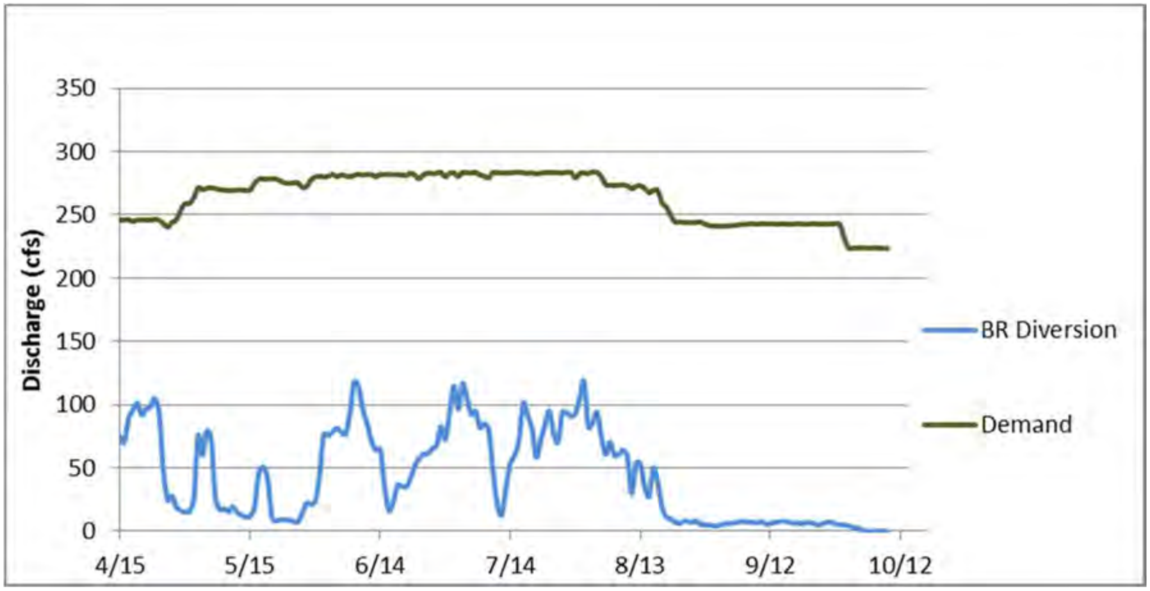


Figure 4b. Daily average flow data for Boise River diversion (Rc0_1) and Demand (Rc9_1) for 2016 Operations.

The daily average RID demand (i.e., the flow at Rc9_1) is measured data and also calculated using a water balance (Figure 5). The “error” is the difference between measured and calculated, which represents the model flow error. The causes of the error vary by measured location, canal reach, and season; and can include errors related to instruments, calculations, calibrations, channel conditions (i.e., weed growth and silting), and unknown inflow or outflow (i.e., unmeasured agricultural and stormwater drains, seepage to groundwater, and groundwater inflows).

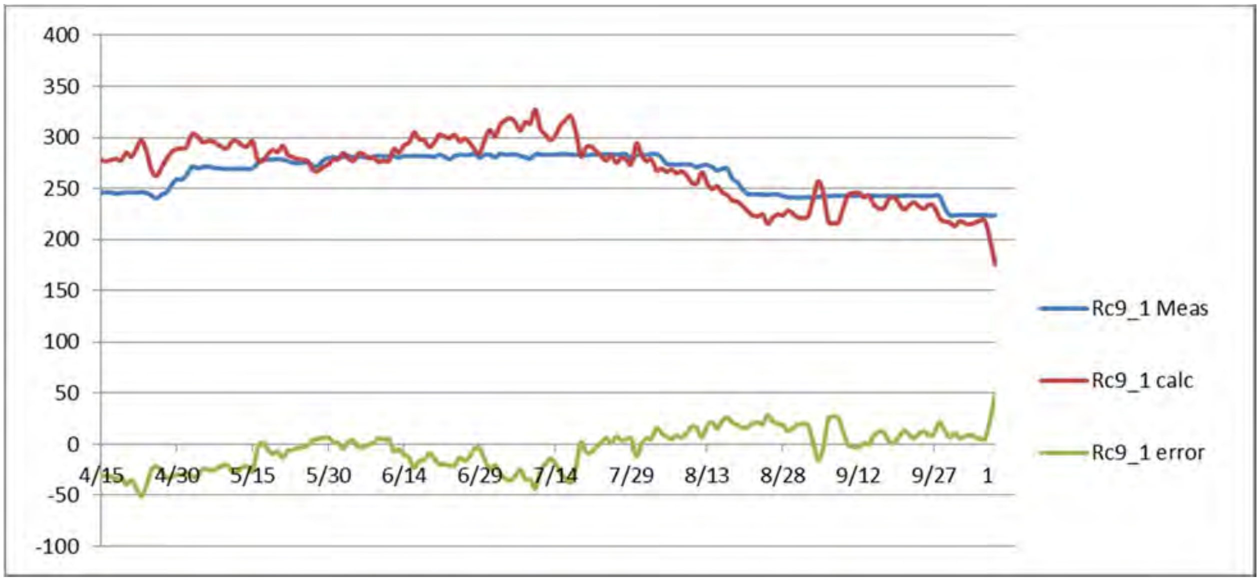


Figure 5. Year 2016 SCADA Corrected (meas) and calculated (calc) demand flows (Rc9_1), and the error.

The error calculation provides a quality control check on the model used to calculate the change in phosphorus delivered to irrigators under the different operations (i.e., water quality and baseline). The measured flow at Rc9_1, shown in Figure 5 as Rc9_1 meas and in Figure 4a as Demand, was used to estimate the RID delivery loads (and the load reductions) for both modeled operations. By using the same flow and changing only the concentration when calculating the loads, the errors related to the modeling assumptions and limitations, as discussed above, is reduced.

Delivered Flow

The daily delivery to RID irrigators is determined using measured Riverside Canal demand (Rc9_1) after subtraction of the lower canal spills (Figure 3). The demand (Rc9_1) is measured in the canal upstream of any RID deliveries, and is just below the Dixie Spill (Rc9_0). The lower spill locations used to calculate the RID delivery are the Dutton, Holly, and End Spills (Figure 3). The delivery calculated for 2016 operations is also used to model daily Baseline delivery loads, under the assumption that water demand for either operation is the same. Total deliveries (Figure 7) are the sum of the RID and upper deliveries, which include deliveries to the Caldwell area, the Pioneer-Dixie, and Cheney (Figure 3). The upper delivery loads are calculated using the measured diversion rates.

Figure 6. Daily modeled total delivery and upper tributaries (tribs) inflows as modeled for 2016.

Also shown in Figure 6 is the sum of the major tributary inflows that discharge into the upper reaches of the canal (Figure 4a). This is the sum of Indian Creek and West End Drain. When the deliveries exceed the inflow from the upper tributaries, the SCADA system diverts water from Boise River (e.g., July through mid-August) to meet irrigation demands. When the upper tributary inflows exceed delivery, then the Boise River diversion is reduced, and upper spills (Indian Creek and Dixie Slough) will tend to increase. During most of the 2016 irrigation season, the Boise River diversion gate was operated by the SCADA system, which was programed to minimize diversions from the Boise River (Figure 4b).

Baseline Diversion

Defining Baseline operations is necessary to determine the amount of phosphorus load reduction resulting from the ROWQIP. A definition of the baseline diversion is the critical parameter because it determines the flow along the canal, which is then used to determine phosphorus concentration in the canal and delivery load for the Baseline operations. The ROWQIP is specifically designed to modify canal operations in a way that reduces phosphorus loading to the Snake and Boise rivers. However, the program does not include any actions to modify or redefine Riverside's overall irrigation requirements or the volume of water diverted as currently specified by adjudicated water rights. Therefore, the baseline relative to water diverted from the Boise River is 271.5 cfs, as legally established by Riverside's water rights.

Lower Spills and Runoff

The lower canal spills (i.e., Dutton, Holly and End Spill) also vary for modeling Baseline and water quality focused 2016 operations. Operating the canal to reduce the lower spills offsets most of the potential changes in runoff loads that could be caused by the slightly higher phosphorus concentration in the delivered canal water. Measured flow data were used for Year 2016 (Table 2). For the baseline model, the average of the spills measured during the 2010 through 2013 irrigations season were used (Harrison et al 2014).

Table 2. Lower canal spills as measured in 2016 (average) and for Baseline Operations.

Flows (cfs)	Rc18_7	Rc23_8	Rc31_1
2016 (average)	17	15	10
Baseline	36	29	28
2016-BL	-19	-14	-18

2016 Phosphorus Data

The 2016 total phosphorus concentration data used in the mass balance model (Table 3) were collected bi-monthly at Boise River diversion (Rc0_0), Indian Creek (Rc1_8), and West End Drain (Rc8_1). The water quality data were collected as part of a Riverside Canal monitoring program, and the monitoring procedures for collection of the data are presented in Harrison et al 2014. The other laboratory data reported for the 2016 irrigation season are summarized in Appendix B.

Table 3. Measured and adjusted (adj) total phosphorus (mg/L) concentrations for inflow locations used in RC mass balance model.

Sample Date	Rc0_1	Rc1_8	Rc8_1	Rc9_1	Rc1_8 adj	Rc8_1adj
03/28/16	0.160	0.581	0.117		0.581	0.117
04/06/16	0.143	0.764	0.327	0.371	0.764	0.327
04/21/16	0.087	0.476	0.328	0.339	0.476	0.328
05/09/16	0.146	0.433	0.364	0.464	0.433	0.364
05/25/16	0.087	0.445	0.264	0.402	0.445	0.264
06/06/16	0.149	0.542	0.703	0.607	0.542	0.703
06/29/16	0.223	0.547	0.722	1.140	0.547	0.722
07/07/16	0.174	0.533	0.860	0.649	0.533	0.860
07/20/16	0.260	0.616	0.664	0.605	0.616	0.664
08/03/16	0.225	0.726	0.522	0.420	0.726	0.522
08/25/16	0.167	1.200	0.195	0.494	0.654	0.528
09/07/16	0.318	0.582	1.990	0.248	0.582	0.528
09/22/16	0.142	1.630	1.240	0.198	0.404	0.528
10/06/16	0.169	0.226	7.030	0.167	0.226	0.528
Average	**0.175**	**0.664**	**1.095**	**0.470**	**0.538**	**0.528**

As discussed in the Flow Section, data collected during 2016 are used as boundary conditions (input files) for modeling the 2016 Riverside Operational Water Quality Improvement Project (ROWQIP) phosphorus load reductions. Prior to use, the data are reviewed, corrected or sometimes adjusted to produce defensible phosphorus load reduction estimates, which can then be used to support HCC permitting and, in the future, compliance reporting. As explained below, this year some of the water quality data were adjusted.

As shown in Figure 7a, the bi-monthly water quality data phosphorus concentration for the canal tributary inflows (Rc1_8 and Rc8_1) are considerably higher compared to the concentration observed earlier in the year. These are in fact higher than concentration reported over the years in previous annual reports. Based on this observation, the elevated TP data were reviewed and then adjusted based on previous measurements and best professional judgement (Figure 7b) to better represent measured canal concentrations as discussed below.

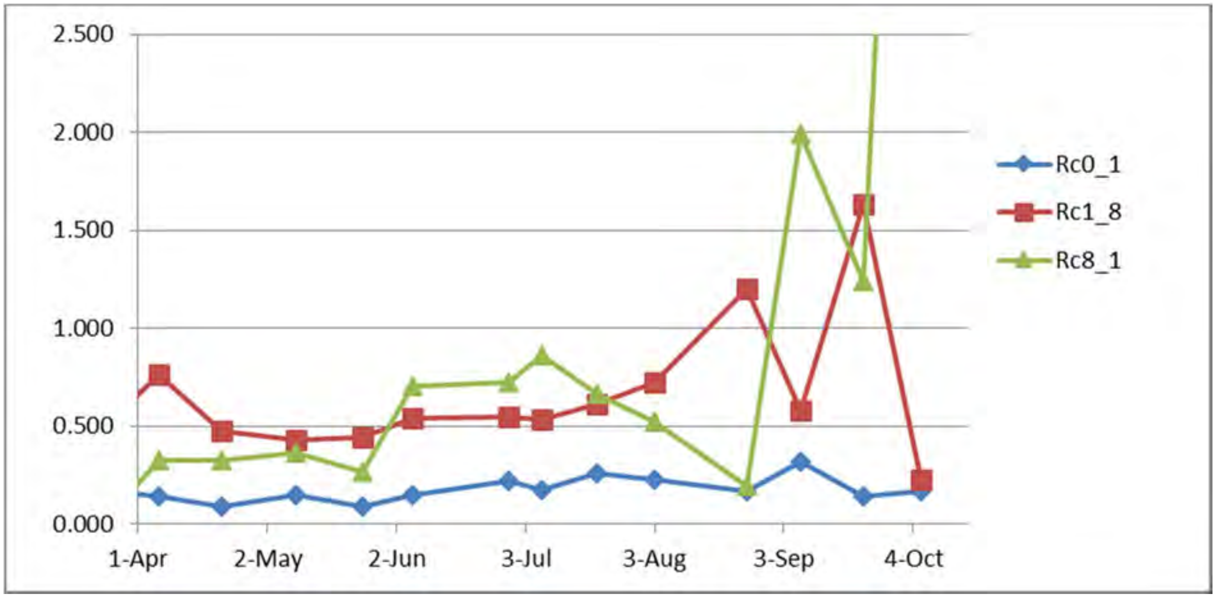


Figure 7a. Graph of measured total phosphorus concentrations (TP) at modeled inflow locations.

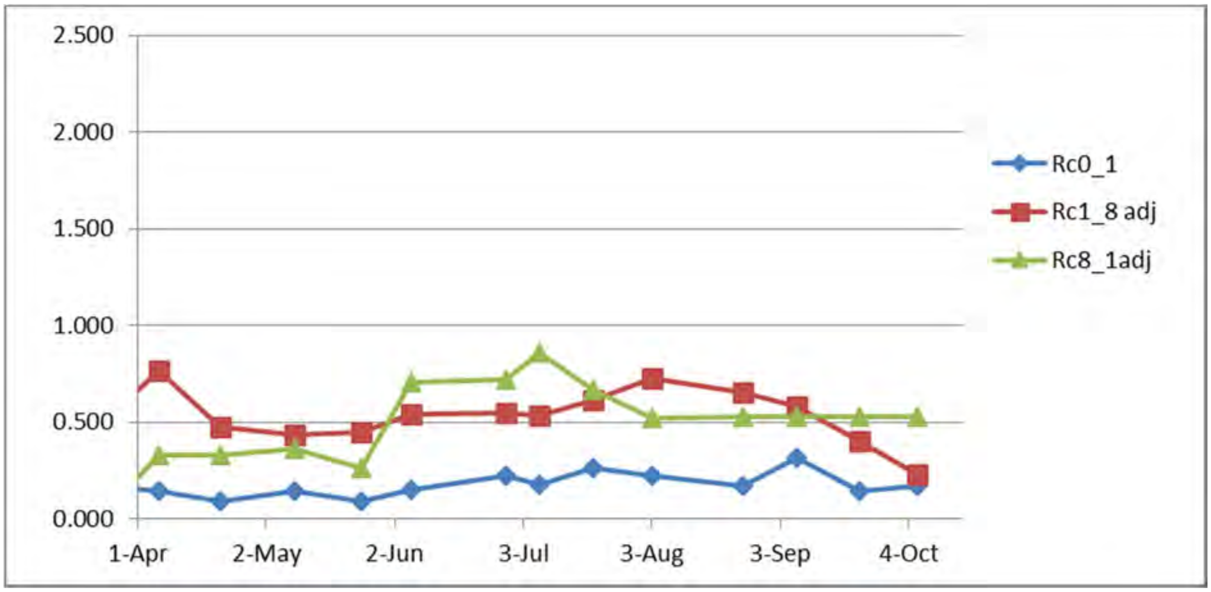


Figure 7b. Graph of adjusted total phosphorus concentrations (TP) at modeled inflow locations.

As discussed in the next section (2016 Load Reduction), a mass balance approach is used to calculate total phosphorus loads delivered to irrigators on a daily basis. To calculate the loads in the canal on a given day, total phosphorus concentration data reported by the laboratory for the three primary inflows were first interpolated to produce daily concentrations. These interpolated daily concentrations are then used with the modeled average daily flows to calculate daily loads along the canal using a simple mass balance equation (e.g., Etheridge, 2014).

As part of the water quality data assessment, both sets of water quality data (i.e., measured and adjusted) were used as boundary conditions in a preliminary load model. The loads and selected model results at Rc9_1 were then compared to measured data (Appendix B). Based on this analyses and best professional judgement, the "adjusted" data were used to estimate load reduction for the 2016 annual reporting. The final modeled TP concentrations using the adjusted TP boundary condition data and the error are shown in Figure 8a. Total phosphorus concentration error based on final model and measured data at Rc9_1 is given in Appendix B.

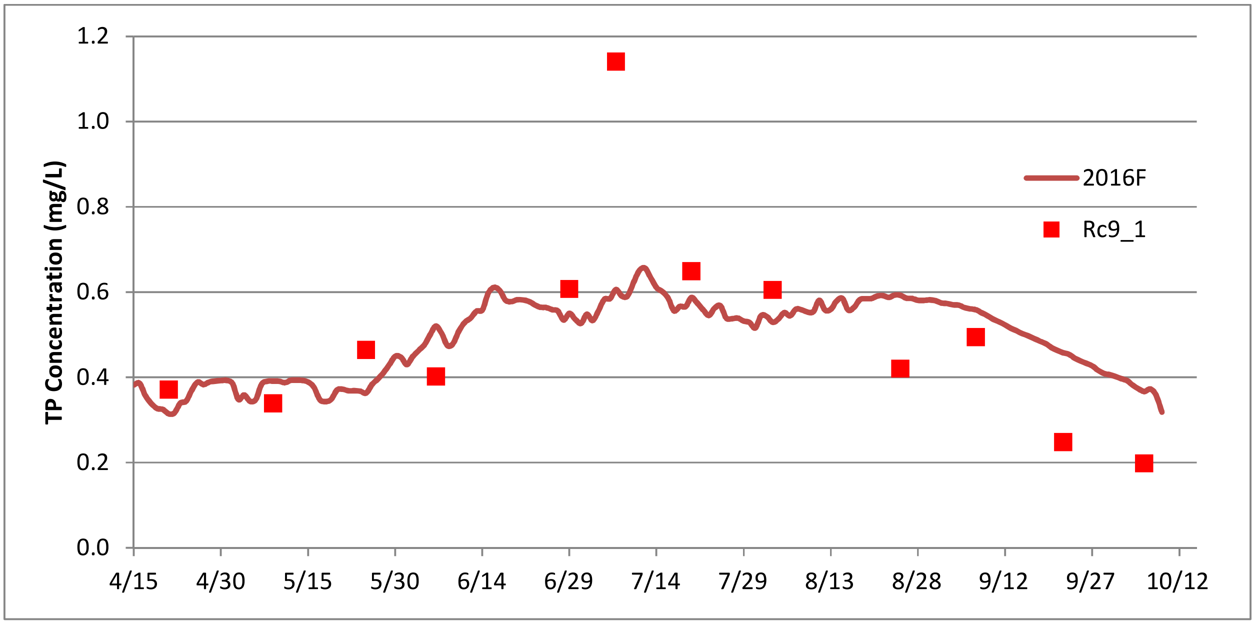


Figure 8a. Final modeled phosphorus using adjusted data (2016F) and measured phosphorus concentration at Rc9_1

As seen in Figure 7b, the bi-monthly water quality data phosphorus concentration for the canal tributary inflows (Rc1_8 and Rc8_1) are consistently higher compared to the Boise River Diversion (Rc0_0). By optimizing the use of the higher phosphorus tributary waters (Rc1_8 and Rc8_1), the concentration of phosphorus (and other pollutants) in the water delivered to the irrigators (Figure 7b: 2016F) is higher compared to the Baseline operations (Figure 7b; BL Ops). By applying more phosphorus to fields and reducing lower spills (primarily achieved through SCADA-controlled automation), overall phosphorus loads discharged to the Boise and Snake Rivers were reduced substantially (Table 1).

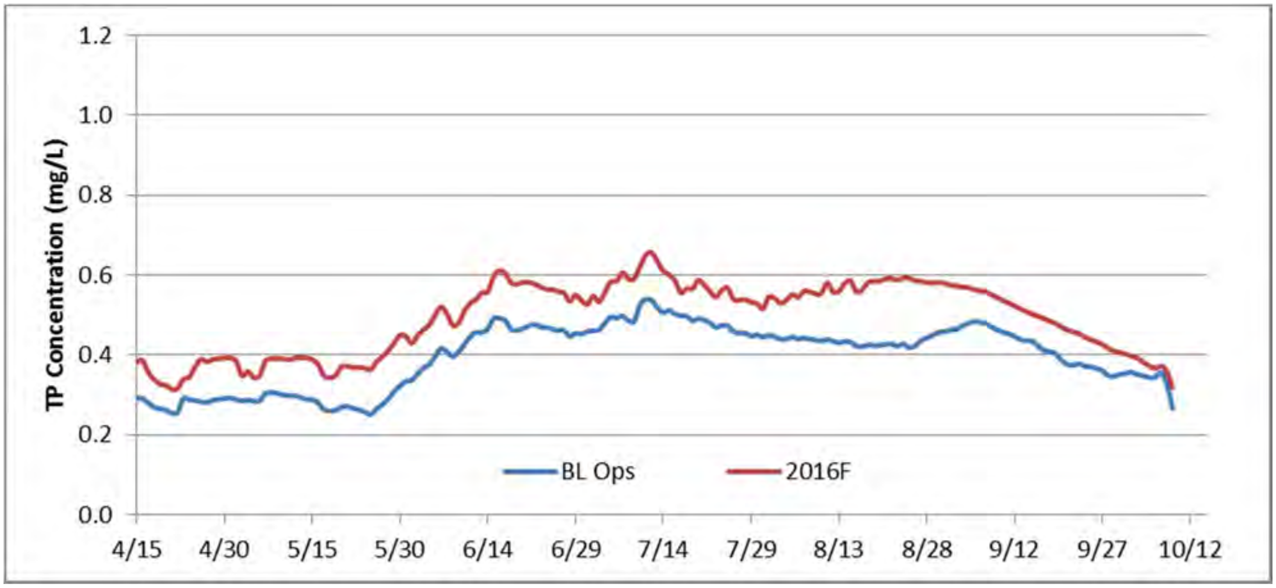


Figure 7b. Modeled daily TP concentration of canal water delivered to RID irrigators for baseline and 2016 water quality operations using adjusted phosphorus data.

2016 Load Reduction

As stated above, a mass balance equation (e.g., Etheridge, 2014) is used to calculate total phosphorus concentrations and loads delivered to irrigators on a daily basis. More detailed discussion on how the mass balance equation is used to model phosphorus along the Riverside Canal is provided in Harrison et al 2014.

The daily TP loads delivered to RID irrigators for 2016 water-quality focused operations were modeled using corrected 2016 daily average flow and interpolated water quality data (Figure 8 – 2016F). The Baseline canal operations were also modeled (Figure 8 – BL Ops) using the same inflow data and assuming Boise River diversions at the permitted rate (i.e., 272 cfs). The “TP Reduction” in Figure 9 represents the daily load reduction and was calculated as the difference between modeled 2016 water quality and Baseline operations (“2016F” and “BL Ops”, respectively). When summed over the 183 day irrigation season, this is the total daily load reduction to the Boise and Snake Rivers for the irrigation season.

Figure 8. Modeled daily average load reductions with lower spills set at Baseline (BL) rates.

Based on these model results, the 2016 annual TP load reduction exceeded 15,000 lbs (Table 4). This annual phosphorus load reduction represents the change in phosphorus load in the Boise and Snake rivers that occurred over the 183-day irrigation season under the water-quality focus operations of the ROWQIP.

Table 4. Preliminary total phosphorus load reductions for 2016.

TP Load Reduction (2016 - BL)		
(lb/d)	**Days**	**lb/yr**
147	183	26818

Conclusions

Similar to the last 2 years, RID operated the Riverside Canal during the 2016 irrigation season with the intent of reducing the discharge of phosphorus loads to the Boise and Snake rivers. The phosphorus originated from upstream urban and agricultural sources, and previously discharged into the canal as tributary drains and discharged from the canal as canal "spills", which then discharge into downstream receiving waters. The canal spills and Boise River diversion were controlled with a SCADA system designed to automatically adjust the Boise River diversion rate as drainage inflows change while meeting irrigation deliveries.

The flow and water quality data were collected in 2016 to model the phosphorus load reduction of the ROWQIP for the irrigation season. The modeling results show that with current implementation, the ROWQIP phosphorus load reduction can exceed 15,000 lb/year. The modeled 2016 load reduction was well above the 2015 load reduction but below reductions for 2013 and 2014 (Harrison et. al., 2016, Harrison et. al., 2014 and Harrison et. al., 2015, respectively). Based on a review of available data, changes in water quality of Indian Creek (i.e., TP levels) have the greatest effect on load reduction.

The modeled load reduction represents phosphorus from upstream sources that was applied to RID and other farm land via the Riverside Canal, and is thereby removed from the Snake River. The modeled load reductions occurring over the 183-day irrigation season exceeds the equivalent phosphorus load reduction of 15,000 lb/yr, which is comparable to the SR-HC TMDL dissolved oxygen allocation.

The information provided in this report documents the methods used to ensure the project performance is transparent, reliable, and verifiable. Laboratory data reports, raw flow measurement data, and other data are available upon request.

References

Etheridge, A. 2013. Evaluation of Total Phosphorus Mass Balance in the Lower Boise River, Southwestern Idaho. USGS SIR 2013-5220.Appendices

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Appendices

Appendix A – Corrected 2016 Flow Data

2016 SCADA Corrected and IPC Final Flow Data (cfs)

2016	Rc1_5	Rc1_6	Rc1_8	Rc2_0	Rc2_3	Rc3_2	Rc6_3	Rc8_1	Rc8_7	Rc9_0	Rc9_1	Rc18_	Rc23_8	Rc30_9
4/15/2016	75.2	3.00	133	0.00	209	20.94	4.800	126	4.33	32.05	245.99	11.70	20.14	10.00
4/16/2016	70.6	3.00	144	0.00	214	21.04	5.333	115	4.33	27.71	246.02	15.46	20.90	10.00
4/17/2016	89.8	3.00	132	0.00	224	21.25	5.867	113	4.33	30.71	246.24	18.95	21.32	10.00
4/18/2016	95.5	3.00	122	0.00	212	20.99	6.400	112	4.33	24.20	244.86	18.28	19.49	10.00
4/19/2016	101.3	3.00	121	0.00	217	21.03	6.933	118	4.33	36.51	245.88	19.01	17.34	10.00
4/20/2016	92.2	3.00	119	0.00	203	20.08	7.467	126	4.33	25.70	245.99	17.01	21.09	10.00
4/21/2016	96.7	3.00	119	0.00	209	20.63	8.000	119	4.33	26.33	246.00	18.61	18.90	10.00
4/22/2016	98.3	3.00	126	0.00	215	22.49	7.889	110	4.33	16.44	246.00	22.23	18.37	10.00
4/23/2016	105.1	3.00	203	60.74	234	20.78	7.778	137	4.33	59.20	246.48	28.53	22.12	10.00
4/24/2016	94.0	3.00	196	53.02	230	18.14	7.667	124	4.33	49.57	245.89	23.76	23.87	10.00
4/25/2016	48.0	3.00	185	17.44	208	18.16	7.556	124	4.33	46.73	243.06	18.79	21.97	10.00
4/26/2016	24.7	3.00	182	0.00	193	17.76	7.444	117	4.33	37.30	240.46	14.67	15.51	10.00
4/27/2016	27.9	3.00	171	0.00	184	18.30	7.333	119	4.33	22.38	244.20	9.61	13.59	10.00
4/28/2016	19.1	3.00	177	0.00	179	18.80	7.222	129	4.33	21.38	246.27	6.64	20.35	10.00
4/29/2016	16.6	3.00	181	0.00	179	18.92	7.111	130	4.33	17.14	253.70	8.71	20.81	10.00
4/30/2016	15.2	3.00	180	0.00	176	18.81	7.000	128	4.33	10.67	258.88	17.14	20.29	10.00
5/1/2016	16.1	3.00	185	0.00	179	18.75	6.889	123	4.33	10.23	258.91	19.64	21.08	10.00
5/2/2016	24.9	3.00	178	0.00	180	18.72	6.778	121	4.33	8.43	263.48	9.74	19.05	10.00
5/3/2016	75.3	3.00	156	0.00	217	19.53	6.667	120	4.33	23.80	271.48	23.54	18.65	10.00
5/4/2016	60.0	3.00	159	0.00	203	19.30	6.556	121	4.33	13.56	270.03	25.08	14.06	10.00
5/5/2016	79.6	3.00	145	0.00	214	19.91	6.444	120	4.33	24.25	270.95	26.66	12.75	10.00
5/6/2016	73.6	3.00	147	0.00	207	19.71	6.333	118	4.33	17.11	271.50	24.88	15.33	10.00
5/7/2016	26.4	3.00	182	0.00	187	19.45	6.222	131	4.33	18.55	270.77	34.88	25.72	10.00
5/8/2016	17.3	3.00	192	0.00	187	19.68	6.111	128	4.33	19.45	269.90	32.98	26.78	10.00
5/9/2016	17.9	3.00	192	0.00	187	19.94	6.000	122	4.33	16.53	269.60	24.08	27.55	10.00

2016	Rc1_5	Rc1_6	Rc1_8	Rc2_0	Rc2_3	Rc3_2	Rc6_3	Rc8_1	Rc8_7	Rc9_0	Rc9_1	Rc18_	Rc23_8	Rc30_9
5/10/2016	15.6	3.00	196	0.00	188	19.95	6.125	120	4.33	17.28	269.19	16.01	27.23	10.00
5/11/2016	19.3	3.00	208	0.00	199	20.17	6.250	116	4.33	22.20	269.59	14.46	21.64	10.00
5/12/2016	15.0	3.00	236	0.00	221	20.89	6.375	109	4.33	37.56	269.49	14.75	15.23	10.00
5/13/2016	13.1	3.00	237	0.00	224	21.16	6.500	105	4.33	35.75	269.74	15.59	11.08	10.00
5/14/2016	11.4	3.00	231	0.00	218	23.13	6.625	100	4.33	22.63	269.22	10.54	10.22	10.00
5/15/2016	12.1	3.00	235	0.24	220	25.10	6.750	107	4.33	27.25	269.80	9.66	14.45	10.00
5/16/2016	18.7	3.00	210	1.93	205	24.88	6.875	116	4.33	33.49	274.78	7.84	13.92	10.00
5/17/2016	45.9	3.00	165	0.00	194	24.34	7.000	113	4.33	17.10	278.45	7.47	13.58	10.00
5/18/2016	51.0	3.00	167	0.00	200	24.65	7.125	108	4.33	12.55	278.32	8.21	13.49	10.00
5/19/2016	42.4	3.00	179	0.00	204	25.15	7.250	113	4.33	15.91	278.53	13.25	15.45	10.00
5/20/2016	11.4	3.00	214	0.00	201	25.45	7.375	125	4.33	32.22	278.51	16.79	18.78	10.00
5/21/2016	8.4	3.00	232	0.00	214	26.29	7.500	131	4.33	47.32	278.42	22.89	19.68	10.00
5/22/2016	9.0	3.00	225	0.00	210	26.24	7.625	130	4.33	47.85	276.81	23.22	15.98	10.00
5/23/2016	9.2	3.00	230	0.00	213	26.61	7.750	123	4.33	47.93	275.18	19.84	20.51	10.00
5/24/2016	8.8	3.00	221	0.00	206	26.72	7.875	115	4.33	33.75	274.99	15.41	20.21	10.00
5/25/2016	8.1	3.00	210	0.00	196	26.58	8.000	114	4.33	20.94	275.14	15.68	20.57	10.00
5/26/2016	7.4	3.00	203	0.00	188	26.55	8.125	111	4.33	11.29	275.46	21.39	15.10	10.00
5/27/2016	14.2	3.00	189	0.00	183	28.29	8.250	107	4.33	6.80	271.96	19.96	10.67	10.00
5/28/2016	21.9	3.00	190	0.00	192	31.10	8.375	98	4.33	4.26	272.41	16.34	10.92	10.00
5/29/2016	21.6	3.00	191	0.00	194	32.06	8.500	109	4.33	11.12	277.49	16.12	10.37	10.00
5/30/2016	23.2	3.00	197	0.00	201	32.92	8.625	102	4.33	8.31	279.92	11.45	11.22	10.00
5/31/2016	44.1	3.00	185	1.35	214	33.69	8.750	99	4.33	6.96	280.65	20.03	16.41	10.00
6/1/2016	76.8	3.00	159	4.81	228	34.44	8.875	95	4.33	4.77	279.95	17.74	18.42	10.00
6/2/2016	75.5	3.00	170	3.31	238	36.01	9.000	90	4.33	4.33	280.70	21.46	14.41	10.00
6/3/2016	78.6	3.00	163	0.00	241	37.26	9.125	95	4.33	11.77	282.01	25.57	10.24	10.00
6/4/2016	81.3	3.00	159	0.00	239	38.39	9.250	92	4.33	9.41	280.42	17.03	8.78	10.00
6/5/2016	78.5	3.00	162	0.00	237	39.10	9.375	97	4.33	6.22	281.46	14.61	8.95	10.00
6/6/2016	76.9	3.00	163	0.00	236	39.44	9.500	99	4.33	7.86	281.00	19.49	11.90	10.00
6/7/2016	93.6	3.00	142	0.00	235	39.88	9.239	100	4.33	7.89	279.98	10.66	13.15	10.00

2016	Rc1_5	Rc1_6	Rc1_8	Rc2_0	Rc2_3	Rc3_2	Rc6_3	Rc8_1	Rc8_7	Rc9_0	Rc9_1	Rc18_	Rc23_8	Rc30_9
6/8/2016	117.9	3.00	128	2.38	249	42.84	8.978	94	4.33	7.04	281.45	9.45	17.17	10.00
6/9/2016	114.5	3.00	137	3.47	258	43.82	8.717	95	4.33	16.16	282.07	17.20	19.55	10.00
6/10/2016	96.1	3.00	137	0.00	237	43.63	8.457	110	4.33	14.55	281.65	18.46	16.48	10.00
6/11/2016	85.0	3.00	142	0.00	228	37.58	8.196	123	4.33	28.12	281.92	20.77	15.68	10.00
6/12/2016	71.2	3.00	146	0.00	213	11.34	7.935	128	4.33	38.13	281.87	26.27	15.05	10.00
6/13/2016	64.3	3.00	149	0.00	204	28.60	7.674	127	4.33	20.56	280.21	13.09	20.05	10.00
6/14/2016	64.8	3.00	159	0.00	218	38.26	7.413	129	4.33	16.65	282.04	17.45	22.12	10.00
6/15/2016	35.5	3.00	174	0.00	195	35.34	7.152	144	4.33	17.37	281.82	22.36	22.51	10.00
6/16/2016	16.3	3.00	203	0.00	200	34.82	6.891	136	4.33	10.20	282.04	24.54	19.84	10.00
6/17/2016	23.5	3.00	197	0.00	205	33.72	6.630	138	4.33	21.04	281.79	15.42	12.97	10.00
6/18/2016	36.2	3.00	193	0.00	217	29.90	6.370	118	4.33	14.07	281.81	16.22	8.63	10.00
6/19/2016	35.6	3.00	198	0.00	226	29.04	6.109	112	4.33	20.94	281.72	21.75	6.41	10.00
6/20/2016	35.2	3.00	193	0.00	217	30.54	5.848	115	4.33	12.69	281.06	19.68	9.40	10.00
6/21/2016	42.2	3.00	181	0.00	214	33.94	5.587	124	4.33	5.80	283.10	14.39	12.33	10.00
6/22/2016	52.1	3.00	162	0.00	203	34.66	5.326	129	4.33	3.53	281.34	13.91	18.95	10.00
6/23/2016	57.6	3.00	160	0.00	205	34.93	5.065	121	4.33	1.19	278.67	15.80	15.62	10.00
6/24/2016	60.8	3.00	165	0.00	213	33.16	4.804	117	4.33	3.86	281.78	20.57	14.72	10.00
6/25/2016	61.5	3.00	163	0.00	212	32.82	4.543	116	4.33	7.69	282.93	13.41	15.29	10.00
6/26/2016	65.3	3.00	165	0.00	215	33.69	4.283	110	4.33	4.69	282.75	17.89	10.33	10.00
6/27/2016	68.1	3.00	161	0.00	215	31.96	4.022	109	4.33	7.96	282.88	26.59	7.92	10.00
6/28/2016	83.0	3.00	148	0.00	223	30.91	3.761	99	4.33	8.66	283.65	19.28	7.00	10.00
6/29/2016	72.6	3.00	150	0.00	210	31.61	3.500	103	4.33	7.68	280.20	15.34	11.22	10.00
6/30/2016	93.8	3.00	151	0.00	225	33.05	4.438	101	4.33	11.51	282.92	16.51	6.97	10.00
7/1/2016	114.9	3.00	150	0.00	236	34.59	5.375	103	4.33	21.70	283.27	21.90	9.16	10.00
7/2/2016	96.6	3.00	154	0.00	224	37.80	6.313	102	4.33	9.17	280.40	19.72	7.72	10.00
7/3/2016	116.8	3.00	155	0.00	252	41.45	7.250	105	4.33	16.31	283.83	11.22	10.97	10.00
7/4/2016	104.9	3.00	159	0.00	241	41.89	8.188	112	4.33	10.34	283.12	16.70	12.22	10.00
7/5/2016	92.6	3.00	165	0.00	229	41.80	9.125	120	4.33	9.16	283.28	17.33	10.02	10.00
7/6/2016	94.7	3.00	163	0.00	227	41.60	10.063	117	4.33	9.18	283.60	19.75	7.67	10.00

2016	Rc1_5	Rc1_6	Rc1_8	Rc2_0	Rc2_3	Rc3_2	Rc6_3	Rc8_1	Rc8_7	Rc9_0	Rc9_1	Rc18_	Rc23_8	Rc30_9
7/7/2016	82.1	3.00	165	0.00	217	41.05	11.000	118	4.33	7.71	281.64	15.77	8.69	10.00
7/8/2016	85.1	3.00	174	0.00	221	38.34	11.192	108	4.33	4.24	280.67	13.84	11.96	10.00
7/9/2016	80.4	3.00	180	0.00	217	38.42	11.385	103	4.33	1.01	279.21	16.10	16.39	10.00
7/10/2016	48.2	3.00	236	0.00	242	40.77	11.577	119	4.33	24.87	283.70	22.95	21.38	10.00
7/11/2016	20.9	3.00	240	0.00	228	40.36	11.769	132	4.33	33.72	283.11	19.21	21.69	10.00
7/12/2016	12.9	3.00	229	0.00	217	40.17	11.962	132	4.33	20.28	283.37	25.06	19.80	10.00
7/13/2016	34.4	3.00	202	0.00	215	40.30	12.154	128	4.33	15.18	283.16	18.52	16.47	10.00
7/14/2016	53.6	3.00	186	0.00	220	40.75	12.346	122	4.33	7.41	283.22	16.79	20.37	10.00
7/15/2016	60.2	3.00	197	0.00	241	42.21	12.538	127	4.33	18.60	283.70	15.67	16.21	10.00
7/16/2016	72.1	3.00	189	2.63	242	32.64	12.731	124	4.33	21.53	283.64	13.10	11.34	10.00
7/17/2016	101.2	3.00	181	13.90	247	9.40	12.923	120	4.33	46.49	283.26	23.41	7.28	10.00
7/18/2016	91.3	3.00	177	10.60	247	32.08	13.115	125	4.33	32.60	282.98	14.84	7.19	10.00
7/19/2016	81.4	3.00	164	9.16	246	40.36	13.308	118	4.33	20.09	283.16	12.19	9.01	10.00
7/20/2016	58.7	3.00	166	0.00	217	41.47	13.500	124	4.33	5.22	282.58	11.28	11.70	10.00
7/21/2016	72.1	3.00	154	0.00	222	42.55	13.714	128	4.33	8.82	282.98	13.36	11.22	10.00
7/22/2016	84.1	3.00	153	0.00	238	43.06	13.929	119	4.33	12.81	283.55	20.77	14.79	10.00
7/23/2016	95.1	3.00	154	0.00	255	42.83	14.143	109	4.33	20.10	283.44	16.14	9.84	10.00
7/24/2016	77.1	3.00	159	0.00	236	41.75	14.357	118	4.33	21.71	283.38	13.34	11.80	10.00
7/25/2016	70.5	3.00	159	0.00	222	41.33	14.571	120	4.33	12.98	283.34	10.22	16.50	10.00
7/26/2016	94.3	3.00	138	0.00	237	41.96	14.786	114	4.33	16.14	283.21	13.04	13.59	10.00
7/27/2016	93.6	3.00	136	0.00	230	41.59	15.000	115	4.33	9.12	283.56	17.44	8.68	10.00
7/28/2016	90.7	3.00	137	0.00	228	41.41	15.214	117	4.33	10.79	283.60	19.89	14.33	10.00
7/29/2016	93.1	3.00	130	0.00	220	41.09	15.429	113	4.33	6.94	279.27	16.54	16.01	10.00
7/30/2016	105.2	3.00	151	0.00	249	42.93	15.643	107	4.33	11.89	282.58	14.70	10.73	10.00
7/31/2016	118.3	3.00	147	0.00	259	43.99	15.857	103	4.33	27.23	283.22	19.77	5.81	10.00
8/1/2016	82.5	3.00	153	0.00	230	41.86	16.071	114	4.33	16.09	282.79	17.62	5.46	10.00
8/2/2016	85.6	3.00	157	0.00	233	41.21	16.286	107	4.33	15.01	283.90	13.88	6.78	10.00
8/3/2016	93.9	3.00	146	0.00	244	41.70	16.500	108	4.33	23.26	283.71	17.69	11.31	10.00
8/4/2016	74.7	3.00	137	0.00	199	41.08	16.500	127	4.33	12.67	280.22	20.46	12.32	10.00

2016	Rc1_5	Rc1_6	Rc1_8	Rc2_0	Rc2_3	Rc3_2	Rc6_3	Rc8_1	Rc8_7	Rc9_0	Rc9_1	Rc18_	Rc23_8	Rc30_9
8/5/2016	60.8	3.00	148	0.00	193	39.75	16.500	125	4.33	12.20	273.99	20.93	16.52	10.00
8/6/2016	70.5	3.00	151	0.00	204	39.79	16.500	116	4.33	13.57	273.61	11.87	17.01	10.00
8/7/2016	60.1	3.00	167	0.00	208	39.44	16.500	103	4.33	10.98	273.27	12.73	23.30	10.00
8/8/2016	60.9	3.00	168	0.00	212	39.36	16.500	101	4.33	8.56	273.51	13.52	16.99	10.00
8/9/2016	64.3	3.00	166	0.00	218	36.61	16.500	102	4.33	18.49	273.67	15.35	14.90	10.00
8/10/2016	59.3	3.00	163	0.00	213	35.93	16.500	107	4.33	22.72	273.08	10.39	15.17	10.00
8/11/2016	30.0	3.00	169	0.00	183	35.20	16.500	113	4.33	5.71	270.77	10.92	16.36	10.00
8/12/2016	54.1	3.00	169	0.00	209	36.18	16.500	106	4.33	11.08	272.64	13.52	12.71	10.00
8/13/2016	53.3	3.00	172	0.00	218	35.69	16.500	100	4.33	18.95	273.11	11.14	13.48	10.00
8/14/2016	35.1	3.00	180	0.00	202	32.52	16.500	99	4.33	16.83	271.09	14.63	15.36	10.00
8/15/2016	27.9	3.00	182	0.00	190	30.86	16.500	97	4.33	8.79	267.59	17.77	13.29	10.00
8/16/2016	50.0	3.00	170	0.00	207	29.65	16.500	92	4.33	20.74	269.43	15.17	11.01	10.00
8/17/2016	38.4	3.00	165	0.00	189	31.17	16.500	102	4.33	15.34	269.43	13.34	11.89	10.00
8/18/2016	18.9	3.00	168	0.00	167	31.48	16.500	107	4.33	8.74	259.56	20.88	6.90	10.00
8/19/2016	11.4	3.00	167	0.00	155	35.29	16.500	112	4.33	3.11	256.09	15.93	2.12	10.00
8/20/2016	9.9	3.00	169	0.00	154	35.70	16.500	112	4.33	5.95	249.46	13.67	8.67	10.00
8/21/2016	7.4	3.00	180	0.00	164	36.56	16.500	108	4.33	15.28	244.51	7.42	14.45	10.00
8/22/2016	6.2	3.00	184	0.00	165	36.99	16.500	107	4.33	21.17	244.54	13.38	17.59	10.00
8/23/2016	7.9	3.00	179	0.00	163	37.22	16.500	105	4.33	16.94	244.06	12.89	14.88	10.00
8/24/2016	8.0	3.00	202	0.00	184	38.86	16.500	100	4.33	31.31	244.30	12.46	14.88	10.00
8/25/2016	6.9	3.00	190	0.00	178	38.90	16.500	95	4.33	22.18	243.76	11.64	16.47	10.00
8/26/2016	8.4	3.00	188	0.00	177	40.47	16.769	99	4.33	18.03	244.36	11.89	17.57	10.00
8/27/2016	5.2	3.00	192	0.00	184	41.91	17.038	112	4.33	27.35	244.32	21.42	19.50	10.00
8/28/2016	5.4	3.00	195	0.00	187	42.66	17.308	120	4.33	38.45	242.49	19.67	18.96	10.00
8/29/2016	4.9	3.00	211	0.00	198	43.46	17.577	121	4.33	48.72	241.47	12.79	14.91	10.00
8/30/2016	4.2	3.00	230	0.00	222	45.21	17.846	122	4.33	68.79	241.32	8.44	15.26	10.00
8/31/2016	4.3	3.00	230	0.00	223	41.81	18.115	118	4.33	71.87	241.14	13.52	16.54	10.00
9/1/2016	6.0	3.00	230	0.00	224	39.93	18.385	125	4.33	83.06	241.25	15.09	14.61	10.00
9/2/2016	5.9	3.00	235	0.00	230	38.56	18.654	119	4.33	81.29	241.21	10.57	12.55	10.00

2016	Rc1_5	Rc1_6	Rc1_8	Rc2_0	Rc2_3	Rc3_2	Rc6_3	Rc8_1	Rc8_7	Rc9_0	Rc9_1	Rc18_	Rc23_8	Rc30_9
9/3/2016	6.5	3.00	246	0.00	242	31.26	18.923	130	4.33	93.62	241.62	23.16	12.70	10.00
9/4/2016	6.6	3.00	264	0.00	255	11.51	19.192	131	4.33	114.61	241.66	20.13	14.23	10.00
9/5/2016	7.9	3.00	283	16.97	248	28.78	19.462	132	4.33	114.14	242.49	16.54	19.24	10.00
9/6/2016	7.4	3.00	292	44.99	236	38.76	19.731	119	4.33	98.38	242.35	9.80	18.31	10.00
9/7/2016	7.3	3.00	269	20.93	241	38.67	20.000	111	4.33	93.28	242.93	18.68	17.44	10.00
9/8/2016	6.9	3.00	259	13.80	236	38.28	19.833	113	4.33	92.14	242.84	16.59	15.50	10.00
9/9/2016	6.7	3.00	261	12.61	241	38.36	19.667	111	4.33	77.66	242.68	13.47	23.28	10.00
9/10/2016	7.6	3.00	247	3.84	235	37.88	19.500	118	4.33	69.54	243.12	17.26	22.90	10.00
9/11/2016	5.7	3.00	250	1.26	240	37.71	19.333	125	4.33	78.34	242.84	20.09	20.41	10.00
9/12/2016	6.2	3.00	266	10.12	244	35.99	19.167	121	4.33	82.87	242.94	23.32	18.29	10.00
9/13/2016	7.2	3.00	264	13.39	241	34.13	19.000	117	4.33	81.74	242.76	29.79	15.55	10.00
9/14/2016	7.4	3.00	253	16.16	227	28.40	18.833	128	4.33	82.94	242.79	28.22	17.03	10.00
9/15/2016	8.0	3.00	259	29.58	219	20.58	18.667	137	4.33	101.81	242.97	26.58	17.42	10.00
9/16/2016	7.6	3.00	264	60.70	192	18.10	18.500	130	4.33	75.25	242.62	21.75	11.89	10.00
9/17/2016	6.3	3.00	269	80.44	181	14.00	18.333	122	4.33	54.86	242.71	22.02	12.98	10.00
9/18/2016	6.8	3.00	276	81.91	185	14.00	18.167	125	4.33	55.02	242.83	20.54	15.25	10.00
9/19/2016	6.1	3.00	276	81.11	185	14.01	18.000	127	4.33	56.53	242.90	23.72	15.90	10.00
9/20/2016	6.9	3.00	278	83.46	185	14.60	17.833	116	4.33	51.01	242.64	18.75	14.42	10.00
9/21/2016	6.8	3.00	279	85.27	185	17.00	17.667	113	4.33	50.28	242.88	15.69	13.40	10.00
9/22/2016	6.2	3.00	291	92.99	187	17.01	17.500	117	4.33	54.77	242.98	13.50	15.26	10.00
9/23/2016	5.1	3.00	305	103.58	184	17.06	18.036	124	4.33	60.97	242.69	11.52	16.94	10.00
9/24/2016	6.0	3.00	307	105.67	185	17.17	18.571	119	4.33	60.56	242.58	10.92	21.05	10.00
9/25/2016	6.9	3.00	300	100.32	185	17.24	19.107	120	4.33	61.68	242.60	13.55	25.62	10.00
9/26/2016	7.4	3.00	293	97.58	181	17.03	19.643	121	4.33	54.26	242.73	15.44	21.29	10.00
9/27/2016	5.7	3.00	291	92.53	183	20.19	20.179	120	4.33	52.52	243.08	15.35	19.69	10.00
9/28/2016	5.3	3.00	290	94.16	183	17.83	20.714	112	4.33	55.34	242.62	11.61	16.89	10.00
9/29/2016	4.7	5.00	291	89.38	185	17.94	21.250	111	4.33	60.21	231.58	10.86	14.88	10.00
9/30/2016	4.6	5.00	292	91.54	182	17.75	21.786	117	4.33	64.64	223.97	13.52	11.63	10.00
10/1/2016	2.9	5.00	285	87.21	180	18.14	22.321	119	4.33	65.17	223.71	18.67	16.34	10.00

2016	Rc1_5	Rc1_6	Rc1_8	Rc2_0	Rc2_3	Rc3_2	Rc6_3	Rc8_1	Rc8_7	Rc9_0	Rc9_1	Rc18_	Rc23_8	Rc30_9
10/2/2016	2.8	5.00	292	86.69	184	18.96	22.857	125	4.33	72.72	223.98	19.21	14.70	10.00
10/3/2016	1.2	5.00	300	96.64	182	18.83	23.393	126	4.33	71.32	223.86	13.30	12.00	10.00
10/4/2016	0.0	5.00	304	94.92	184	18.95	23.929	120	4.33	69.84	223.91	22.60	18.03	10.00
10/5/2016	0.0	5.00	314	101.93	185	18.93	24.464	117	4.33	68.83	223.86	27.90	15.94	10.00
10/6/2016	0.0	5.00	313	98.96	186	18.64	25.000	119	4.33	69.73	223.93	27.63	19.01	10.00
10/7/2016	0.0	5.00	322	110.80	186	18.65	25.000	129	4.33	77.45	223.91	25.41	20.59	10.00
10/8/2016	0.0	5.00	302	102.76	182	18.30	25.000	103	4.33	57.91	223.41	25.21	24.79	10.00
10/9/2016	0.0	5.00	229	42.51	180	18.19	25.000	55	4.33	22.53	223.65	21.25	25.02	10.00
10/10/2016	0.0	5.00	211	22.80	179	18.00	25.000	40	4.33	11.78	223.64	16.05	27.39	10.00
10/11/2016	0.0	5.00	206	13.18	181	18.25	25.000	38	4.33	11.36	223.79	13.34	31.79	10.00
10/12/2016	0.0	5.00	202	6.01	182	19.58	25.000	37	4.33	13.65	223.93	23.79	33.24	10.00

2016 Flow QC Data

Flow measurements by IPC Water Management during 2016.

2016		Discharge (cfs)								
Location	**ID**	**3/22**	**3/29**	**4/12**	**5/3**	**5/31**	**6/22**	**7/19**	**8/5**	**8/24**
Centennial Q	Rc1_5	134.0	68.7	110.0	83.1	28.2	54.5	105.0	68.8	6.9
IC Kimball	Rc1_8	178.0	148.0	--	150.0	195.0	169.0	--	164.0	--
Rc Gage	Rc2_3	--	172.0	231.0	203.0	--	--	--	199.0	--
WED	Rc8_1	44.9	--	110.0	126.0	--	137.0	--	128.0	101.0
Dixie Spill	Rc9_0b	67.8	--	54.9	26.6	14.3	18.2	--	--	43.0
Rc Demand	Rc9_1	--	181.0	260.0	--	--	--	--	--	--
MmG upstream	Rc14_2	--	--	21.9	--	34.9	34.7	--	--	--
MmG div into Rc	Rc14_3	--	--	--	--	12.0	18.5	--	12.8	--

Appendix B – Water Quality and Quality Control Data

2016 Water Quality Data

Riverside Canal at Boise River Headgate (Rc0_0)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/28/2016	9:30		41	0.089	0.160	21
4/6/2016	11:35		46	0.045	0.143	43
				0.045	0.142	42
4/21/2016	11:40		63	0.047	0.087	20
5/9/2016	14:40		9	0.080	0.146	33
5/25/2016	13:00		8	0.040	0.087	18
6/6/2016	11:00		74	0.066	0.149	37
6/29/2016	11:00		75	0.103	0.223	70
7/7/2016	11:00		99	0.081	0.174	64
7/20/2016	11:20		46	0.122	0.260	65
8/3/2016	11:30		67	0.129	0.225	51
8/25/2016	11:05		12	0.118	0.167	18
				0.115	0.161	19
9/7/2016	11:00		11	0.094	0.318	40
9/28/2016	11:00		10	0.087	0.142	10
10/7/2016	11:30		9	0.124	0.169	20

Gate 1 Spill to Dixie Drain (Rc9.0)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
4/6/2016	9:30	65	225	0.207	0.371	115
4/21/2016	9:00	31	246	0.180	0.339	80
5/9/2016	10:00	25	268	0.271	0.464	100
				0.277	0.472	102
5/25/2016	10:25	27	274	0.241	0.402	90
6/6/2016	9:10	15	281	0.252	0.607	163
6/29/2016	9:20	13	282	0.242	1.140	347
7/7/2016	9:00	44	283	0.239	0.649	295
7/20/2016	9:05	12	281	0.254	0.605	186
8/3/2016	9:15	23	283	0.254	0.420	90
8/25/2016	9:10	26	244	0.270	0.494	382
9/7/2016	9:20	5	242	0.203	0.248	25
9/28/2016	9:25	82	241	0.139	0.215	26
				0.139	0.198	28
10/7/2016	10:00	74	224	0.119	0.167	22

Riverside Canal Gate 2 Spill to East Alkali Drain - aka Dutton (RC18.7

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
4/6/2016	8:40	14		0.184	0.379	146
4/21/2016	8:25	19		0.177	0.337	154
5/9/2016	8:35	28		0.267	0.545	124
5/25/2016	9:30	16		0.202	0.497	103
6/6/2016	8:10	22		0.228	0.739	163
6/29/2016	8:40	39		0.208	1.120	256
				0.207	0.565	257
7/7/2016	8:05	17		0.207	0.619	316

Riverside Canal Gate 2 Spill to East Alkali Drain - aka Dutton (RC18.7

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
7/20/2016	8:20	11		0.224	0.585	207
8/3/2016	8:30	14.7		0.209	0.462	134
8/25/2016	8:30	14.6		0.224	0.306	39
9/7/2016	8:40	18		0.166	0.204	22
9/28/2016	9:00	11.5		0.126	0.205	34
10/7/2016	9:00	25		0.102	0.162	26

Riverside Canal Gate 3 Spill to Holly Drain (RC23.8)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
4/6/2016	8:10	11		0.153	0.400	192
4/21/2016	8:00	22		0.169	0.379	113
5/9/2016	8:00	26.7		0.222	0.479	139
5/25/2016	8:30	19		0.193	0.417	141
6/6/2016	7:45	11		0.189	0.317	79
6/29/2016	8:00	21		0.187	0.494	193
7/7/2016	7:40	6.6		0.195	0.440	143
				0.199	0.406	157
7/20/2016	7:40	15		0.199	0.423	131
8/3/2016	7:55	8.5		0.188	0.377	115
8/25/2016	8:05	18		0.208	0.293	53
9/7/2016	8:25	21		0.149	0.213	37
9/28/2016	8:30	16		0.121	0.206	34
10/7/2016	8:00	18		0.105	0.169	26
4/6/2016	8:10	11		0.153	0.400	192

Riverside End Spill to Snake River (RC30.9)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
4/6/2016	7:30	3		0.239	0.332	41
4/21/2016	7:30	6		0.193	0.283	42
5/9/2016	7:00	4		0.229	0.377	77
5/25/2016	7:30	4		0.184	0.344	60
6/6/2016	7:45	3		0.179	0.290	40
				0.181	0.291	40
6/29/2016	7:30	4		0.151	0.419	79
7/7/2016	7:00	4		0.133	0.456	39
7/20/2016	7:00	10		0.219	0.310	27
				0.222	0.329	30
8/3/2016	7:22	11		0.137	0.219	32
8/25/2016	7:30	12		0.191	0.233	25
9/7/2016	7:35	10		0.128	0.187	16
				0.135	0.178	15
9/28/2016	8:00	15		0.095	0.158	11
10/7/2016	7:00	15		0.075	0.115	9

Indian Creek at Kimball Rd, Caldwell (RC1.8 IC-1)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/28/2016	8:30		151	0.478	0.581	47
4/6/2016	11:10		132	0.540	0.764	101
4/21/2016	11:00		134	0.361	0.476	60
5/9/2016	14:00		205	0.462	0.433	49
5/25/2016	12:00		234	0.346	0.473	42
				0.347	0.445	50
6/6/2016	10:30		179	0.395	0.542	67
6/29/2016	10:45		166	0.425	0.547	57

Indian Creek at Kimball Rd, Caldwell (RC1.8 IC-1)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
7/7/2016	10:30		183	0.401	0.533	58
7/20/2016	10:40		194	0.415	0.616	71
8/3/2016	12:10		183	0.423	0.726	375
8/25/2016	10:45		213	0.402	1.200	257
9/7/2016	10:35		281	0.326	0.582	240
9/28/2016	10:35		296	0.213	1.630	2330
10/7/2016	11:00		332	0.182	0.226	17
				0.176	0.232	17

West End Drain above Riverside Canal (WED)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
3/28/2016	8:00		48	0.057	0.117	44
4/6/2016	10:15		106	0.072	0.327	213
4/21/2016	10:00		113	0.077	0.328	162
				0.076	0.335	171
5/9/2016	10:40		118	0.097	0.364	193
5/25/2016	11:00		119	0.060	0.264	144
6/6/2016	9:30		109	0.095	0.703	395
6/29/2016	9:50		101	0.100	0.722	520
7/7/2016	9:30		112	0.089	0.860	480
7/20/2016	9:35		115	0.102	0.664	325
8/3/2016	9:55		93	0.076	0.522	371
				0.080	1.540	529
8/25/2016	9:40		88	0.081	0.195	55
9/7/2016	9:45		103	0.058	1.990	1620
9/28/2016	9:50		106	0.054	1.240	2320
10/7/2016	10:30		121	2.840	7.030	3280

Mammon Gulch above Riverside Canal (MmG)

Date	Time	Discharge (spill, cfs)	Discharge (Canal, Trib, Diversion, cfs)	Dissolved P (mg/L)	Total P (mg/L)	TSS (mg/L)
4/6/2016	9:00		2	0.157	0.389	137
4/21/2016			12			
5/9/2016	9:20		1.5	0.075	0.310	120
6/6/2016	8:30		21	0.063	0.249	97
7/7/2016	8:30		22	0.072	0.207	80
9/7/2016	8:55		14	0.044	0.119	32

2016 Quality Control Data Analysis

Site	Date	Time	Ortho PO4 (mg/L)	Total PO4 (mg/L)	TSS (mg/L)	Ortho PO4	Total PO4	TSS
RC0.0	4/6/2016	11:35	0.045	0.143	43	0.000	0.001	1
RC0.0			0.045	0.142	42	0%	1%	2%
RC0.0	8/25/2016	11:05	0.118	0.167	18	0.003	0.006	-1
RC0.0			0.115	0.161	19	3%	4%	-6%
RC1.8	5/25/2016	12:00	0.346	0.473	42	-0.001	0.028	-8
RC1.8			0.347	0.445	50	0%	6%	-19%
RC1.8	10/7/2016	11:00	0.182	0.226	17	0.006	-0.006	0
RC1.8			0.176	0.232	17	3%	-3%	0%
RC8.1	4/21/2016	10:00	0.077	0.328	162	0.001	-0.007	-9
RC8.1			0.076	0.335	171	1%	-2%	-6%
RC8.1	8/3/2016	9:55	0.076	**0.522**	**371**	-0.004	-1.018	-158
RC8.1			0.080	**1.540**	**529**	-5%	-195%	-43%
RC9.0	5/9/2016	10:00	0.271	0.464	100	-0.006	-0.008	-2
RC9.0			0.277	0.472	102	-2%	-2%	-2%
RC9.0	9/28/2016	9:25	0.139	0.215	26	0.000	0.017	-2

Site	Date	Time	Ortho PO4 (mg/L)	Total PO4 (mg/L)	TSS (mg/L)	Ortho PO4	Total PO4	TSS
RC9.0			0.139	0.198	28	0%	8%	-8%
RC18.7	6/29/2016	8:40	0.208	**1.120**	256	0.001	**0.555**	-1
RC18.7			0.207	**0.565**	257	0%	**50%**	0%
RC23.8	7/7/2016	7:40	0.195	0.440	143	-0.004	0.034	-14
RC23.8			0.199	0.406	157	-2%	8%	-10%
RC30.9	6/6/2016	7:45	0.179	0.290	40	-0.002	-0.001	0
RC30.9			0.181	0.291	40	-1%	0%	0%
RC30.9	7/20/2016	7:00	0.219	0.310	27	-0.003	-0.019	-3
RC30.9			0.222	0.329	30	-1%	-6%	-11%
RC30.9	9/7/2016	7:35	0.128	0.187	16	-0.007	0.009	1
RC30.9			0.135	0.178	15	-5%	5%	6%

Water Quality Boundary Conditions Adjustment

Preliminary Modeled TP concentration (red line) at Rc9_1 shows model results with measured TP data boundary conditions (Figure B1) compared to adjusted TP boundary conditions (Figure B2).

Figure B1 Preliminary Modeled (2016p) with measured water quality boundary conditions and measured (Rc9_1) total phosphorus concentration

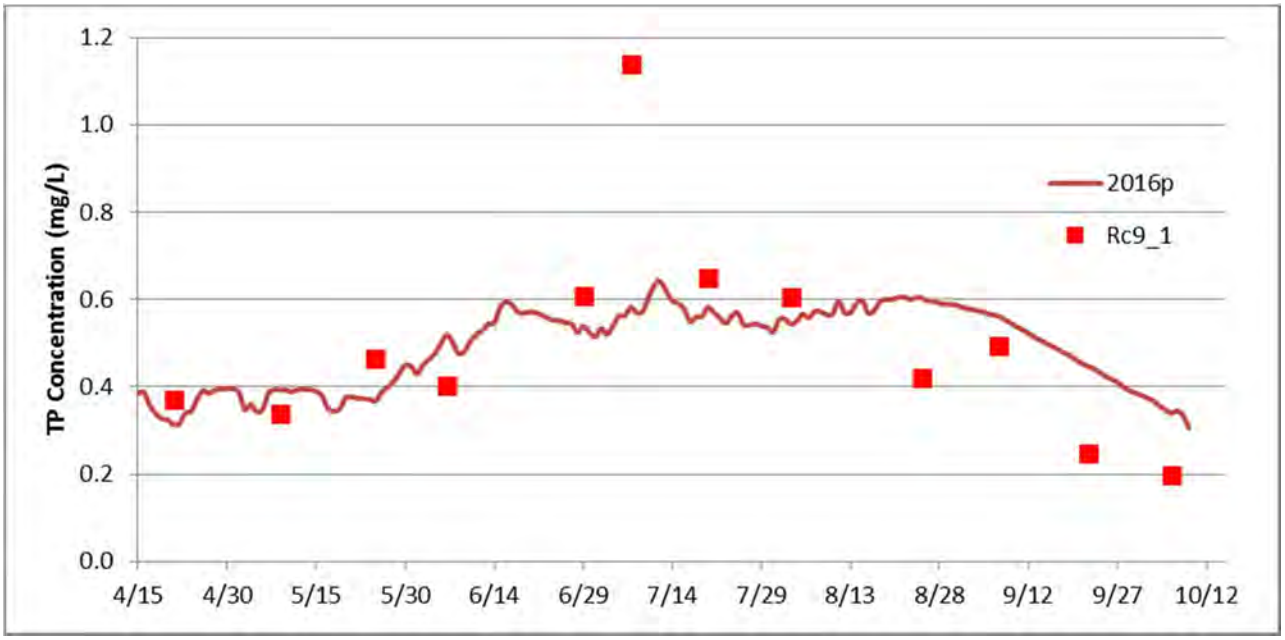

Figure B2 Preliminary modeled (2016p) with “Adjusted” water quality boundary conditions and measured (Rc9_1) total phosphorus concentration

Total Phosphorus Concentration Error

Total phosphorus concentration error based on final model and measured data at Rc9_1

	Mean Error	
	Arithmetic	**Absolute**
4/6/2016	0.011	0.011
4/21/2016	0.052	0.052
5/9/2016	-0.075	0.075
5/25/2016	0.009	0.009
6/6/2016	-0.078	0.078
6/29/2016	-0.604	0.604
7/7/2016	-0.028	0.028
7/20/2016	-0.046	0.046
8/3/2016	0.138	0.138
8/25/2016	0.091	0.091
9/7/2016	0.325	0.325
9/22/2016	0.293	0.293
10/6/2016	0.200	0.200
Average	**0.022**	**0.150**
Percent Avg	**5%**	**31%**

Exhibit 7.2-7

Riverside Operational Water Quality Improvement Project 2017 annual report

Riverside Operational Water Quality Improvement Project

2017 Annual Report

Prepared for: Idaho Power Company
Riverside Irrigation District

Prepared by: Jack Harrison, PhD, P.E.,
HyQual, P.A.

Date: April 19, 2018

Riverside Operational Water Quality Improvement Project

2017 Annual Report

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Date: April 19, 2018

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- Appendix A – Corrected 2017 Flow Data 1
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Acknowledgements: This is the 4th annual report for the Riverside Operational Water Quality Improvement Project (ROWQIP) and is intended to provide the supporting documentation to ensure the project is transparent, reliable, and verifiable. While this work is funded by Idaho Power Company (IPC), under the direction of Ralph Myers and Andrew Knight, it is the commitment by Riverside Irrigation District (RID), and their manager Andy Bishop, that leads to the substantial water quality improvement presented below. This report provides the water quality data collected by RID staff along with canal operations as controlled by RID, with assistance from HyQual, Scott Mooney with Control Engineers (who oversees SCADA system), and Scott King with SPF Water Engineering. Additionally, IPC Water Management collects canal and tributary discharge verification data, and provides model flow data for selected locations.

Photo on cover: Riverside Canal at Gate 1 (RC9.1) with Dixie spill on right after end of 2017 irrigation season, located in canal about 9.1 miles downstream of Boise River diversion (photo by A. Knight).

Executive Summary

Idaho Power Company (IPC) is proposing to address its dissolved oxygen (DO) load allocation assigned to the transition zone and metalimnion of Brownlee Reservoir in the Snake River-Hells Canyon total maximum daily load (SR–HC TMDL) (IDEQ and ODEQ, 2004) by implementing the Riverside Operational Water-Quality Improvement Project (ROWQIP). Beginning in 2014, the Riverside Irrigation District (RID) operated its primary water delivery facility (Riverside Canal) in a way that delivers more drain water from upstream sources onto Riverside agricultural lands. Through these automated canal operations, additional phosphorus and other pollutants were applied to agricultural lands and removed from drains that under historical operations would have discharged to the Boise and Snake rivers.

As part of the ROWQIP, the Boise River diversion to the Riverside canal and four major spills from the canal have been automated and were controlled during the 2017 irrigation season by a supervisory control and data acquisition (SCADA) system. In addition to recording real-time flow data, the SCADA system monitored tributary inflows to the canal and automatically adjusted the Boise River diversion and spills to increase the phosphorus delivered to Riverside irrigators while decreasing phosphorus discharged to the Boise and Snake Rivers. In doing so, canal inflows from phosphorus-rich tributaries were preferentially utilized for irrigation, while canal diversion from the Boise River and canal spills to the Boise and Snake rivers were minimized. To assess changes in water quality, data were collected bi-monthly at three canal locations and weekly at 4 canal and inflow locations.

Using the flow and water quality data collected in 2017, a Riverside Canal mass balance model was used to calculate the daily average total phosphorus (TP) load reductions occurring over the 183-day irrigation season. The model results show that the average TP load reduction was 130 lb/day, ranging from 21 to 282 lb/day over the season. The annual TP load reduction achieved by the ROWQIP over the season was over 23,000 lbs. This model-calculated annual load reduction exceeds the equivalent Snake River phosphorus load reduction of 15,000 lb/yr, which is comparable to the dissolved oxygen allocation as identified in the SR-HC TMDL (Harrison et al., 2014).

This supporting information provides details of the project and the load reduction calculation methods needed to support 401 Certification, along with the methods used to ensure the project performance is transparent, reliable, and verifiable. Additional information on the project and its development is provided in Harrison et al., 2014, Harrison et al., 2015, Harrison 2016, and Harrison, 2017.

Riverside Irrigation District

The RID is located at the western end of the Boise River valley, near the confluence of the Boise and Snake rivers (Figure 1). The RID diverts water from the south bank of the Boise River near Caldwell (Figure 1: RC0.1), and receives inflows from other tributary streams and drains along its length. The Riverside Canal (RC) flows northwesterly and crosses US Highway 95 approximately five miles southeast of Parma, Idaho. The canal turns westerly then southwesterly, crossing into Oregon approximately two miles southeast of Adrian, Oregon. The canal then flows south and east, re-crossing the state line into Idaho, before draining into the Snake River approximately four miles west of Wilder, Idaho (Figure 1: near RC30.9).

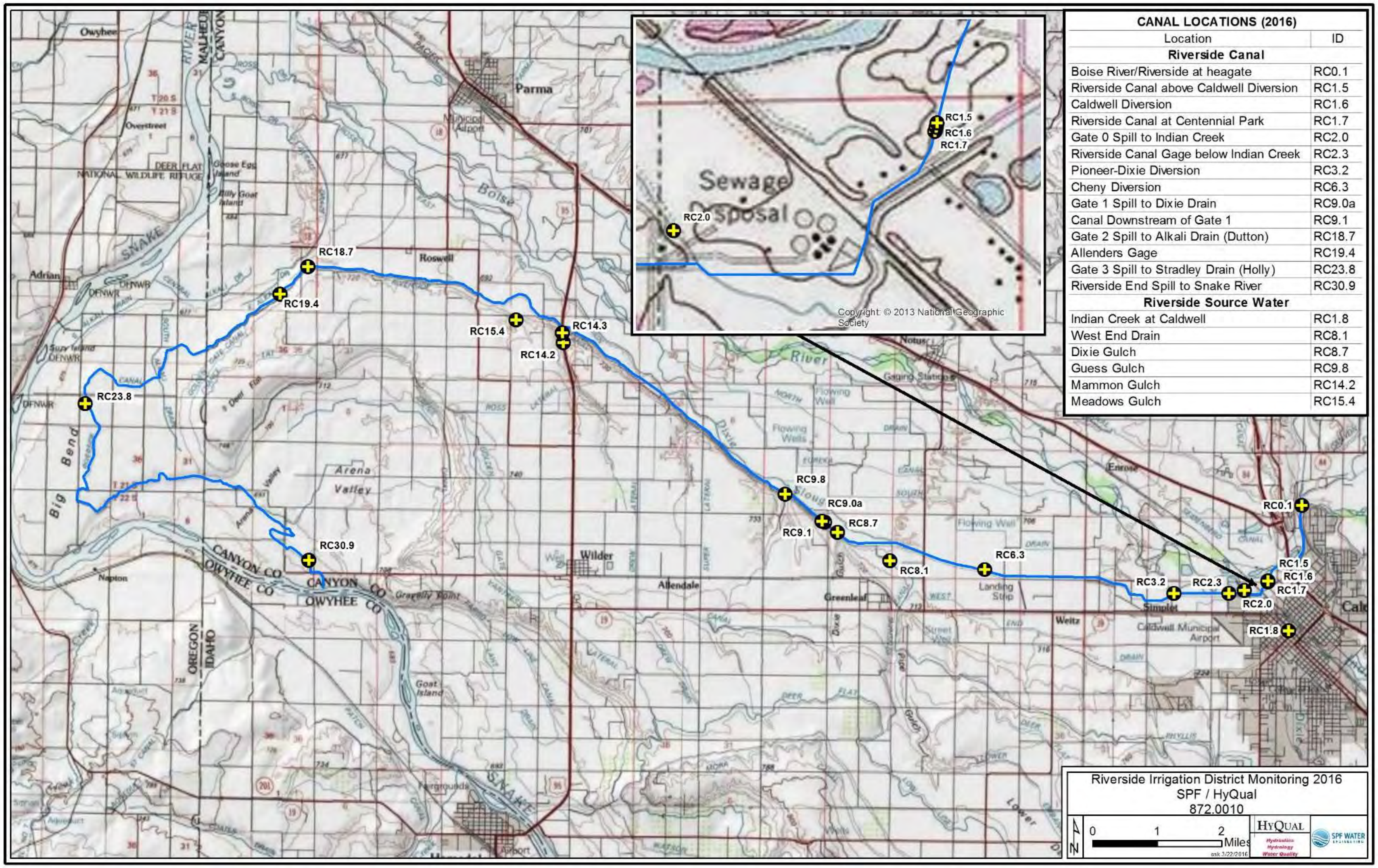
The RID delivers water to approximately 230 water users for agricultural purposes, with principal crops being onions, sugar beets, wheat, potatoes, alfalfa, beans, and hops. According to Idaho Department of Water Resources records, the RID water rights authorize irrigation of 10,158 acres within a District boundary totaling 13,082 acres (the later estimated via GIS mapping). The RC is also used to deliver water for irrigation of 2,348 acres within the service area of the Pioneer Dixie Ditch Company, and for 454 acres at the Cheney Diversion (Figure 1: RC3.2 and RC6.3, respectively). Thus, the total irrigated acreage supplied by the canal is over 12,000 acres.

SCADA System

As a key part of the ROWQIP, an automated canal control system was designed, constructed, and implemented. The system includes automatic control of spill gates and real-time flow monitoring of the canal flows, tributary inflows, and spills. Cellular communications equipment and a centralized server are used to control the upper reach of the RC operations by a supervisory control and data acquisition (SCADA) system. With this equipment in place and operational as of 2014, RID can prioritize use of drainage water flowing into their canal and limit the amount of canal discharge (i.e., spill) that flows unused to the Boise and Snake Rivers.

Since 2014 there have been a number of improvements to the ROWQIP. These include:

- Installed a Doppler current meter at Centennial Park location (RC1.5)
- Installed a Rubicon gate at Centennial Park location (RC1.7)
- Replaced the rated section at RC8.1 with a weir located upstream about 100 feet at Greenleaf Bridge
- Installed flow measurement equipment at a weir on Indian Creek to improve inflow measurement



CANAL LOCATIONS (2016)	
Location	ID
Riverside Canal	
Boise River/Riverside at heagate	RC0.1
Riverside Canal above Caldwell Diversion	RC1.5
Caldwell Diversion	RC1.6
Riverside Canal at Centennial Park	RC1.7
Gate 0 Spill to Indian Creek	RC2.0
Riverside Canal Gage below Indian Creek	RC2.3
Pioneer-Dixie Diversion	RC3.2
Cheny Diversion	RC6.3
Gate 1 Spill to Dixie Drain	RC9.0a
Canal Downstream of Gate 1	RC9.1
Gate 2 Spill to Alkali Drain (Dutton)	RC18.7
Allenders Gage	RC19.4
Gate 3 Spill to Stradley Drain (Holly)	RC23.8
Riverside End Spill to Snake River	RC30.9
Riverside Source Water	
Indian Creek at Caldwell	RC1.8
West End Drain	RC8.1
Dixie Gulch	RC8.7
Guess Gulch	RC9.8
Mammon Gulch	RC14.2
Meadows Gulch	RC15.4

Riverside Irrigation District Monitoring 2016
SPF / HyQual
872.0010

Figure 1. Riverside Irrigation District irrigated sampling locations (no changes since 2016).

Modeled Load Reductions

The RC model was developed to estimate the daily total phosphorus (TP) loads that are delivered to RID irrigators under different canal operations (Harrison et al. 2014). A simplified schematic diagram (Figure 2) shows conceptually how the canal is structured with water diverted from the Boise River and a tributary containing drainage water discharging into the canal. Any excess drain water then “spills” back to the river downstream of the diversion and tributary along with agricultural runoff. The change in TP load in the river is calculated using delivered water, which is adjusted for downstream spills and runoff. The use of delivered water, which is based on measured discharge and not modeled discharge, reduces the uncertainty of model load reductions by relying on the same measurements for canal inflows and agricultural water delivery.

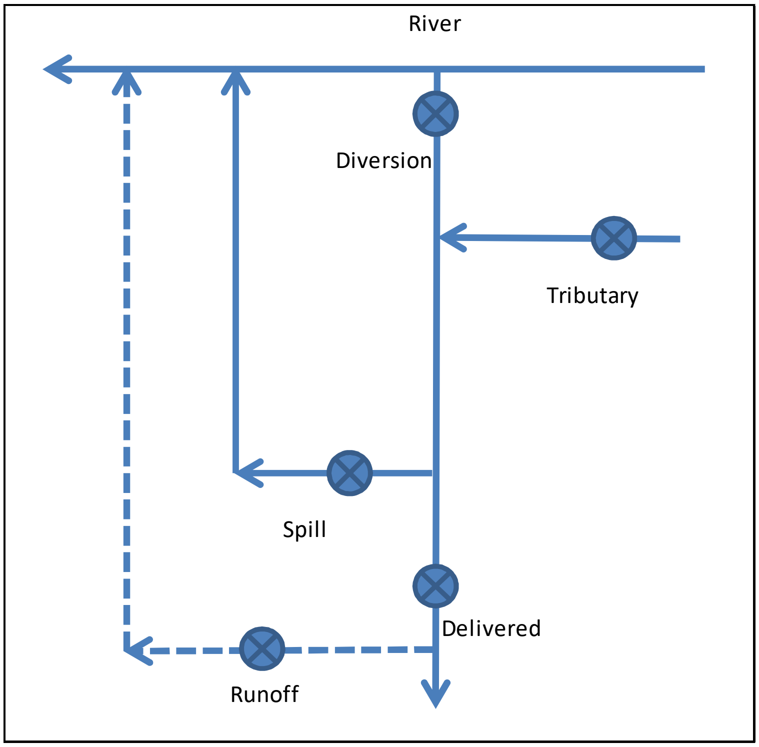


Figure 2. Simplified schematic of ROWQIP showing main components of the phosphorus-reduction calculation methodology.

The 2017 water-quality-focused canal operations were designed to maximize the use of high-nutrient agricultural and municipal drainage water on RID agricultural lands. This was accomplished by minimizing diversion of the comparatively higher-quality (lower phosphorus) Boise River, resulting in the greater utilization of the lower quality (higher phosphorus) water from the tributaries for delivery to irrigators.

To calculate annual phosphorous load reduction under 2017 operations, flow data collected at the Boise River diversion and other inflow locations (i.e., tributaries) are used to model the flow and phosphorus concentrations along the canal. Next, flows for “Baseline” operations were modeled with the Boise River diversion based on Riverside's decreed water rights from the river, totaling 271.5 cfs (http://www.idwr.idaho.gov). Then, the 2017 flow and Baseline flow models were used to calculate concentrations along the canal using a mass balance approach. Finally, the load reduction was calculated as the difference between delivered loads for the current water year and baseline operations (Table 1).

Table 1. Average annual loads for 2017 and Baseline operations, and TP reduction based average model results.

	Flow	**Total Phosphorus**	
		Conc.	**Load**
Yr 2017	(cfs)	(mg/L)	(lb/d)
Diversion	24	0.068	9
Tributary	337	0.358	648
Spill	133	0.311	223
Delivered	228	0.354	434
Baseline	(cfs)	(mg/L)	(lb/d)
Diversion	271	0.068	100
Tributary	337	0.358	648
Spill	380	0.217	444
Delivered	228	0.247	304
TP Reduction			**130**

The primary function of the Riverside Canal model was to calculate "comparable" concentrations for the water delivered under each of the operations (Table 1). Increasing the phosphorus concentration of the water delivered to irrigators, which increases the delivered load, is the primary goal of the ROWQIP. Because the quantity of water delivered for irrigation is the same for both operations, the change in TP load delivered (i.e., average daily reduction of 130 pounds per day) is the result of applying irrigation water at the higher TP concentrations during the 2017 irrigation season.

For comparison, the estimated load reductions for 2014 through 2016 were 174, 86 and 147 lbs/day, respectively. Beginning in 2014 (and continuing through 2017) water quality operations were a primary consideration beginning early in April and extending through mid-October. Note that the primary purpose of the RID canal is delivery of water to the district irrigators, and water quality improvement operations are secondary to this.

While not shown in Table 1, changes in lower canal spills, which affect downstream runoff (Figure 1Figure 2), were included in the daily mass balance load model and reduce the delivery load for the water quality improvement operations compared to the Baseline operations. This reflects the higher level of automated control under the current canal operations that were fully implemented beginning 2014, and discussed in more detail below.

2017 and Baseline Flows

As stated above, the 2017 water-quality-focused canal operations were designed to maximize the use of relatively high phosphorus tributary drainage water on the RID agricultural lands. The Boise River diversion and major spills are controlled by an automated SCADA system designed for real time monitoring of primary inflows and adjustment of the Boise River diversion and canal spills.

The 2017 operations flow data collected and recorded for the Boise River diversion and other inflow locations (Figure 3) are used to model the flow (and phosphorus concentrations) along the canal. Next, Baseline operation flows were modeled with the Boise River diversion set at Riverside's legally established water right of 271.5 cfs. These daily flows and measured water quality data were then used to model the phosphorus load reductions, which were calculated by difference (Table 1).

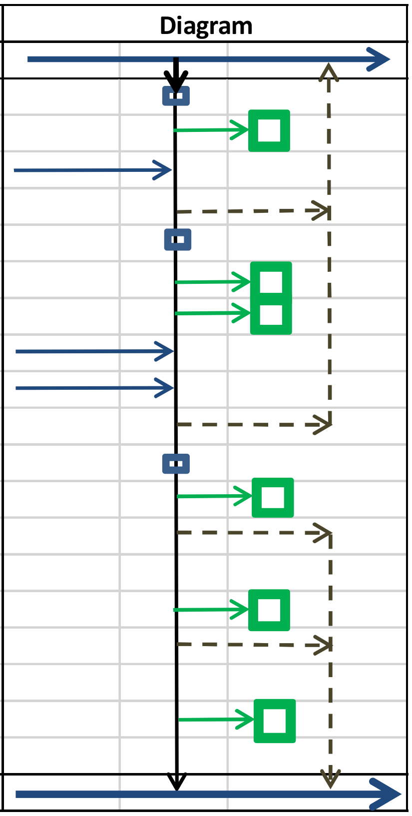
RC Mile	Location	Type	Diagram
Rc0_0	**Riverside diversion from Boise River**	**Boise R (Auto)**	
Rc0_1	**Canal gage below Diversion**	**Canal (SCADA)**	
Rc1_6	**Caldwell Res. water delivery (~60 ac)**	**Delivery**	
Rc1_8	Indian Creek at Kimbal Rd.	**Trib (SCADA)**	
Rc2_0	**Indian Creek Spill (Gate #0)**	**Spill (Auto)**	
Rc2_3	**Canal gage (rated section)**	**Canal (SCADA)**	
Rc3_2	**Pioneer-Dixie water delivery (2348 ac)**	**Delivery**	
Rc6_3	**Cheney water delivery (454 ac)**	**Delivery**	
Rc8_1	West End Drain (WED)	**Trib (SCADA)**	
Rc8_7	Dixie Gulch Drain (DgD)	**Trib**	
Rc9_0	**Dixie Spill (Gate #1)**	**Spill (Auto)**	
Rc9_1	**Demand gage (below Dixie Spill)**	**Canal (SCADA)**	
	RID-Upper Area (~3434 ac)	**Delivery**	
Rc18_6	**Dutton Spill (Gate #2)**	**Spill (Auto)**	
Rc18_7	Canal below Spill #2	**Canal**	
	RID-Middle Area (~3941 ac)	**Delivery**	
Rc23_7	**Holly Spill (Gate #3)**	**Spill (Auto)**	
Rc23_8	Canal below Spill #3	**Canal**	
	RID-Lower Area (~2782 ac)	**Delivery**	
Rc30_8	**End Spill (to Snake River)**	**Spill**	
		Snake R	

Figure 3. Diagram of Riverside Canal showing RC mile, location (with sampling ID or estimated irrigated acreage in parentheses), and type (i.e., source and receiving waters, delivery in green, tributary (Trib) creek or drain in blue, and spill in dashed line to receiving water). Also shown are automated gates (Auto) and gages linked into the SCADA system.

The raw 15-minute flow data were converted to average daily data to model the flows and phosphorus concentrations along the canal. Most of the 15-minute discharge data from water-level measuring devices were recorded in the SCADA system and used on a real-time basis during the entire irrigation season to manage operations. Additionally, some minor flows were measured manually or visually estimated at various locations by RID staff to provide preliminary flow data (Appendix A).

Corrected Flow and Quality Control

After the irrigation season, the flow (and water quality) data are used as boundary conditions (input files) for modeling the phosphorus load reductions. Prior to use, the data were reviewed, corrected or sometimes adjusted to produce more defensible phosphorus load reduction estimates, which can then be used to support Hells Canyon Complex permitting and, in the future, compliance reporting.

The general process for finalizing the boundary condition files includes:

- **Review:** During the irrigation season data are graphed, compared with quality control data (i.e., measured flow), and water balances are calculated.
- **Correction**: Prior to use in the model relatively minor changes to the raw flow data are made to eliminate data collection and reporting errors caused by short term electrical or communication problems.
- **Adjustment:** Some years a more substantial change to flow (or water quality) data are justified based on water balance analyses, flow measurements, QC review, and other analyses. Often these changes are based, in-part, on best professional judgement.

Flow and water quality boundary condition data used in the final model, along with supporting quality control (QC) information, are given Appendices A and B.

Inflow and Demand

The 2017 daily discharge for major inflows and irrigation demand are shown in Figures 4a and 4b. The two major inflows of Indian Creek (RC1.8) and West End Drain (RC8.1) have a combined flow near or above 300 cfs (Figure 4a). This creek and drain contain elevated levels of sediment, nutrients and other pollutants from upstream agricultural and urban sources. The total of the inflows shown in Figure 4a often exceeds the RID irrigation demand, as measured at RC9.1 (Figure 4b). The canal spill gates at RC2.0 and RC9.0, along with Boise River diversion gate at RC0.1, are controlled by the SCADA system to minimize the diversions from the Boise River (Figure 4b). The RID demand is generally over 250 cfs during much of the irrigation season, while the Boise River diversion averages less than 25 cfs. It is evident that the two major inflows (Figure 4a) provide most of the irrigation water under these water quality focused operations.

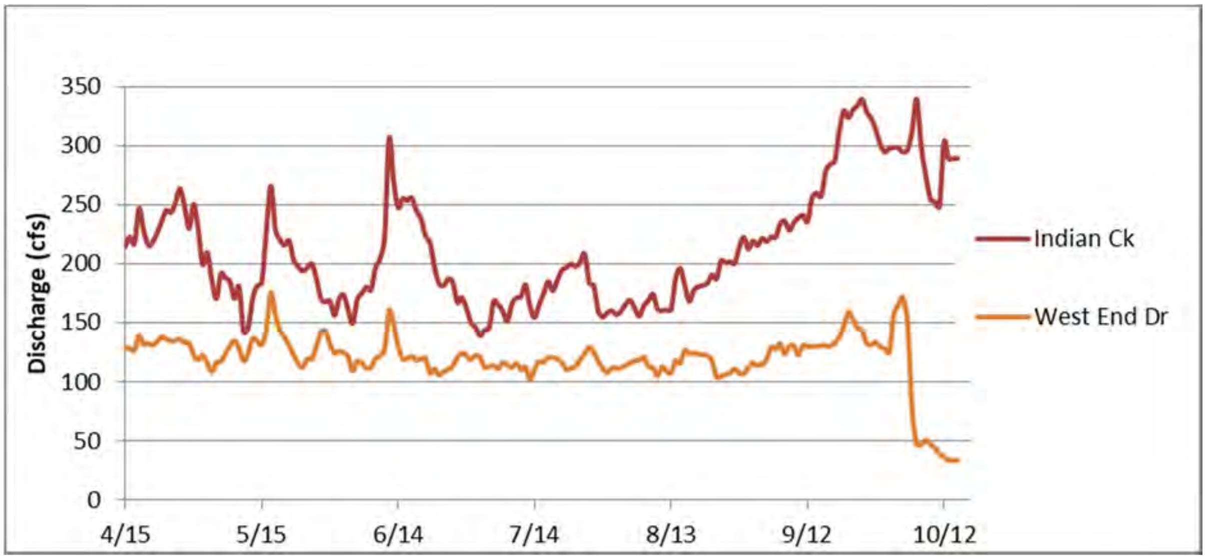


Figure 4a. 2017 daily average inflow data for Indian Creek at Kimball (RC1.8) and West End Drain (RC8.1).

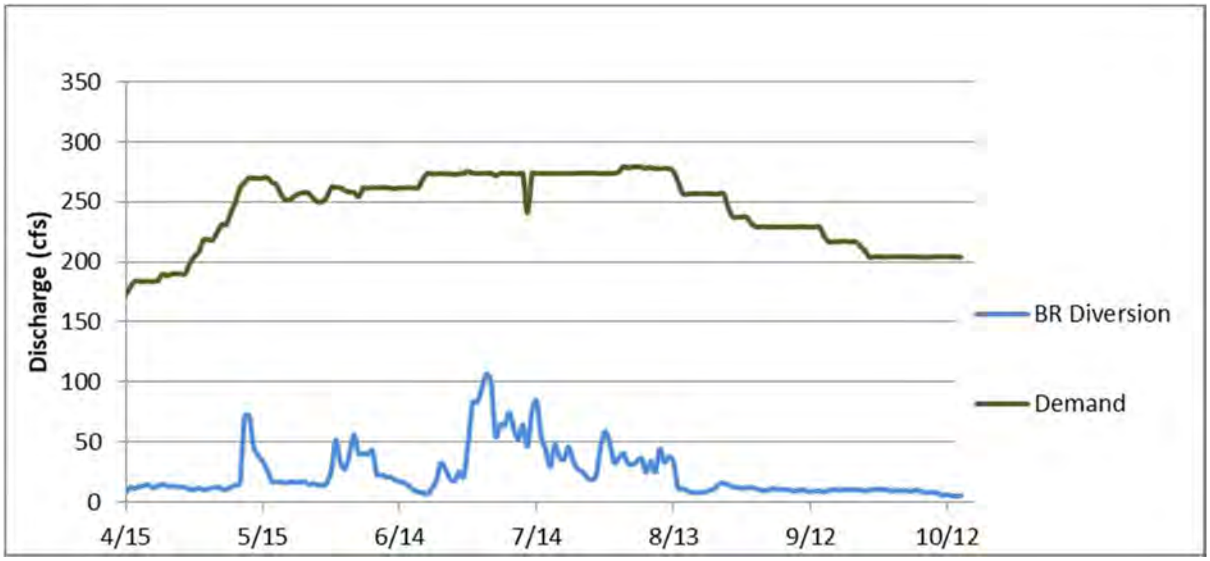


Figure 4b. Daily average flow data for Boise River diversion (RC0.1) and Demand (RC9.1) for 2017 Operations.

The daily average RID demand (i.e., the flow at RC9.1) is measured data, calculated using a water balance (Figure 5). The "error" is the difference between measured and calculated, which represents the model flow error. The causes of this model error vary by measured location, canal reach, and season; and can include errors related to instruments, calculations, calibrations, channel conditions (i.e., weed growth and silting), and unknown inflow or outflow (i.e., unmeasured agricultural and stormwater drains, seepage to groundwater, and groundwater inflows).

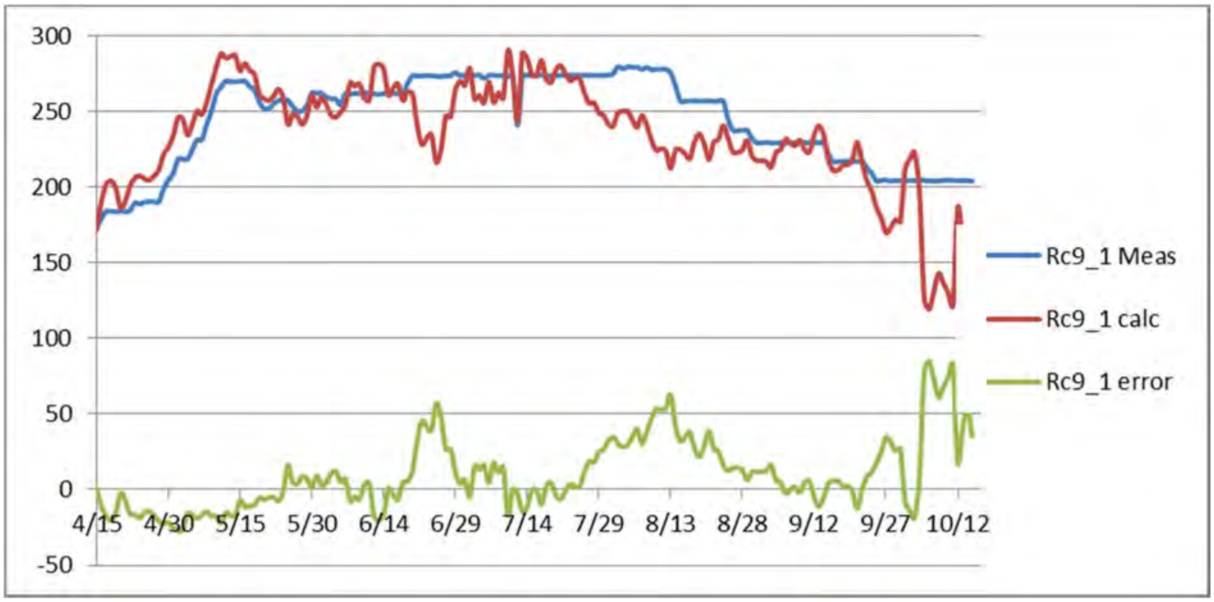


Figure 5. Year 2017 SCADA Corrected (meas) and calculated (calc) demand flows (RC9.1), and the model error.

The model error calculation provides a quality control check on the model used to calculate the change in phosphorus delivered to irrigators under the different operations (i.e., water quality and baseline). As discussed below, the model is used calculate total phosphorus concentrations for both operations (i.e. Yr 2017 and Baseline). The measured flow at RC9.1, shown in Figure 5 as RC9.1 meas and in Figure 4a as Demand, was then used to estimate the daily RID delivery loads for both modeled operations (and the load reductions). By using the same flow data and changing only the concentration when calculating the loads, the potential for errors related to the modeling assumptions and limitations, as discussed above, are reduced.

Delivered Flow

The daily delivery to RID irrigators is determined using measured Riverside Canal demand (RC9.1) after subtraction of the lower canal spills (Figure 3). The demand (RC9.1) is measured in the canal upstream of any RID deliveries, and is just below the Dixie Spill (RC9.0). The lower spill locations used to calculate the RID delivery are the Dutton, Holly, and End Spills (Figure 3). The delivery calculated for 2017 operations is also used to model daily Baseline delivery loads, under the assumption that water demand for either operation is the same. Total deliveries (Figure 7) are the sum of the RID and upper deliveries, which include deliveries to the Caldwell area, the Pioneer-Dixie, and Cheney (Figure 3). The upper delivery loads are calculated using the measured diversion rates.

Figure 6. Daily total delivery and upper tributaries (tribs) inflows as modeled for 2017.

Figure 6 shows the sum of the major tributary inflows that discharge into the upper reaches of the canal (Figure 4a). This is the sum of Indian Creek and West End Drain. When the deliveries exceed the inflow from the upper tributaries, the SCADA system diverts water from Boise River (e.g., mid-June through mid-August) to meet irrigation demands. When the upper tributary inflows exceed delivery, then the Boise River diversion is reduced, and upper spills (Indian Creek and Dixie Slough) tend to increase. During most of the 2017 irrigation season, the Boise River diversion gate was operated by the SCADA system, which was programed to minimize diversions from the Boise River (Figure 4b).

Baseline Diversion

Defining Baseline operations is necessary to determine the amount of phosphorus load reduction resulting from the ROWQIP. A definition of the baseline diversion is the critical parameter because it determines the flow along the canal, which is then used to determine phosphorus concentration in the canal and delivery load for the Baseline operations. The ROWQIP is specifically designed to modify canal operations in a way that reduces phosphorus loading to the Snake and Boise rivers. However, the program does not include any actions to modify or redefine Riverside's overall irrigation requirements or the volume of water diverted as currently specified by adjudicated water rights. Therefore, the baseline relative to water diverted from the Boise River is 271.5 cfs, as legally established by Riverside's water rights.

Lower Spills and Runoff

The lower canal spills (i.e., Dutton, Holly and End Spill) also vary for modeling Baseline and water quality focused 2017 operations. Operating the canal to reduce the lower spills offsets most of the potential changes in runoff loads that could be caused by the slightly higher phosphorus concentration in the delivered canal water. Measured flow data were used for Year 2017 (Table 2). For the baseline model, the average of the spills measured during the 2010 through 2013 irrigations season were used (Harrison et al 2014).

Table 2. Lower canal spills as measured in 2017 (average) and for Baseline Operations.

Flows (cfs)	RC18.7	RC23.8	RC30.9
2017 (average)	24	19	20
Baseline	36	29	28
2017-BL	-12	-10	-8

2017 Phosphorus Data

The 2017 total phosphorus concentration data used in the mass balance model (Table 3) were collected weekly at Boise River diversion (RC0.0), Indian Creek (RC1.8), and West End Drain (RC8.1). The water quality data were collected as part of a Riverside Canal monitoring program, and the monitoring procedures for collection of the data are presented in Harrison et al 2014. The other laboratory data reported for the 2017 irrigation season are summarized in Appendix B.

Table 3. Measured and adjusted (adj) total phosphorus (mg/L) concentrations for inflow and canal locations used in RC mass balance model.

Sample Date	RC0.0	RC1.8	RC8.1	RC9.1	RC8.1adj
4/11/2017	0.079	0.371	0.194	0.000	0.194
4/19/2017	0.070	0.392	0.194	0.314	0.194
4/26/2017	0.075	0.303	0.143	0.243	0.143
5/3/2017	0.073	0.166	0.233	0.219	0.233
5/11/2017	0.032	0.473	0.374	0.372	0.374
5/18/2017	0.052	0.547	0.203	0.442	0.203
5/24/2017	0.051	0.304	0.419	0.297	0.419
5/30/2017	0.052	0.421	0.435	0.414	0.435
6/7/2017	0.058	0.367	0.356	0.512	0.356
6/15/2017	0.042	0.336	0.444	0.403	0.444
6/21/2017	0.063	0.489	2.390	0.442	0.396
6/27/2017	0.042	0.416	0.347	0.361	0.347
7/3/2017	0.086	0.238	2.510	0.331	0.474
7/10/2017	0.069	0.436	0.623	0.534	0.623
7/17/2017	0.043	0.509	0.560	0.515	0.560
7/25/2017	0.077	0.473	0.436	0.407	0.436
8/9/2017	0.116	0.511	0.328	0.392	0.328
8/14/2017	0.091	0.687	0.453	0.566	0.453
8/21/2017	0.097	0.425	0.271	0.357	0.271
8/28/2017	0.035	0.442	0.290	0.341	0.290
9/6/2017	0.121	0.368	0.223	0.330	0.223
9/11/2017	0.135	0.345	0.244	0.279	0.244
9/21/2017	0.100	0.256	0.127	0.192	0.127
9/25/2017	0.039	0.289	0.130	0.197	0.130
10/4/2017	0.034	0.252	0.134	0.183	0.134

Sample Date	RC0.0	RC1.8	RC8.1	RC9.1	RC8.1adj
10/11/2017	0.038	0.335	0.166	0.253	0.166
Average	**0.068**	**0.390**	**0.470**	**0.342**	**0.315**

As discussed in the Flow Section, data collected during 2017 are used as boundary conditions (input files) for modeling the 2017 Riverside Operational Water Quality Improvement Project (ROWQIP) phosphorus load reductions. Prior to use, the data are reviewed, corrected or sometimes adjusted to produce defensible phosphorus load reduction estimates, which can then be used to support HCC permitting and, in the future, compliance reporting. As explained below, this year some of the water quality data were adjusted.

As shown in Figure 7a, the weekly water quality data phosphorus concentration for the canal tributary inflow at RC8.1 are considerably higher for 2 sample events compared to the concentration observed through the rest of the year. These are, in fact, higher than concentration reported over the years in previous annual reports. Based on this observation, the elevated TP data were reviewed and adjusted based on previous measurements and best professional judgement (Figure 7b) to better represent measured canal concentrations as discussed below.

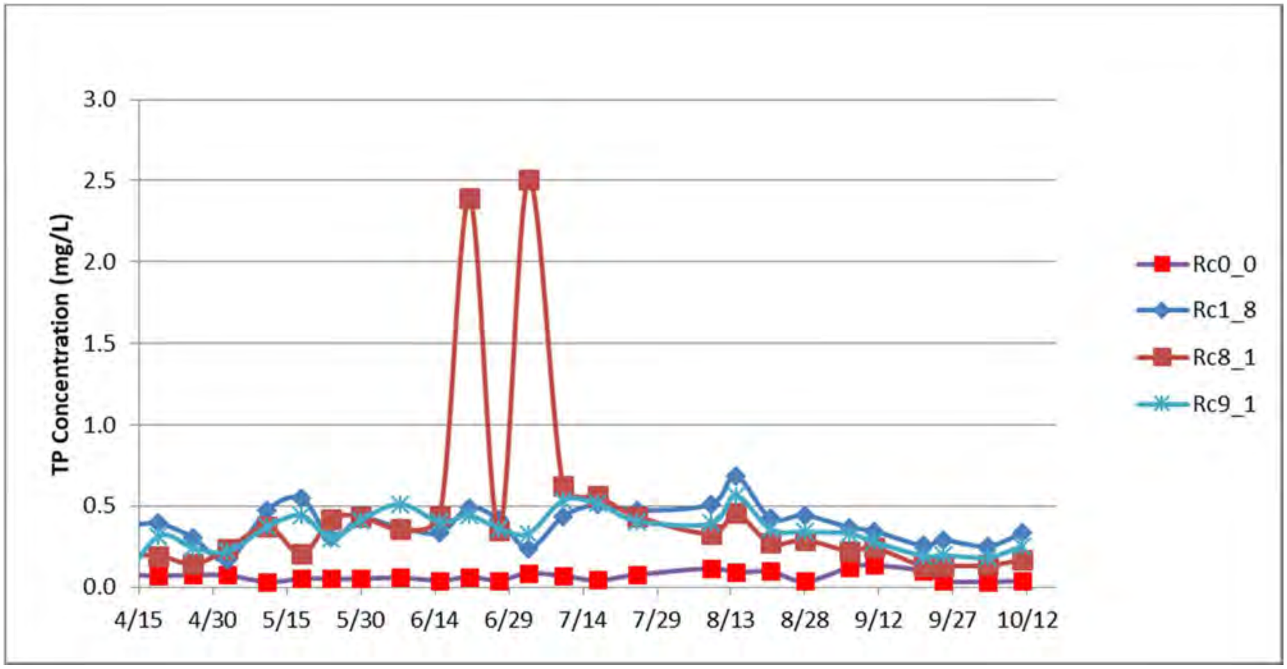


Figure 7a. Graph of measured total phosphorus concentrations (TP) at modeled inflow locations.

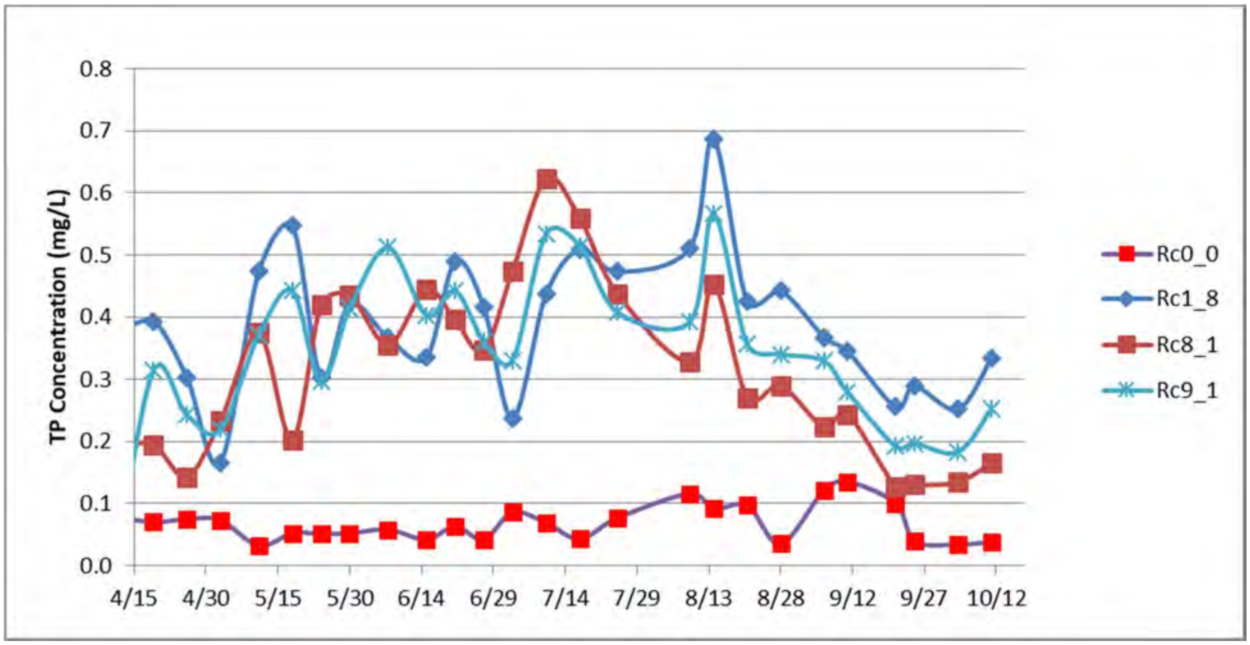


Figure 7b. Graph of adjusted total phosphorus concentrations (TP) at modeled inflow locations.

As discussed in the next section (2017 Load Reduction), a mass balance approach is used to calculate total phosphorus loads delivered to irrigators on a daily basis. To calculate the loads in the canal on a given day, total phosphorus concentration data reported by the laboratory for the three primary inflows were first interpolated to produce daily concentrations. These interpolated daily concentrations are then used with the modeled average daily flows to calculate daily loads along the canal using a simple mass balance equation (e.g., Etheridge, 2014).

As part of the water quality data assessment, both sets of water quality data (i.e., measured and adjusted) were used as boundary conditions in a preliminary load model. The loads and selected model results at RC9.1 were then compared to measured data (Appendix B). Based on this analysis and best professional judgement, the "adjusted" data were used to estimate load reduction for the 2017 annual reporting. The final modeled TP concentrations using the adjusted TP boundary condition data and the error are shown in Figure 8a. Total phosphorus concentration error based on final model and measured data at RC9.1 is given in Appendix B.

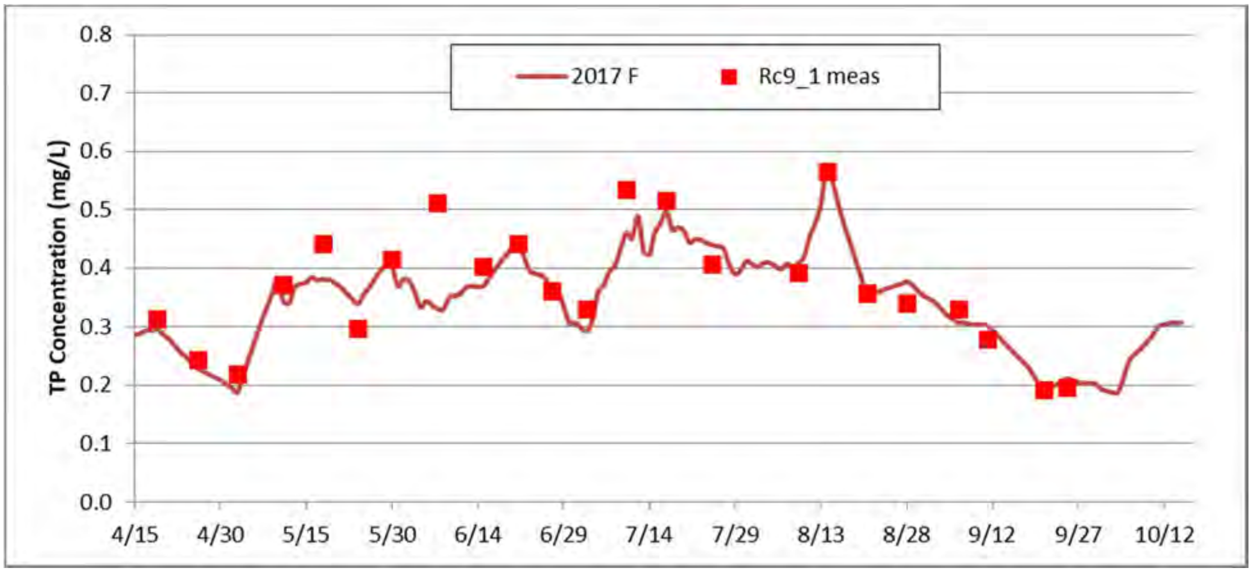


Figure 8a. Final modeled phosphorus using adjusted data (2017F) and measured phosphorus concentration at RC9.1.

As seen in Figure 7b, the weekly water quality data phosphorus concentration for the canal tributary inflows (RC1.8 and RC8.1) are consistently higher compared to the Boise River Diversion (RC0.0). By optimizing the use of the higher phosphorus tributary waters (RC1.8 and RC8.1), the concentration of phosphorus (and other pollutants) in the water delivered to the irrigators (Figure 7b: 2017F) is higher compared to the Baseline operations (Figure 7b; BL Ops). By applying more phosphorus to fields and reducing lower spills (primarily achieved through SCADA-controlled automation), overall phosphorus loads discharged to the Boise and Snake Rivers were reduced substantially (Table 1).

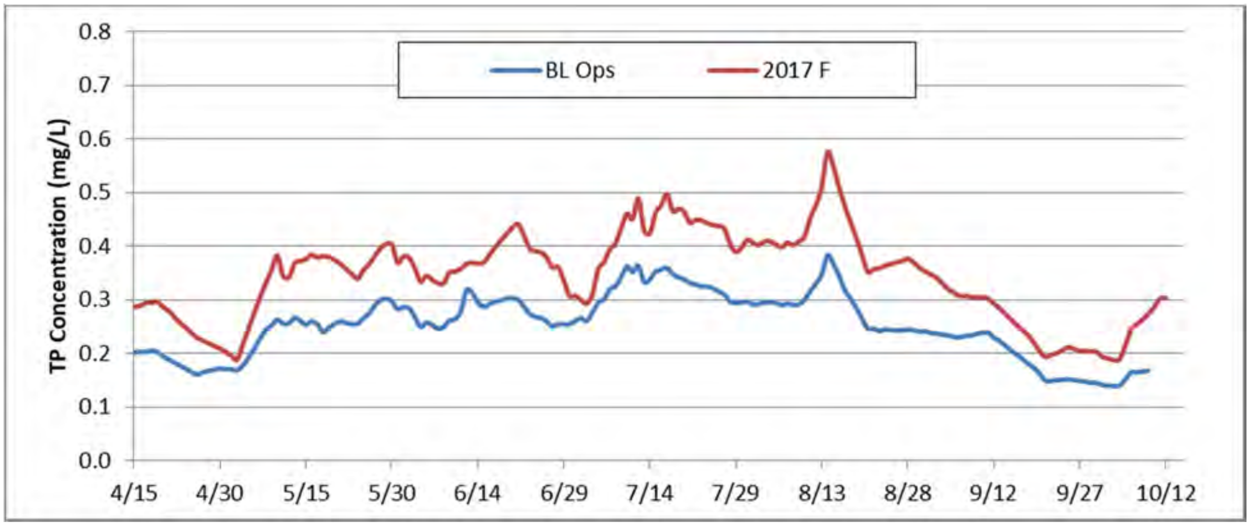


Figure 7b. Modeled daily TP concentration of canal water delivered to RID irrigators for baseline and 2017 water quality operations using adjusted phosphorus data.

2017 Phosphorus Load Reduction

As stated previously, a mass balance equation (e.g., Etheridge, 2014) is used to calculate total phosphorus concentrations and loads delivered to irrigators on a daily basis. More detailed discussion on how the mass balance equation is used to model phosphorus along the Riverside Canal is provided in Harrison et al 2014.

The daily TP loads delivered to RID irrigators for 2017 water-quality focused operations were modeled using corrected 2017 daily average flow and interpolated water quality data (Figure 8 – 2017F). The Baseline canal operations were also modeled (Figure 8 – BL Ops) using the same inflow data and assuming Boise River diversions at the permitted rate (i.e., 271.5 cfs). The "TP Reduction" in Figure 8 represents the daily load reduction and was calculated as the difference between modeled 2017 water quality and Baseline operations ("2017F" and "BL Ops", respectively). When summed over the 183-day irrigation season, the total daily load reduction to the Boise and Snake Rivers for the irrigation season is 23,800 lb/yr.

Figure 8. Modeled daily average TP loads and TP load reductions with lower spills set at Baseline (BL) rates.

Conclusions

Similar to the last 3 years, RID operated the Riverside Canal during the 2017 irrigation season with the intent of reducing the discharge of phosphorus loads to the Boise and Snake rivers. The phosphorus originated from upstream urban and agricultural sources, and previously discharged into the canal as tributary drains and discharged from the canal as canal "spills", which then discharge into downstream receiving waters. The canal spills and Boise River diversion were controlled with a SCADA system designed to automatically adjust the Boise River diversion rate as drainage inflows change, while still meeting irrigation deliveries.

The flow and water quality data were collected in 2017 to model the phosphorus load reduction of the ROWQIP for the irrigation season (Table 4). The modeling results show that with current implementation, the ROWQIP phosphorus load reduction can exceed 15,000 lb/year. The modeled 2017 load reduction was well above the 2015 load reduction but below reductions for 2014 and 2016 (Harrison et. al., 2016, Harrison et. al., 2015 and Harrison, 2017, respectively). Based on a review of available data, changes in phosphorus concentrations for the Boise River and Indian Creek (RC0.1 and RC1.8, respectively) have the greatest effect on load reductions.

Table 4. Modeled total phosphorus load reductions produced by the ROWQIP for the 2014 through 2017 irrigation seasons (note that 2017 annual load is rounded to 3 significant digits).

Year	Total Load Reduction
	(lb/yr)
2014	31840
2015	15826
2016	26818
2017	23800

The modeled load reduction represents phosphorus from upstream sources that was applied to RID and other farmland via the Riverside Canal, and is thereby removed from the Snake River. The modeled load reductions occurring over the 183-day irrigation season exceeds the equivalent phosphorus load reduction of 15,000 lb/yr, which is comparable to the SR-HC TMDL dissolved oxygen allocation.

The information provided in this report documents the methods used to ensure the project performance is transparent, reliable, and verifiable. Laboratory data reports, raw flow measurement data, and other data are available upon request.

References

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Idaho and Oregon Departments of Environmental Quality (IDEQ and ODEQ). 2004. Snake River–Hells Canyon total maximum daily load (TMDL). IDEQ, Boise Regional Office, Boise, ID, and ODEQ, Pendleton Office, Pendleton, OR.

Appendices

Appendix A – Corrected 2017 Flow Data

2017 Corrected Final Average Daily Flow Data (cfs)

Date	RC0.1	RC1.6	RC1.8	RC2.0	RC2.3	RC3.2	RC6.3	RC8.1	RC8.7	RC9.0	Rc9.1	RC18.7	RC23.8	RC30.9
Source>	IPC	RID	IPC	SCADA	IPC	Logger	RID	IPC	RID	SCADA	SCADA	SCADA	SCADA	Logger
4/15/2017	8.4	0.0	214.5	65.3	158.7	16.6	0.0	128.5	0.0	97.4	172.7	22.9	18.6	20.0
4/16/2017	12.3	0.0	222.7	63.1	170.2	16.6	0.0	128.6	0.0	93.6	179.4	24.6	19.6	20.0
4/17/2017	11.3	0.0	217.1	42.9	180.3	16.6	0.0	126.4	0.0	93.6	183.9	29.4	21.4	20.0
4/18/2017	13.2	0.0	246.9	62.6	193.4	16.6	0.0	139.0	0.0	116.0	183.8	29.9	23.6	20.0
4/19/2017	13.7	0.0	228.6	51.6	195.2	15.4	0.0	131.6	3.5	111.0	183.7	33.0	23.3	20.0
4/20/2017	14.5	0.0	215.8	43.9	203.6	15.6	0.0	132.7	3.5	120.6	184.0	33.4	21.8	20.0
4/21/2017	11.6	0.0	218.5	41.3	201.8	14.7	0.0	131.2	3.5	118.2	183.8	33.5	23.6	20.0
4/22/2017	13.4	0.0	226.2	38.1	205.0	15.1	0.0	134.1	3.5	123.3	184.5	37.3	22.1	20.0
4/23/2017	14.8	0.0	236.1	47.4	207.8	17.4	0.0	138.1	3.5	121.8	189.5	38.6	21.1	20.0
4/24/2017	13.4	0.0	245.3	60.5	206.1	17.2	0.0	136.0	3.5	113.0	188.6	38.7	22.9	20.0
4/25/2017	13.2	0.0	243.4	60.6	203.1	17.1	0.0	134.7	3.5	111.6	190.2	29.9	28.1	20.0
4/26/2017	13.0	0.0	251.4	66.1	207.7	17.3	0.0	134.8	3.5	114.7	190.2	22.8	28.9	20.0
4/27/2017	12.8	0.0	263.5	80.3	206.4	17.3	0.0	136.2	3.5	111.1	190.2	25.0	29.4	20.0
4/28/2017	12.4	0.0	249.0	68.0	204.9	17.1	0.0	133.2	3.5	101.9	190.3	24.3	25.7	20.0
4/29/2017	10.5	0.0	229.8	45.7	204.3	17.0	0.0	132.7	3.5	92.4	198.8	23.4	27.7	20.0
4/30/2017	10.5	0.0	250.3	60.8	211.0	17.2	0.0	122.8	3.5	82.8	204.6	27.9	30.8	20.0
5/1/2017	11.8	0.0	229.7	32.4	217.9	19.3	0.0	118.7	3.5	78.4	208.6	27.0	26.1	20.0
5/2/2017	10.1	0.0	199.6	0.0	219.8	21.1	0.0	122.6	3.5	69.0	218.4	34.2	21.7	20.0
5/3/2017	11.1	0.0	209.4	0.0	230.0	20.2	7.5	115.9	4.0	67.6	218.5	34.0	16.5	20.0
5/4/2017	11.9	0.0	186.4	0.0	209.5	19.6	7.5	108.7	4.0	49.5	218.5	29.3	15.0	20.0
5/5/2017	12.5	0.0	170.3	0.0	189.6	21.0	7.5	116.2	4.0	33.2	224.6	24.7	16.9	20.0
5/6/2017	11.0	0.0	191.6	0.0	211.6	20.8	7.5	117.3	4.0	45.5	231.1	22.2	20.4	20.0
5/7/2017	10.4	0.0	188.1	0.0	208.5	20.1	7.5	123.9	4.0	50.8	231.2	20.9	26.9	20.0
5/8/2017	12.5	0.0	184.8	0.0	206.4	22.0	7.5	130.3	4.0	46.3	241.4	22.1	27.6	20.0
5/9/2017	14.2	0.0	170.5	0.0	191.0	23.5	7.5	135.0	4.0	25.1	249.8	19.3	18.3	20.0

Date	RC0.1	RC1.6	RC1.8	RC2.0	RC2.3	RC3.2	RC6.3	RC8.1	RC8.7	RC9.0	Rc9.1	RC18.7	RC23.8	RC30.9
Source>	IPC	RID	IPC	SCADA	IPC	Logger	RID	IPC	RID	SCADA	SCADA	SCADA	SCADA	Logger
5/10/2017	16.0	0.0	180.4	0.0	204.7	24.6	7.5	128.7	4.0	18.0	261.5	14.9	18.6	20.0
5/11/2017	71.2	0.0	142.4	0.0	223.5	25.8	12.5	117.7	4.0	9.0	265.9	14.6	17.6	20.0
5/12/2017	72.1	0.0	145.2	0.0	232.8	25.0	12.5	124.2	4.0	22.8	270.0	23.7	22.9	20.0
5/13/2017	45.5	0.0	170.7	0.0	228.0	22.9	12.5	136.7	4.0	35.2	269.5	35.2	21.6	20.0
5/14/2017	38.9	0.0	181.2	0.0	231.3	20.2	12.5	134.6	4.0	39.2	269.7	31.5	25.4	20.0
5/15/2017	33.8	1.0	184.4	0.0	230.8	21.9	12.5	131.4	4.0	41.4	269.8	31.6	24.0	20.0
5/16/2017	26.3	3.0	227.6	27.2	236.0	22.6	12.5	144.0	4.0	55.1	270.1	31.5	19.5	20.0
5/17/2017	16.9	3.0	265.7	62.9	236.9	21.3	12.5	175.1	4.0	84.9	266.4	34.4	17.6	20.0
5/18/2017	17.1	3.0	228.6	20.5	241.0	20.3	12.5	156.3	4.0	75.5	264.2	29.2	22.9	20.0
5/19/2017	16.7	3.0	220.4	13.2	239.1	20.2	12.5	143.6	4.0	74.1	256.2	28.0	21.0	20.0
5/20/2017	16.1	3.0	215.7	2.6	241.5	21.4	12.5	137.8	4.0	75.8	251.8	17.0	23.0	20.0
5/21/2017	16.7	3.0	219.5	6.1	240.6	22.4	12.5	130.9	4.0	69.8	251.9	16.4	21.1	20.0
5/22/2017	16.6	3.0	203.3	1.1	228.4	23.0	12.5	122.7	4.0	46.9	255.0	17.2	15.7	20.0
5/23/2017	16.3	3.0	197.6	0.0	218.9	23.4	12.5	115.8	4.0	30.1	257.1	21.4	15.2	20.0
5/24/2017	17.2	3.0	194.0	0.0	216.4	23.5	17.5	112.1	4.0	24.1	257.6	18.2	22.4	20.0
5/25/2017	14.8	3.0	196.5	0.0	217.4	23.8	17.5	119.3	4.0	49.0	257.3	14.2	17.3	20.0
5/26/2017	15.6	3.0	199.8	0.0	218.6	23.7	17.5	119.3	4.0	46.4	253.1	15.4	19.6	20.0
5/27/2017	14.6	3.0	187.6	0.0	206.3	23.6	17.5	130.0	4.0	45.7	250.2	21.9	18.9	20.0
5/28/2017	14.0	3.0	170.3	0.0	187.6	25.0	17.5	141.6	4.0	43.0	250.2	17.9	20.6	20.0
5/29/2017	16.0	3.0	167.5	0.0	193.8	26.5	17.5	143.0	4.0	36.2	254.1	17.0	18.1	20.0
5/30/2017	26.0	3.0	168.5	2.1	207.2	28.0	17.5	131.7	4.0	19.0	262.1	20.6	17.0	20.0
5/31/2017	51.7	3.0	156.3	9.3	221.8	28.7	17.5	124.3	4.0	25.1	261.9	21.0	16.6	20.0
6/1/2017	32.9	3.0	170.1	0.0	223.0	28.9	17.5	126.2	4.0	24.7	262.0	32.3	16.4	20.0
6/2/2017	27.8	3.0	173.7	0.0	219.3	29.5	17.5	124.4	4.0	25.3	259.5	35.4	21.2	20.0
6/3/2017	39.7	3.0	160.5	0.0	217.7	30.7	17.5	121.0	4.0	26.3	258.2	21.0	18.3	20.0
6/4/2017	56.2	3.0	149.4	2.2	224.6	31.2	17.5	109.2	4.0	18.9	258.1	13.2	19.0	20.0
6/5/2017	40.2	3.0	170.0	7.2	220.2	32.0	17.5	117.3	4.0	22.3	254.4	13.8	20.6	20.0
6/6/2017	40.7	3.0	174.8	6.6	224.0	34.0	17.5	116.2	4.0	20.0	261.7	23.3	20.3	20.0
6/7/2017	39.7	3.0	180.3	1.9	225.8	35.8	12.0	111.5	6.0	16.1	261.3	15.6	19.5	20.0

Date	**RC0.1**	**RC1.6**	**RC1.8**	**RC2.0**	**RC2.3**	**RC3.2**	**RC6.3**	**RC8.1**	**RC8.7**	**RC9.0**	**Rc9.1**	**RC18.7**	**RC23.8**	**RC30.9**
Source>	IPC	RID	IPC	SCADA	IPC	Logger	RID	IPC	RID	SCADA	SCADA	SCADA	SCADA	Logger
6/8/2017	42.7	3.0	177.8	3.5	233.6	37.2	12.0	112.3	6.0	16.3	261.9	21.4	17.3	20.0
6/9/2017	22.9	3.0	196.3	0.0	231.9	38.1	12.0	119.5	6.0	23.6	261.7	24.0	15.9	20.0
6/10/2017	23.0	3.0	203.9	0.0	240.8	38.5	12.0	121.6	6.0	42.6	262.1	16.7	14.4	20.0
6/11/2017	20.7	3.0	221.8	4.8	250.6	37.9	12.0	127.6	6.0	61.2	261.7	19.8	21.4	20.0
6/12/2017	20.9	3.0	306.2	76.1	250.8	37.1	12.0	160.4	6.0	86.2	261.6	20.2	27.8	20.0
6/13/2017	18.3	3.0	269.3	45.9	244.6	32.8	12.0	148.3	6.0	66.8	261.1	24.2	32.1	20.0
6/14/2017	17.3	3.0	247.6	18.7	247.3	33.6	12.0	129.9	6.0	55.3	261.7	18.4	29.9	20.0
6/15/2017	16.1	3.0	255.2	21.0	248.6	38.7	17.5	119.7	4.0	53.8	261.5	15.6	23.7	20.0
6/16/2017	13.4	3.0	253.4	15.6	246.8	40.9	17.5	119.5	4.0	47.9	261.8	20.1	20.5	20.0
6/17/2017	10.0	3.0	255.8	15.4	246.5	39.7	17.5	121.8	4.0	47.8	261.7	12.2	16.3	20.0
6/18/2017	8.5	3.0	244.7	9.0	243.7	41.7	17.5	118.0	4.0	46.8	261.8	14.4	19.6	20.0
6/19/2017	8.1	3.0	238.4	3.1	242.0	42.4	17.5	119.8	4.0	41.3	268.5	17.3	18.2	20.0
6/20/2017	6.7	3.0	223.5	0.0	232.3	44.2	17.5	119.6	4.0	27.3	273.5	17.5	17.3	20.0
6/21/2017	11.2	3.0	217.6	0.0	231.4	46.5	27.5	107.3	4.0	21.8	273.4	12.9	10.8	20.0
6/22/2017	17.4	3.0	196.5	0.0	218.8	48.5	27.5	110.8	4.0	21.6	273.3	18.5	13.5	20.0
6/23/2017	32.3	3.0	183.0	0.0	221.1	45.1	27.5	105.8	4.0	17.3	273.7	18.2	16.4	20.0
6/24/2017	27.6	3.0	181.4	0.0	214.1	35.8	27.5	108.6	4.0	20.7	273.5	23.3	18.5	20.0
6/25/2017	19.9	3.0	187.4	0.0	210.1	37.3	27.5	110.2	4.0	37.3	273.4	31.9	21.8	20.0
6/26/2017	17.8	3.0	183.9	0.0	203.0	39.5	27.5	113.5	4.0	24.4	272.9	32.8	26.9	20.0
6/27/2017	25.3	3.0	167.3	0.0	193.7	38.9	17.5	120.6	4.0	11.0	273.5	23.2	30.5	20.0
6/28/2017	20.9	3.0	171.3	0.0	191.3	40.6	17.5	124.3	4.0	12.9	273.4	17.2	23.4	20.0
6/29/2017	49.7	3.0	162.2	0.0	211.4	42.1	17.5	122.4	4.0	11.6	275.7	24.6	15.9	20.0
6/30/2017	83.1	3.0	150.0	5.5	236.1	41.2	17.5	119.0	4.0	19.2	273.6	28.0	15.2	20.0
7/1/2017	83.1	3.0	145.9	8.4	231.3	40.0	17.5	122.2	4.0	19.0	273.9	26.5	16.9	20.0
7/2/2017	94.6	3.0	139.2	8.8	232.1	34.5	17.5	121.0	4.0	16.4	273.6	33.1	16.3	20.0
7/3/2017	106.7	3.0	143.6	20.0	242.3	36.5	27.5	112.2	4.0	21.3	273.9	28.8	17.5	20.0
7/4/2017	101.3	3.0	145.6	9.7	248.7	37.8	27.5	113.0	4.0	25.5	273.9	32.2	18.3	20.0
7/5/2017	55.3	3.0	168.3	0.0	231.0	38.4	27.5	113.6	4.0	16.6	271.9	32.2	15.5	20.0
7/6/2017	64.5	3.0	165.2	0.0	235.3	36.6	27.5	111.2	4.0	8.4	273.8	19.1	20.3	20.0

Date	**RC0.1**	**RC1.6**	**RC1.8**	**RC2.0**	**RC2.3**	**RC3.2**	**RC6.3**	**RC8.1**	**RC8.7**	**RC9.0**	**Rc9.1**	**RC18.7**	**RC23.8**	**RC30.9**
Source>	IPC	RID	IPC	SCADA	IPC	Logger	RID	IPC	RID	SCADA	SCADA	SCADA	SCADA	Logger
7/7/2017	63.5	3.0	159.9	0.0	233.8	38.1	27.5	116.2	4.0	19.2	273.7	22.3	18.6	20.0
7/8/2017	74.9	3.0	151.3	0.0	232.6	37.5	27.5	114.0	4.0	13.8	273.6	22.0	14.0	20.0
7/9/2017	61.2	3.0	165.6	0.0	235.5	36.7	27.5	112.2	4.0	17.1	273.7	28.9	10.9	20.0
7/10/2017	52.5	3.0	171.0	0.0	224.5	36.9	5.0	115.7	4.0	8.2	273.3	20.7	16.8	20.0
7/11/2017	64.3	3.0	172.1	20.4	217.9	34.2	5.0	110.3	4.0	15.1	273.3	15.8	17.9	20.0
7/12/2017	46.7	3.0	182.1	46.6	167.6	38.3	5.0	112.3	4.0	8.6	240.9	8.1	10.9	20.0
7/13/2017	75.7	3.0	163.3	0.0	246.8	39.4	5.0	102.0	4.0	9.4	273.6	15.0	14.3	20.0
7/14/2017	84.0	3.0	154.5	0.2	251.4	39.8	5.0	111.0	4.0	20.7	273.7	18.5	12.2	20.0
7/15/2017	54.4	3.0	165.5	0.0	225.5	40.6	5.0	117.2	4.0	18.4	273.8	30.5	12.6	20.0
7/16/2017	43.7	3.0	175.2	0.0	220.8	39.0	5.0	116.5	4.0	18.3	273.7	38.2	11.8	20.0
7/17/2017	29.4	3.0	185.1	0.0	211.6	37.7	5.0	120.5	4.0	9.5	273.8	33.6	11.5	20.0
7/18/2017	47.6	3.0	177.3	0.0	232.3	40.7	5.0	120.5	4.0	29.5	273.7	24.1	10.9	20.0
7/19/2017	37.5	3.0	186.2	0.0	231.7	42.3	5.0	119.4	4.0	27.8	273.5	18.2	9.1	20.0
7/20/2017	35.8	3.0	194.5	0.0	237.2	43.8	5.0	116.1	4.0	21.2	273.6	17.2	13.4	20.0
7/21/2017	46.0	3.0	196.8	0.0	256.7	43.4	5.0	110.6	4.0	25.9	273.7	17.8	18.4	20.0
7/22/2017	34.2	3.0	199.8	0.0	243.7	42.6	5.0	111.2	4.0	23.8	273.7	18.1	23.1	20.0
7/23/2017	27.5	3.0	197.6	0.0	234.7	41.7	5.0	113.1	4.0	22.3	273.8	21.4	21.3	20.0
7/24/2017	25.4	3.0	201.3	0.0	235.0	42.4	5.0	118.6	4.0	26.8	273.9	29.3	16.9	20.0
7/25/2017	20.9	3.0	208.4	0.0	239.3	42.0	5.0	123.8	4.0	35.8	273.8	24.0	10.0	20.0
7/26/2017	18.6	3.0	183.8	0.0	210.6	41.3	5.0	129.0	4.0	24.3	273.8	20.4	10.6	20.0
7/27/2017	21.7	3.0	181.5	0.0	216.3	41.1	5.0	124.9	4.0	27.8	273.9	16.0	8.7	20.0
7/28/2017	45.6	3.0	159.6	0.0	222.2	39.3	5.0	117.3	4.0	23.7	273.7	10.4	12.2	20.0
7/29/2017	58.7	3.0	154.9	0.0	237.1	38.3	5.0	111.3	4.0	33.6	273.7	19.3	18.4	20.0
7/30/2017	49.6	3.0	158.7	0.0	230.0	37.6	5.0	107.8	4.0	27.3	273.8	33.1	18.6	20.0
7/31/2017	33.2	3.0	160.0	0.0	208.6	39.4	5.0	112.1	4.0	20.3	273.9	32.8	18.5	20.0
8/1/2017	36.5	3.0	156.9	0.0	206.6	44.1	5.0	111.1	4.0	16.0	275.0	16.8	18.3	20.0
8/2/2017	40.6	3.0	159.8	0.0	219.6	45.6	5.0	112.1	4.0	13.8	279.5	22.0	19.8	20.0
8/3/2017	32.6	3.0	165.7	0.0	215.4	46.3	5.0	113.8	4.0	11.8	278.1	25.4	19.6	20.0
8/4/2017	31.3	3.0	168.9	0.0	217.4	46.8	5.0	115.8	4.0	15.2	279.6	29.7	20.7	20.0

Date	RC0.1	RC1.6	RC1.8	RC2.0	RC2.3	RC3.2	RC6.3	RC8.1	RC8.7	RC9.0	Rc9.1	RC18.7	RC23.8	RC30.9
Source>	IPC	RID	IPC	SCADA	IPC	Logger	RID	IPC	RID	SCADA	SCADA	SCADA	SCADA	Logger
8/5/2017	33.9	3.0	162.3	0.0	216.6	47.2	5.0	118.0	4.0	18.6	279.0	31.6	20.3	20.0
8/6/2017	36.4	3.0	155.7	0.0	217.5	46.8	5.0	118.0	4.0	19.9	279.3	34.4	19.1	20.0
8/7/2017	24.9	3.0	164.4	0.0	205.1	48.9	5.0	120.9	4.0	10.0	277.7	31.3	20.3	20.0
8/8/2017	34.2	3.0	168.7	0.0	228.4	48.8	5.0	113.1	4.0	22.3	278.9	23.6	20.6	20.0
8/9/2017	25.5	3.0	174.3	0.0	221.1	49.9	8.0	111.7	4.0	23.8	277.6	17.5	22.1	20.0
8/10/2017	44.2	3.0	161.8	0.0	236.7	48.0	8.0	105.2	4.0	32.0	277.8	16.4	19.8	20.0
8/11/2017	33.1	3.0	160.4	0.0	217.5	44.8	8.0	112.6	4.0	29.0	277.8	19.6	14.0	20.0
8/12/2017	37.9	3.0	161.0	0.0	223.7	40.0	8.0	109.2	4.0	37.3	277.9	20.7	11.3	20.0
8/13/2017	33.3	3.0	161.0	0.0	220.0	38.5	8.0	107.6	4.0	43.9	275.2	25.5	17.8	20.0
8/14/2017	11.7	3.0	187.6	0.0	223.1	37.7	10.0	117.9	4.0	46.0	266.8	33.0	22.5	20.0
8/15/2017	11.3	3.0	196.1	0.0	235.7	38.1	10.0	115.7	4.0	51.4	256.9	27.6	23.5	20.0
8/16/2017	9.7	3.0	182.0	0.0	217.1	37.8	10.0	126.5	4.0	49.4	256.6	21.3	21.7	20.0
8/17/2017	8.0	3.0	168.2	0.0	196.4	37.6	10.0	123.9	4.0	34.7	256.8	16.5	20.1	20.0
8/18/2017	7.8	3.0	177.6	0.0	199.2	36.5	10.0	124.2	4.0	34.3	257.0	12.4	19.5	20.0
8/19/2017	7.9	3.0	180.4	0.0	204.4	33.8	10.0	123.5	4.0	33.9	256.7	24.5	19.4	20.0
8/20/2017	8.5	3.0	181.7	0.0	209.6	35.2	10.0	122.8	4.0	40.1	256.9	22.9	14.1	20.0
8/21/2017	10.1	3.0	183.6	0.0	214.8	38.1	9.0	122.1	4.0	51.3	257.0	21.6	12.3	20.0
8/22/2017	11.4	3.0	190.5	0.0	226.4	38.9	9.0	117.6	4.0	43.2	256.6	16.5	13.5	20.0
8/23/2017	15.2	3.0	187.3	0.0	225.7	39.3	9.0	104.2	4.0	27.7	256.7	20.9	12.5	20.0
8/24/2017	15.9	3.0	202.5	0.0	242.7	38.4	9.0	104.7	4.0	36.1	256.8	21.1	13.5	20.0
8/25/2017	14.4	3.0	200.8	0.0	239.2	38.7	9.0	106.3	4.0	42.5	245.0	26.3	12.8	20.0
8/26/2017	12.6	3.0	201.6	0.0	239.2	38.5	9.0	107.7	4.0	52.4	237.5	21.3	9.5	20.0
8/27/2017	12.1	3.0	200.3	0.0	237.8	36.1	9.0	110.8	4.0	56.1	237.4	31.4	10.3	20.0
8/28/2017	11.7	3.0	214.0	0.0	246.1	36.6	15.0	107.2	4.0	57.8	237.3	30.4	14.2	20.0
8/29/2017	12.0	3.0	222.3	0.0	251.2	37.6	15.0	106.7	4.0	58.6	237.3	16.5	13.0	20.0
8/30/2017	12.0	3.0	212.6	0.0	246.7	36.4	15.0	112.0	4.0	65.4	232.3	14.6	15.7	20.0
8/31/2017	11.6	3.0	219.3	0.0	248.3	33.2	15.0	115.9	4.0	82.0	229.2	14.9	18.2	20.0
9/1/2017	10.2	3.0	215.5	0.0	246.6	30.9	15.0	113.7	4.0	77.3	229.2	14.2	14.8	20.0
9/2/2017	9.6	3.0	221.5	0.0	251.6	29.7	15.0	114.6	4.0	85.2	229.3	18.2	9.2	20.0

Date	RC0.1	RC1.6	RC1.8	RC2.0	RC2.3	RC3.2	RC6.3	RC8.1	RC8.7	RC9.0	Rc9.1	RC18.7	RC23.8	RC30.9
Source>	IPC	RID	IPC	SCADA	IPC	Logger	RID	IPC	RID	SCADA	SCADA	SCADA	SCADA	Logger
9/3/2017	10.2	3.0	218.8	0.0	247.2	29.1	15.0	119.1	4.0	91.9	229.2	19.2	8.0	20.0
9/4/2017	11.8	3.0	222.7	0.0	250.7	30.9	15.0	129.1	4.0	96.1	229.1	23.4	8.8	20.0
9/5/2017	10.4	3.0	222.5	0.0	250.5	32.1	15.0	127.6	4.0	89.5	229.3	25.6	11.0	20.0
9/6/2017	10.7	3.0	233.8	0.1	256.6	32.3	10.0	132.2	4.0	103.7	229.2	25.5	11.5	20.0
9/7/2017	10.5	3.0	236.1	0.4	256.4	32.4	10.0	123.6	4.0	99.3	229.1	22.6	14.3	20.0
9/8/2017	9.5	3.0	228.3	0.0	252.4	31.7	10.0	130.2	4.0	100.1	229.1	29.4	19.3	20.0
9/9/2017	9.2	3.0	234.9	0.2	257.1	30.3	10.0	130.2	4.0	104.0	229.2	33.9	19.2	20.0
9/10/2017	10.7	3.0	239.0	0.7	262.9	32.1	10.0	123.0	4.0	106.4	229.4	32.9	16.3	20.0
9/11/2017	9.2	3.0	241.2	2.2	262.2	34.1	15.0	130.8	4.0	107.8	229.1	21.9	15.1	20.0
9/12/2017	8.8	3.0	235.7	2.3	255.1	32.0	15.0	129.8	4.0	91.7	229.1	22.6	17.8	20.0
9/13/2017	9.2	3.0	255.8	8.5	267.7	31.3	15.0	129.8	4.0	100.7	229.2	31.4	16.6	20.0
9/14/2017	9.4	3.0	259.8	16.3	266.2	32.7	15.0	130.5	4.0	102.5	229.2	27.6	21.4	20.0
9/15/2017	8.8	3.0	257.1	21.5	258.8	31.5	15.0	130.5	4.0	111.9	221.6	21.8	27.7	20.0
9/16/2017	9.7	3.0	278.4	46.2	255.7	30.5	15.0	130.6	4.0	116.8	216.8	20.0	25.5	20.0
9/17/2017	11.0	3.0	284.2	52.8	261.2	31.1	15.0	130.2	4.0	116.5	216.9	20.5	20.9	20.0
9/18/2017	9.7	3.0	287.4	55.1	263.7	31.2	15.0	132.8	4.0	115.2	216.9	20.6	18.9	20.0
9/19/2017	10.2	3.0	312.4	103.7	238.5	30.1	15.0	137.9	4.0	98.0	217.0	17.5	19.5	20.0
9/20/2017	10.8	3.0	329.6	146.0	216.0	28.4	15.0	147.0	4.0	80.9	217.0	21.5	18.3	20.0
9/21/2017	10.0	3.0	323.8	145.5	213.5	22.1	10.0	158.9	4.0	86.7	216.9	28.8	20.0	20.0
9/22/2017	10.5	3.0	330.6	154.6	205.5	23.5	10.0	152.4	4.0	89.5	216.8	39.7	21.5	20.0
9/23/2017	10.2	3.0	334.0	167.1	192.2	24.9	10.0	145.6	4.0	84.4	212.8	36.4	21.4	20.0
9/24/2017	9.5	3.0	339.5	171.7	192.9	24.9	10.0	143.2	4.0	88.9	209.1	29.6	20.3	20.0
9/25/2017	9.9	3.0	329.0	169.7	188.0	24.9	10.0	132.7	4.0	81.4	204.0	28.5	20.8	20.0
9/26/2017	10.7	3.0	323.1	168.8	184.8	26.8	10.0	131.3	4.0	80.9	204.4	24.9	19.4	20.0
9/27/2017	11.0	3.0	313.7	165.2	184.2	29.3	10.0	133.6	4.0	85.0	204.4	18.9	20.1	20.0
9/28/2017	10.9	3.0	301.4	155.2	186.4	29.5	10.0	129.5	4.0	75.1	204.0	16.8	20.4	20.0
9/29/2017	9.8	3.0	294.6	146.8	187.2	29.7	10.0	128.0	4.0	68.5	204.3	27.6	23.0	20.0
9/30/2017	9.1	3.0	297.9	148.0	186.4	29.9	10.0	125.0	4.0	67.7	204.3	28.7	24.6	20.0
10/1/2017	10.1	3.0	298.4	148.3	187.9	30.0	10.0	157.8	4.0	67.0	204.2	27.6	25.2	20.0

Date	RC0.1	RC1.6	RC1.8	RC2.0	RC2.3	RC3.2	RC6.3	RC8.1	RC8.7	RC9.0	Rc9.1	RC18.7	RC23.8	RC30.9
Source>	IPC	RID	IPC	SCADA	IPC	Logger	RID	IPC	RID	SCADA	SCADA	SCADA	SCADA	Logger
10/2/2017	9.4	3.0	298.1	148.5	187.4	29.4	10.0	164.8	4.0	67.0	204.4	18.0	30.4	20.0
10/3/2017	9.5	3.0	294.7	146.2	185.3	29.6	10.0	171.3	4.0	68.0	204.2	13.7	25.5	20.0
10/4/2017	9.0	3.0	296.5	146.6	186.0	30.4	10.0	150.3	4.0	72.8	204.4	11.6	20.0	20.0
10/5/2017	9.9	3.0	312.5	153.2	188.1	30.3	10.0	76.7	4.0	80.3	204.4	17.7	16.9	20.0
10/6/2017	9.6	3.0	339.4	172.0	232.9	29.3	10.0	47.2	4.0	66.8	203.9	23.9	14.6	20.0
10/7/2017	7.9	3.0	299.0	152.0	230.9	31.8	10.0	46.9	4.0	30.6	204.0	27.0	13.9	20.0
10/8/2017	7.9	3.0	275.3	131.1	232.1	31.8	10.0	50.6	4.0	18.9	203.9	28.3	15.6	20.0
10/9/2017	8.2	3.0	255.2	114.3	231.4	31.6	10.0	47.2	4.0	19.2	204.4	25.4	13.2	20.0
10/10/2017	7.4	3.0	252.4	108.1	229.6	31.8	10.0	44.0	4.0	24.7	204.3	24.1	13.2	20.0
10/11/2017	5.4	3.0	248.2	105.3	235.4	31.8	10.0	38.6	4.0	24.6	204.3	26.9	14.7	20.0
10/12/2017	6.2	3.0	303.0	98.0	238.3	32.0	10.0	36.5	4.0	20.9	204.2	31.5	14.7	20.0
10/13/2017	5.1	3.0	289.1	105.1	247.2	32.1	10.0	33.5	4.0	16.3	204.3	37.4	16.6	20.0
10/14/2017	5.1	3.0	289.1	123.3	247.2	32.3	10.0	33.5	4.0	14.0	204.2	33.8	16.8	20.0
10/15/2017	5.1	3.0	289.1	103.1	247.2	32.3	10.0	33.5	4.0	14.7	204.0	26.3	19.6	20.0

2016 Flow Data Source

Final flow data source code.

Code	Final Flow Source
IPC	Idaho Power Co (WM)
SCADA	SCADA System (CE)
RID	Riverside Irrigation Dist. (RID)
Logger	Data Logger (SPF)

2017 Flow QC Data

Flow measurements by IPC Water Management (WM) during 2017 used for post season flow correction.

Date	Time	Stage (ft)	Flow (cfs)
RC1.5 - Riverside Canal at Centennial Park			
4/6/2017	7:45	3.31	11.0
5/18/2017	14:00	3.82	17.0
6/6/2017	7:45	3.83	46.5
RC 1.8 - Indian Creek at Kimball Ave			
2/16/2017	13:00	4.93	224.0
4/6/2017	10:30	5.24	269.0
6/6/2017	8:45	4.89	170.0
6/29/2017	7:15	4.90	166.0
7/19/2017	8:00	5.06	190.0
9/6/2017	13:00	5.14	223.0
RC 2.3 - Riverside Canal Main Gage below Indian Creek			
4/6/2017	11:15	2.55	155.0
5/18/2017	10:40	3.11	224.0
6/29/2017	8:20	2.97	192.0
7/19/2017	11:30	3.21	213.0
RC 8.1 - West End Drain near Greenleaf			
2/16/2017	11:50	1.43	75.0
3/8/2017	12:00	1.09	55.5
4/28/2017	10:45	1.75	134.0
6/29/2017	9:45	1.73	129.0
7/19/2017	9:40	1.67	139.0
9/6/2017	11:15	1.74	136.0
RC 9.0 - Dixie Spill below Riverside Canal			
2/16/2017	10:30	0.35	54.6
4/6/2017	13:45	0.46	65.6
4/28/2017	12:00	1.00	101.0
6/6/2017	12:30	0.02	31.0
RC 9.1 - Riverside Canal below Dixie Spill			
4/6/2017	12:30	0.75	171.0
4/28/2017	12:45	1.00	198.0
5/18/2017	7:00	1.77	263.0
6/29/2017	10:45	2.01	284.0
7/19/2017	10:30	1.93	272.0
9/6/2017	12:00	1.51	234.0

Appendix B – Water Quality and Quality Control Data

2017 Water Quality Data

Date	Time	TSS (mg/L)	Total PO4 (mg/L)	Ortho PO4 (mg/L)
RC0.0	Riverside Canal Diversion at Boise River			
3/31/2017	10:56	35	0.166	0.069
4/4/2017	11:10	15	0.083	0.032
4/11/2017	11:00	9	0.079	0.042
4/19/2017	11:00	11	0.070	0.029
4/26/2017	12:00	6	0.075	0.039
5/3/2017	11:40	8	0.073	0.027
5/11/2017	10:00	5	0.032	0.014
5/18/2017	11:00	9	0.052	0.025
5/24/2017	9:30	6	0.051	0.024
5/30/2017	10:20	6	0.052	0.019
6/7/2017	13:45	4	0.058	0.015
6/15/2017	10:30	7	0.042	0.017
6/21/2017	10:30	11	0.063	0.025
6/27/2017	9:40	11	0.042	0.017
7/3/2017	10:40	13	0.086	0.044
7/10/2017	14:44	8	0.069	0.021
7/17/2017	11:30	7	0.043	0.021
7/25/2017	10:45	13	0.077	0.032
8/9/2017	10:35	15	0.116	0.051
8/14/2017	9:05	7	0.091	0.060
8/21/2017	10:35	10	0.097	0.066
8/28/2017	10:10	5	0.035	0.059
9/6/2017	11:55	4	0.121	0.112
9/11/2017	10:55	8	0.135	0.107
9/21/2017	11:05	8	0.100	0.097
9/25/2017	10:20	<2	0.039	0.032
10/4/2017	11:20	<2	0.034	0.030
10/11/2017	10:13	<2	0.038	0.032
RC9.1	Riverside Canal at Dixie Drain			
4/4/2017	10:00	96	0.368	0.207
4/19/2017	9:20	64	0.314	0.208
4/26/2017	11:00	53	0.243	0.156
5/3/2017	9:20	57	0.219	0.076
5/11/2017	7:30	96	0.372	0.209
5/18/2017	9:30	68	0.442	0.329

5/24/2017	7:00	98	0.297	0.117
5/30/2017	8:50	128	0.414	0.187
6/7/2017	11:30	214	0.512	0.178
6/15/2017	7:30	95	0.403	0.248
6/21/2017	8:40	292	0.442	0.238
6/27/2017	7:30	163	0.361	0.164
7/3/2017	8:40	175	0.331	0.112
7/10/2017	13:37	245	0.534	0.249
7/17/2017	9:45	158	0.515	0.253
7/25/2017	9:35	152	0.484	0.291
8/9/2017	8:50	86	0.407	0.246
8/9/2017	8:50	98	0.392	0.241
8/14/2017	7:45	75	0.566	0.361
8/21/2017	9:05	60	0.357	0.238
8/28/2017	8:30	57	0.341	0.280
9/6/2017	10:10	36	0.330	0.236
9/11/2017	9:15	44	0.279	0.217
9/21/2017	9:30	26	0.192	0.154
9/25/2017	8:45	22	0.197	0.141
10/4/2017	9:50	29	0.183	0.149
10/11/2017	9:00	26	0.253	0.191
RC18.7	Riverside Canal at Dutton Spill			
4/4/2017	8:55	70	0.379	0.248
4/19/2017	8:30	88	0.363	0.192
5/3/2017	8:35	104	0.300	0.078
5/18/2017	8:45	90	0.478	0.334
5/30/2017	8:50	149	0.408	0.185
6/7/2017	10:55	129	0.396	0.170
6/21/2017	8:15	130	0.455	0.234
7/3/2017	7:40	195	0.364	0.090
7/17/2017	8:20	178	0.526	0.220
8/9/2017	8:30	110	0.360	0.203
8/21/2017	7:25	77	0.338	0.180
9/6/2017	8:25	52	0.303	0.209
9/21/2017	8:50	28	0.177	0.152
10/4/2017	8:30	28	0.190	0.150
RC23.8	Riverside Canal below Holly Spill			
4/4/2017	8:40	69	0.334	0.214
4/19/2017	8:10	110	0.381	0.186

5/3/2017	7:40	107	0.328	0.081
5/18/2017	8:00	100	0.466	0.321
5/30/2017	7:40	132	0.336	0.138
6/7/2017	10:15	92	0.334	0.181
6/21/2017	8:00	84	0.373	0.205
7/3/2017	7:20	177	0.376	0.101
7/17/2017	7:45	189	0.490	0.186
8/9/2017	8:15	104	0.371	0.180
8/21/2017	8:18	100	0.341	0.171
9/26/2017	8:45	48	0.271	0.182
9/21/2017	7:55	24	0.148	0.138
10/4/2017	8:50	27	0.195	0.137
RC30.9	Riverside End Spill to Snake River			
4/4/2017	8:10	28	0.147	0.088
4/19/2017	7:45	31	0.272	0.186
5/3/2017	7:30	64	0.221	0.073
5/18/2017	7:30	95	0.510	0.321
5/30/2017	7:25	27	0.169	0.096
6/7/2017	9:40	24	0.234	0.162
6/21/2017	7:00	26	0.226	0.162
7/3/2017	6:30	24	0.137	0.087
7/3/2017	6:30	24	0.137	0.087
7/17/2017	7:00	40	0.258	0.166
8/9/2017	7:45	33	0.238	0.156
8/21/2017	8:00	24	0.191	0.138
9/6/2017	9:15	31	0.260	0.197
9/6/2017	9:15	31	0.278	0.197
9/21/2017	8:30	23	0.164	0.133
10/4/2017	9:15	14	0.141	0.117
RC1.8	Indian Creek at Kimball Rd, Caldwell			
3/31/2017	11:25	35	0.324	0.241
4/4/2017	11:30	61	0.410	0.305
4/11/2017	11:45	53	0.371	0.310
4/19/2017	11:40	43	0.392	0.280
4/26/2017	11:30	35	0.303	0.230
5/3/2017	11:20	31	0.166	0.089
5/11/2017	9:14	39	0.473	0.361
5/18/2017	10:40	53	0.547	0.437
5/24/2017	8:50	59	0.304	0.180

5/30/2017	9:50	50	0.421	0.296
6/7/2017	13:10	39	0.367	0.286
6/15/2017	10:00	39	0.336	0.255
6/21/2017	10:00	38	0.489	0.392
6/27/2017	9:20	52	0.416	0.352
7/3/2017	10:10	47	0.238	0.153
7/10/2017	14:30	47	0.436	0.364
7/17/2017	12:25	63	0.509	0.338
7/25/2017	11:00	50	0.473	0.416
8/9/2017	10:50	30	0.511	0.401
8/14/2017	9:45	32	0.687	0.533
8/21/2017	11:15	21	0.425	0.376
8/28/2017	10:35	25	0.442	0.438
9/6/2017	12:20	23	0.368	0.362
9/11/2017	11:22	24	0.345	0.325
9/21/2017	11:25	24	0.256	0.240
9/25/2017	9:55	21	0.289	0.229
10/4/2017	11:40	14	0.252	0.251
10/11/2017	10:30	13	0.335	0.303
RC8.1	West End Drain near Greenleaf			
3/31/2017	9:45	124	0.317	0.112
4/4/2017	10:25	168	0.251	0.050
4/11/2017	10:00	122	0.194	0.360
4/19/2017	9:55	103	0.194	0.051
4/26/2017	10:30	74	0.143	0.029
5/3/2017	9:55	88	0.233	0.054
5/11/2017	8:10	155	0.374	0.076
5/18/2017	9:50	85	0.203	0.090
5/24/2017	7:45	197	0.419	0.072
5/30/2017	9:12	197	0.435	0.085
6/7/2017	12:00	174	0.356	0.092
6/15/2017	8:20	360	0.444	0.072
6/21/2017	9:05	1980	2.390	0.068
6/27/2017	8:00	497	0.347	0.103
7/3/2017	9:30	2260	2.510	0.087
7/10/2017	13:55	475	0.623	0.113
7/17/2017	10:25	281	0.560	0.105
7/25/2017	10:05	268	0.436	0.118
8/9/2017	9:20	165	0.328	0.100

8/14/2017	8:25	724	0.453	0.097
8/21/2017	9:35	94	0.271	0.091
8/28/2017	9:10	143	0.290	0.103
9/6/2017	10:50	63	0.223	0.087
9/11/2017	9:47	95	0.244	0.075
9/21/2017	10:05	42	0.127	0.080
9/25/2017	9:10	28	0.130	0.060
10/4/2017	10:15	34	0.134	0.060
10/11/2017	9:20	40	0.166	0.075

2017 Quality Control Data Analysis

		Laboratory Analysis			Data QC		
Date	**Time**	**Ortho PO4 (mg/L)**	**Total PO4 (mg/L)**	**TSS (mg/L)**	**Ortho PO4 (mg/L)**	**Total PO4 (mg/L)**	**TSS (mg/L)**
RC0.0	Riverside Canal Diversion at Boise River						
4/11/2017	11:00	0.042	0.079	9	0.003	0.001	0
		0.039	0.080	9	7.1%	1.3%	0.0%
7/17/2017	11:30	0.021	0.043	7	0.005	0.006	0
		0.026	0.049	7	23.8%	14.0%	0.0%
RC9.0	Riverside Canal at Dixie Spill						
6/15/2017	7:30	0.248	0.403	95	0.003	0.029	4
		0.251	0.432	91	1.2%	7.2%	4.2%
8/9/2017	8:50	0.246	0.407	86	0.005	0.015	12
		0.241	0.392	98	2.0%	3.7%	14.0%
RC18.7	Riverside Canal at Dutton Spill						
5/18/2017	8:45	0.334	0.478	90	0.012	0.006	11
		0.322	0.472	101	3.6%	1.3%	12.2%
RC23.8	Riverside Canal at Holly Spill						
5/3/2017	7:40	0.081	0.328	107	0.001	0.017	15
		0.082	0.345	122	1.2%	5.2%	14.0%
5/30/2017	7:40	0.138	0.336	132	0.000	0.018	17
		0.138	0.318	115	0.0%	5.4%	12.9%
7/3/2017	7:20	0.101	0.376	177	0.000	0.036	16
		0.101	0.340	193	0.0%	9.6%	9.0%
RC30.9	Riverside End Spill to Snake River						
6/7/2017	9:40	0.162	0.234	24	0.002	0.011	2
		0.160	0.223	22	1.2%	4.7%	8.3%
9/6/2017	9:15	0.197	0.260	31	0.000	0.018	0
		0.197	0.278	31	0.0%	6.9%	0.0%

		Laboratory Analysis			Data QC		
Date	**Time**	**Ortho PO4 (mg/L)**	**Total PO4 (mg/L)**	**TSS (mg/L)**	**Ortho PO4 (mg/L)**	**Total PO4 (mg/L)**	**TSS (mg/L)**
RC1.8	Indian Creek at Kimball Rd, Caldwell						
4/4/2017	11:30	0.305	0.410	61	0.020	0.019	3
		0.285	0.391	58	6.6%	4.6%	4.9%
8/21/2017	11:15	0.376	0.425	21	0.000	0.017	0
		0.376	0.442	21	0.0%	4.0%	0.0%
RC8.1	West End Drain above Riverside Canal						
3/31/2017	9:45	0.112	0.317	124	0.001	0.005	3
		0.111	0.312	127	0.9%	1.6%	2.4%
6/27/2017	8:00	0.103	0.347	497	0.001	0.069	77
		0.102	0.416	420	1.0%	19.9%	15.5%
9/21/2017	10:05	0.080	0.127	42	0.000	0.007	9
		0.080	0.134	33	0.0%	5.5%	21.4%

Water Quality Boundary Conditions Adjustment

Preliminary Modeled TP concentration (red line) at RC9.1 shows model results with measured TP data boundary conditions (Figure B1) compared to adjusted TP boundary conditions (Figure B2).

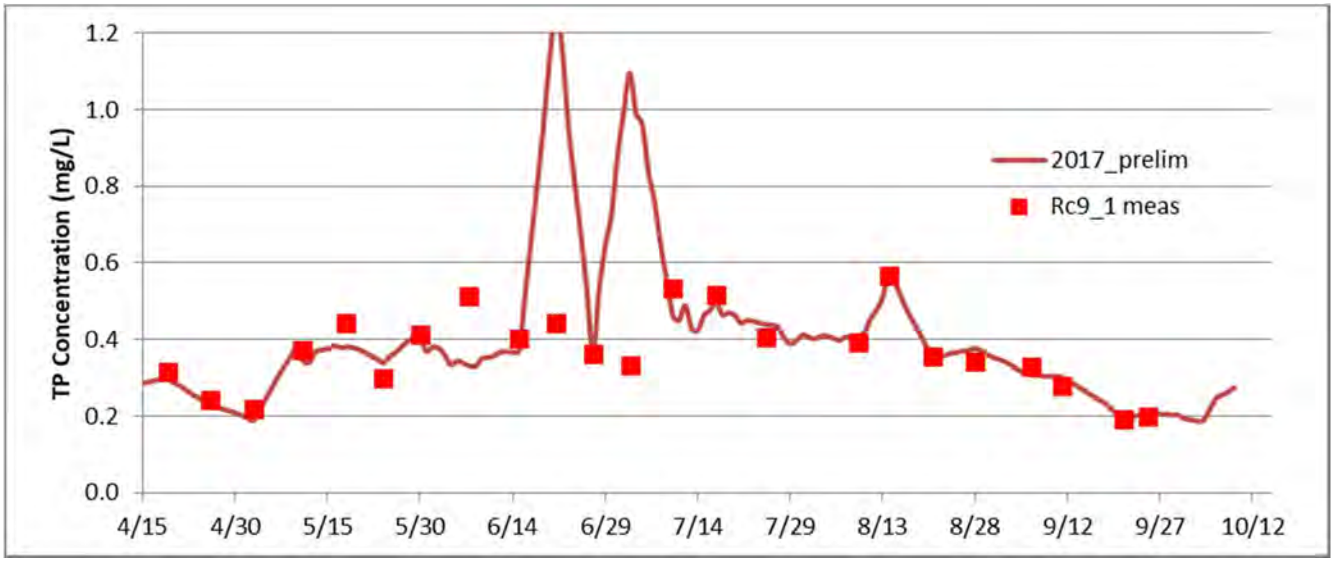

Figure B1 Preliminary Modeled (2017 prelim) with measured water quality boundary conditions and measured (R9.1) total phosphorus concentration.

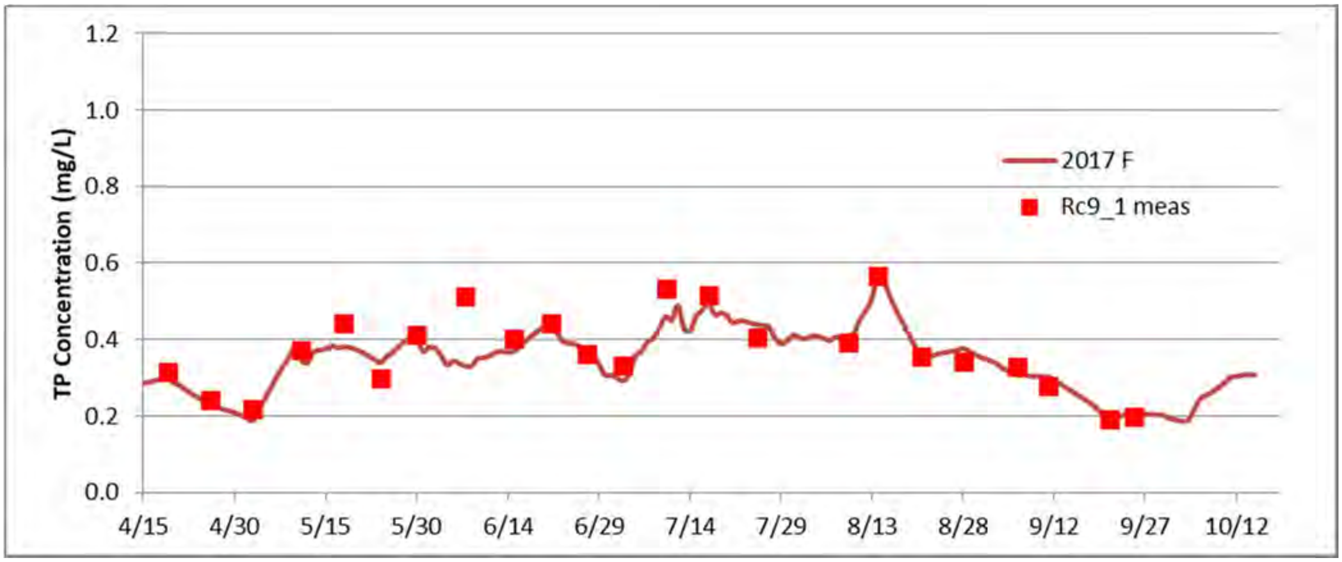

Figure B2 Final modeled (2017F) with “Adjusted” water quality boundary conditions and measured (RC9.1) total phosphorus concentration.

Total Phosphorus Concentration Error

Total phosphorus concentration error based on final model and measured data at RC9.1

Date	Mean Error

	Arithmetic	**Absolute**
4/19/2017	-0.017	0.017
4/26/2017	-0.014	0.014
5/3/2017	-0.031	0.031
5/11/2017	-0.027	0.027
5/18/2017	-0.061	0.061
5/24/2017	0.042	0.042
5/30/2017	-0.011	0.011
6/7/2017	-0.181	0.181
6/15/2017	-0.033	0.033
6/21/2017	-0.001	0.001
6/27/2017	-0.001	0.001
7/3/2017	-0.038	0.038
7/10/2017	-0.074	0.074
7/17/2017	-0.018	0.018
7/25/2017	0.032	0.032
8/9/2017	0.017	0.017
8/14/2017	0.010	0.010
8/21/2017	-0.005	0.005
8/28/2017	0.036	0.036
9/6/2017	-0.023	0.023
9/11/2017	0.024	0.024
9/21/2017	0.111	0.111
9/25/2017	0.014	0.014
10/4/2017	0.006	0.006
10/11/2017	0.049	0.049

Average	-0.008	0.035
Percent avg	-0.09%	0.39%

Exhibit 7.2-8

Evaluation of upstream phosphorus reductions— Riverside operational water-quality improvement project reasonable assurance

Evaluation of Upstream Phosphorus Reductions

Riverside Operational Water-Quality Improvement Project Reasonable Assurance

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1. INTRODUCTION

The Snake River–Hells Canyon total maximum daily load (SR–HC TMDL) assigned Idaho Power Company (IPC) a dissolved oxygen (DO) load allocation of 1,125 tons per year to the transition zone and metalimnion of Brownlee Reservoir (IDEQ and ODEQ 2004). The Brownlee Reservoir annual DO load allocation, as stated in the SR–HC TMDL is as follows:

> The dissolved oxygen allocation requires the addition of 1,125 tons of oxygen (1.02×10^6 kg) into the metalimnion and transition zone of Brownlee Reservoir (approximately 17.3 tons/day (15,727 kg/day)).

The SR–HC TMDL specifically allows IPC to use total phosphorus (TP) and organic matter reductions to satisfy the DO load allocation. As stated in the SR–HC TMDL, the use of equivalent reductions for meeting the DO load allocation is described as follows:

> This load allocation does not require direct oxygenation of the metalimnetic and transition zone waters. It can be accomplished through equivalent reductions in total phosphorus or organic matter upstream, or other appropriate mechanism that can be shown to result in the required improvement of dissolved oxygen in the metalimnion and transition zones to the extent required.

The Riverside Operational Water-Quality Improvement Project (ROWQIP), as described in Section 7.2.1. of the Hells Canyon Complex (HCC) *Clean Water Act of 1972* (CWA) § 401 certification application (IPC 2017), hereafter referred to as the HCC § 401 application, is the mechanism proposed to meet IPC's 1,125 tons per year DO load allocation assigned to the transition zone and metalimnion of Brownlee Reservoir. Early implementation of the ROWQIP began in 2010, and the project has since demonstrated the ability to meet IPC's DO load allocation annually through a proposed phosphorus-reduction equivalency of 15,000 pounds (lbs). IPC is proposing the Grand View Sediment Reduction Program and removal of aquatic vegetation and debris at the Swan Falls hydroelectric project (Swan Falls project) as reasonable assurance for the ROWQIP.

Sediment caused by the erosion of Idaho's croplands is the greatest nonpoint source pollutant to Idaho's surface waters (Mahler et al. 2003). Erosion of sediments from cropland and deposition of these sediments in the Snake River is a root cause of degradation. Sediment deposition in Snake River substrate prevents oxygen exchange between the water column and the interstitial substrate environment, provides a medium for macrophyte establishment, and reduces hyporheic exchange (Groves and Chandler 2005). Channel aggradation is exacerbated by sediment. Cropland erosion also results in phosphorus loading to the Snake River. Furrow-irrigated agriculture is known to cause considerable amounts of cropland erosion. The Grand View Sediment Reduction Program is an IPC incentive program offered to growers near Grand View, Idaho, to convert from furrow to pressurized irrigation. The benefit is improved upland soil retention and, therefore, less sediment erosion to the Snake River.

IPC removes aquatic vegetation and debris from the Snake River at the Swan Falls project. Material is disposed of in a location where it cannot return to the river. Removal of this material results in downstream decreases in floating or submerged organic matter, excess nutrients, and oxygen-demanding material.

The Grand View Sediment Reduction Program is not proposed in the HCC § 401 application (IPC 2017) as a measure to address a SR-HC TMDL load allocation nor is removal of aquatic vegetation and debris at the Swan Falls project a compliance measure for certification. Further, these activities were initiated after EPA approval of the SR HC TMDL, therefore, associated phosphorus reductions represents improvements toward SR-HC TMDL targets. This allows IPC to use their benefits toward reasonable assurance of measures proposed in the HCC § 401 application. Specifically, phosphorus and organic matter reductions resulting from the Grand View Sediment Reduction Program and aquatic vegetation and debris removal will be used to provide reasonable assurance for meeting IPC's SR-HC TMDL DO load allocation.

2. EVALUATION OF UPSTREAM PHOSPHORUS REDUCTIONS

2.1. Grand View Sediment Reduction Program

The Grand View Sediment Reduction Program targets furrow-irrigated lands located within the Grand View Irrigation District (Figure 1). Research projects were initiated in 2015 and have been completed on 14 projects totaling over 1,700 acres. Full implementation is expected to occur within 10 years of HCC license issuance.

2.1.1. Drain and Tributary Phosphorus Loading

In 2013, IPC conducted a study to quantify pollutant loads contributed by drains and tributaries to the Snake River in southwest Idaho near Grand View (Knight 2014). The study documented and sampled 27 drains and tributaries between the C.J. Strike Reservoir outflow and near the inflow to Swan Falls Reservoir.

The Grand View Sediment Reduction Program has specifically identified furrow-irrigated lands located on the south side of the Snake River for program inclusion. For this evaluation, drain and tributary data obtained from the 2013 study were limited to the program area. The study was conducted between March 27 and October 30, 2013. For purposes of this analysis, data were limited to those collected between April 17 and October 17, 2013. This period is analogous to the April 15 to October 15, 183-day typical growing season as described in the ROWQIP.

Pollutant load estimates indicated drains and tributaries targeted for inclusion in the Grand View Sediment Reduction Program cumulatively contributed average TP and total suspended solids (TSS) loads of 95 and 70,946 lbs per day, respectively (Table 1). When extrapolated over a 183-day typical growing season, the resulting TP and TSS loads contributed 17,374 and 12,983,101 lbs per year, respectively.

2.1.2. *Surface Irrigation Soil Loss Model Development, Verification, and Use for Evaluating Phosphorus Reductions*

The Surface Irrigation Soil Loss (SISL) model, a version of the Universal Soil Loss Equation, was developed by the Idaho National Resources Conservation Service (NRCS) to estimate irrigation-induced soil loss (i.e., sediment) from furrow-irrigated fields. The model was developed using data from southern Idaho and is used by Idaho NRCS to assess benefits of conservation practices (NRCS 2003). Bjorneberg et al. (2007) evaluated the performance of the SISL model and reported the model predicted the relative effects of conservation practices reasonably well; however, the absolute differences between measured and predicted soil loss were sometimes large and biased toward underprediction of measured soil loss. This suggests that any error in modeled loads would likely result in conservative load reduction estimates.

With reasonable performance demonstrated in southern Idaho, IPC, in consultation with The Freshwater Trust, selected the SISL model to evaluate sediment reductions to the Snake River resulting from the Grand View Sediment Reduction Program. Modeling included only furrow-irrigated acres, as observed from satellite imagery, for potential conversion to pressurized irrigation. All furrow-irrigated fields were mapped and delineated with publicly available data on soils, slope, crop data, and irrigation practices. Crop data from 2005 to 2014 (excluding 2006) were used to populate the SISL model. IPC believes the 9 years of crop data represents typical rotations and, therefore, represents average annual sediment loss. The SISL model does not represent a growing season duration, however, represents a defined number of crop category-specific flood irrigation events that occur in a growing season. Further, it was unknown whether specific fields were siphon or gated-pipe irrigated; therefore, both irrigation methods were modeled, and the average of the 2 was considered to represent the average annual sediment loss.

Cumulative drain and tributary load estimates derived from measured data collected during the 2103 study were compared to program-wide SISL model sediment loss estimates to assess the feasibility of using model predictions to evaluate sediment reduction as implementation occurs. SISL is a soil-loss model. Data indicate TSS measured in south-side drains and tributaries is dominated by the inorganic (i.e., sediment) component. As such, TSS and sediment are considered analogous for purposes of this analysis.

2.1.2.1. Total Suspended Solids

Measured TSS data and SISL model sediment loss resulted in annual sediment loads of 12,983,101 and 21,474,000 lbs per year, respectively, for all south-side drains and tributaries combined (Table 2). The between-estimate discrepancy is expected, and much of the difference can likely be explained when the following factors are considered.

- Not all drains and tributaries were sampled. Sampling was limited due to 1) the timing of sample events, 2) inaccessibility, and 3) private ownership. This resulted in a conservative estimate of TSS loads delivered to the river.

- Measured-data load estimates were developed using samples collected at the point of inflow to the river; whereas the SISL model estimates sediment loss at the edge of the field. Therefore, sediment stored between the edge of the field and the river was not captured in measured data.

- Measured data represent finer-particle suspended sediment only. Therefore, larger-particle unsuspended sediment is not represented in measured data.

Considering the factors above, it was determined the sediment loss estimate produced by the SISL model is a reasonable approximation of the sediment load delivered to the Snake River by drains and tributaries. The coarse validation of the modeled sediment load estimate supports the use of the SISL model for estimating load reductions resulting from the Grand View Sediment Reduction Program.

Many factors (e.g., wetted radius, application rate, uniformity of application, sprinkler pressure, localized differences in field slope, application of erosion controls, such as polyacrylamide) contribute to determining if, or how much, runoff might occur under sprinkler irrigation (Klocke et al. 1996; Aase et al. 1998). Many of these are accounted for in the SISL model and sediment loss should be reduced to almost zero and be negligible when pressurized irrigation systems are used properly. Nevertheless, IPC applied an additional margin of safety to the model results. SISL model sediment loss estimates were reduced to 90% to address any concerns regarding the effectiveness of pressurized irrigation in reducing sediment loss (i.e., pressurized irrigation will reduce sediment loss by 90%). The resulting annual sediment load reduction estimate produced by the SISL model and adjusted to 90% is 19,326,600 lbs per year (Table 2). The goal of the Grand View Sediment Reduction Program is 80% conversion of furrow-irrigated acres to pressurized irrigation. This further reduces the annual sediment load reduction estimate produced by the SISL model to 15,461,280 lbs per year.

2.1.2.2. Total Phosphorus

Following an evaluation of SISL model sediment loss, results were converted to a TP load. Regression results for all south-side drains and tributaries combined indicated there are 1.56 lbs of TP associated with each ton of TSS (Figure 2). This calculated TP:TSS ratio (1.56 lbs:1 ton) falls within reported literature values that generally range from 0.8 lbs:1 ton to 2.8 lbs:1 ton (NRCS 2015; Mullins 2009; Mahler et al. 1996). SISL model sediment loss was then converted to TP using the ratio described above.

Measured data for all south-side drains and tributaries combined and SISL model predictions resulted in annual TP load estimates of 17,374 and 16,750 lbs per year, respectively. TP load estimates were very similar compared to the TSS estimates. Two factors that likely contribute to the relative difference between TSS and TP load estimates produced with measured data and the SISL model include the following:

- The regression analysis indicates the TP:TSS ratio is considerably higher than 1.56 lbs TP:1 ton TSS, and that a few data points with considerably lower ratios skewed the regression equation to a lower ratio than what was observed in most of drains and tributaries (Figure 2).

- The TP:TSS ratio was likely higher in suspended sediments represented in the measured data relative to unsuspended sediment. The suspended fraction of the sediment load is generally represented by finer clays and silts with increased TP absorptive capacity relative to larger particles not represented in the measured data.

The close agreement between measured data and modeled TP load estimates supports using the SISL model to evaluate TP load reductions resulting from the Grand View Sediment Reduction Program. Further, TP load estimates produced by the SISL model are less than those produced using measured data, which did not include data from all drains and tributaries in the modeled area, suggesting the SISL model may yield conservative estimates of load reductions resulting from the Grand View Sediment Reduction Program. The Grand View Sediment Reduction Program assumes a 90% efficiency and targets 80% of the furrow-irrigated lands for conversion to sprinklers. The potential Grand View Sediment Reduction Program annual TP load reduction is 12,060 lbs per year.

2.2. Aquatic Vegetation and Debris Removal

IPC has been removing aquatic vegetation and debris that accumulates on the trash rake over the intake turbines at the Swan Falls project since October 2011. IPC proposed continued operation as part of the project final license application. Idaho Department of Environmental Quality (IDEQ) acknowledged the proposed action in the CWA § 401 certification for the project but did not make it a condition of the certification necessary to ensure compliance with Idaho water quality standards. Since IPC proposed continued operation as part of the license application, Federal Energy Regulatory Commission included the action in the license issued September 28, 2012. Article 404 requires IPC remove aquatic vegetation and debris that accumulates on the trash rake and dispose of the material in a location where it cannot return to the Snake River.

IPC has removed 56–417 truckloads of material from the Snake River annually between April 15 and October 15 and disposed of the material in a location where it cannot return to the river (Table 3). IPC weighed 8 truckloads from June through September 2014 to estimate a wet weight of material removed from the river. The average truckload of material weighed 14,019 lbs. This material was then converted to TP using a value of 489.2 milligrams TP per kilogram of wet weight. This value is based on 2002-2003 laboratory results of TP concentrations measured in wet material collected upstream at IPC's Upper Salmon Falls "B" hydroelectric project. IPC estimates that annually 1,547 lbs TP is removed from the Snake River through aquatic vegetation and debris removal at the Swan Falls project.

3. DOWNSTREAM TRANSPORT OF PHOSPHORUS

Snake River phosphorus data were reviewed to evaluate trends in TP transport through the river. The data were collected between 2003 and 2006 and describe conditions in the Snake River at Swan Falls Reservoir inflow, Swan Falls Reservoir outflow, and at Celebration Park (Figure 3). This river reach and locations were used to evaluate TP transport due to the following:

- minimal sources of phosphorus to the reach;

- best available data applicable to the evaluation; and
- represents TP transport in both Swan Falls Reservoir (14.5 miles) and a free-flowing section downstream (10 miles).

Concentration data were analyzed to evaluate between-location differences. Mean TP concentrations from 2003 to 2006 varied between locations within a year (Table 4), however, median concentrations were not statistically different ($P>0.050$) when using a Kruskal-Wallis one-way analysis of variance on ranks. This test was used due to the non-normal distribution of data. The lack of statistical difference in median TP concentrations between upstream and downstream locations indicates TP is not being appreciably retained within a year either in Swan Falls Reservoir or in a riverine reach of the Snake River. The between location variability may be attributable to the following:

- the timing and duration of sample collection, which may have been biased toward conditions of export;
- sample collection at Swan Falls Reservoir inflow occurring in an unmixed location relative to upstream contributions;
- in-reservoir load contributions from 2 minor tributary sources (Castle Creek and Sinker Creek); and
- processes related to TP uptake and release by macrophytes and algae.

USGS (2016) identifies 3 approaches to estimate reach-scale nutrient attenuation. Mass–balance is the preferred method when there are minimal surface and groundwater contributions within the evaluated reach. The mass–balance method of estimating nutrient attenuation does not consider adsorption, uptake, and remineralization processes. However, phosphorus is a conservative constituent that remains in the system regardless of phase. As such, results obtained using the mass–balance method can be used to describe TP transport within the evaluated reach. The intent of this evaluation is to generally describe TP attenuation, and how it is transported downstream to Brownlee Reservoir. Given that Snake River hydraulics are similar between the evaluated reach and Brownlee Reservoir, it is reasonable to suggest transport dynamics are similar as well.

While load data indicate minimal, if any, long-term storage of TP occurs, some level of short-term storage and subsequent export is likely dictated by streamflow conditions. Naymik and Hoovestol (2008) reported that when Swan Falls Reservoir inflow and outflow loads were evaluated on an annual basis, TP was slightly retained in 2003 and 2004 (4% and 2%, respectively) with low streamflow. A small amount of export occurred in 2005 (6%) under conditions of slightly higher flows. Export was highest in 2006 (27%) and was associated with the highest annual flows among evaluated years. The export observed in 2006 may have been related to unaccounted for in-reservoir tributary loading resulting from rain and snowmelt events. Seasonal trends are discernible in plots of the data (Figure 4). These findings are generally consistent with those reported in the literature. Wetzel (2001) reported that in a stream dominated by particulate phosphorus, no annual net retention of phosphorus occurred, but transport dynamics included short periods of storage with export occurring during pulses in streamflow. Similar findings representing differing stream types have been reported by others (Nyenje et al. 2014; Ensign et al. 2006).

Naymik and Hoovestol (2008) evaluated monthly loads at both the Swan Falls Reservoir inflow and outflow locations using FLUX, a water-quality analysis software developed by the U.S. Army Corps of Engineers. FLUX Method 2 was used to generate interpolated daily phosphorus concentrations, and the average daily streamflow was applied to generate daily loads. Daily loads were summed to generate monthly phosphorus loads for 2005 (Figure 5) and 2006 (Figure 6). Seasonal pulses of export are evident in both years, with most of the export occurring between April and May. This period of export is associated with marked increases in streamflow (Figure 7). An additional description of seasonal phosphorus storage and export trends within Swan Falls Reservoir is provided by Naymik and Hoovestol (2008) as reported in the Swan Falls project license application (IPC 2008).

Naymik and Hoovestol (2008) determined that pulses in streamflow were the primary mechanism by which phosphorus was transported from Swan Falls Reservoir. These findings, along with an independent analysis of data and a literature review, suggest the primary factor affecting Snake River TP transport dynamics is streamflow, where particulate phosphorus is deposited during low-flow conditions and exported during streamflow pulses. Myers et al. (1998) reported similar phosphorus transport dynamics in a free-flowing section of the Snake River between Swan Falls Dam and Brownlee Reservoir in 1995. They concluded that increased flows preceded by low-flow conditions resulted in mobilization and transport of sediments and associated phosphorus. Based on the period of record, Naymik and Hoovestol (2008) reported that flows measured below Swan Falls Reservoir (USGS gage #13172500) during their 2003-2006 study were generally biased toward low flows, representing conditions when storage would be more likely to occur.

Swan Falls Reservoir inflow and outflow loads reported by Naymik and Hoovestol (2008) were compared to 1912 through 2017 Snake River flows near Murphy, Idaho, to determine the occurrence frequency of flows that facilitate downstream transport of TP (Figure 8). In 2003 and 2004, when minimal storage occurred, average annual flows were in the 99th percentile of historically low flows, indicating that flows equal or greater to these occur 99% of the time. The small amount of downstream export that was observed in 2005 was associated with an average annual flow that is exceeded 93% of the time. This indicates that flows of required magnitude to facilitate downstream transport of TP are likely to occur in approximately 14 out 15 years. These findings support the concept that TP is functionally transported through the evaluated reach at about a 1:1 ratio on an annual basis even during low water years, when storage might otherwise be expected.

Based on this analysis, and in the absence of water storage reservoirs between Swan Falls Reservoir and Brownlee Reservoir, it is reasonable to suggest similar transport dynamics exist within the extent of river between C. J. Strike Reservoir and the inflow to Brownlee Reservoir. Therefore, reductions in TP loading to the Snake River resulting from the Grand View Sediment Reduction Program and Swan Falls project aquatic vegetation and debris removal translate to reduced TP loading to, and reduced oxygen demand within, Brownlee Reservoir.

The growth, transport, and subsequent deposition and decay of organic material in Brownlee Reservoir are not limited to temporal periods identified in the SR-HC TMDL. If phosphorus reductions equivalent to 1,125 tons of DO occur within the May to September SR-HC TMDL critical period, the oxygen benefits would likely not be fully realized due to the deposition of organic material in the transition zone that occurs during periods outside the critical period. Therefore, it is logical that upstream nutrient reductions occurring outside this period would contribute to improved DO conditions within Brownlee Reservoir for the May to September critical period.

4. TRANSLATING PHOSPHORUS TO OXYGEN

Phosphorus, oxygen, and organic matter can be related by inorganic stoichiometry, which varies in response to environmental conditions (Sterner and Elser 2002). IPC has proposed the use of stoichiometric ratios based on those reported in the literature and with consideration for what might typically apply within the Snake River and Brownlee Reservoir environments (Table 5). The proposed stoichiometry, as used to establish a TP-DO equivalency for the ROWQIP by Harrison et al. (2014), indicates a phosphorus reduction of approximately 15,000 lbs annually is needed for IPC to satisfy the assigned DO load allocation of 1,125 tons (Table 6). Additional support for the stoichiometric logic used to derive the TP-DO equivalent is provided in Exhibit 7.2-2 of the HCC §401 application (Harrison et al. 2014).

As described in Section 2.1.2.2., the SISL model phosphorus load reduction estimate resulting from full implementation of the Grand View Sediment Reduction Program is 12,060 lbs per year. The phosphorus reduction from Swan Falls project aquatic vegetation and debris removal (Section 2.2.) is 1,547 lbs per year. Stoichiometric relationships indicate this cumulative level of TP reduction translates to an DO demand reduction of 1,021 tons per year within the transition zone and metalimnion of Brownlee Reservoir (Table 6).

5. ADDITIONAL BENEFITS OF UPSTREAM PHOSPHORUS REDUCTIONS

IPC believes reducing TP loading to the Snake River addresses a core issue underlying DO demand and generally degraded water-quality conditions within the Snake River and Brownlee Reservoir rather than using direct aeration, or a similar reservoir-specific measure, to meet IPC's SR-HC TMDL DO load allocation within Brownlee Reservoir. Upstream TP reductions will not only contribute to improving in-reservoir DO conditions but will also provide in-river benefits that contribute to supporting beneficial uses. Improvements in water quality conditions are likely to include, but are not limited to, the following:

- increased hyporheic exchange;
- reduction of habitat that contributes to mercury methylation;
- reduction of near-substrate anoxia;

- dampening of diel DO swings; and
- reduced algal and aquatic plant growth.

6. CONCLUSIONS

- TP reductions resulting from the Grand View Sediment Reduction Program and the Swan Falls project aquatic vegetation and debris removal would result in 13,607 lbs TP reductions annually from April 15 through October 15.
- IPC has demonstrated minimal annual storage of TP within the Snake River indicating about a 1:1 ratio of TP transport in most years. IPC concludes that upstream phosphorus loads are functionally transported through the Snake River into Brownlee Reservoir.
- IPC concludes that upstream phosphorus reductions achieved through implementation of the Grand View Sediment Reduction Program and the Swan Falls project aquatic vegetation and debris removal translates to reduced loading to, and reduced oxygen demand within Brownlee Reservoir.
- These reductions would be equivalent to 1,021 tons of DO within the transition zone and metalimnion of Brownlee Reservoir. Therefore, the Grand View Sediment Reduction Program and Swan Falls project aquatic vegetation and debris removal provide reasonable assurance that IPC’s DO load allocation within the transition zone and metalimnion of Brownlee Reservoir will be met.
- Grand View Sediment Reduction Program research projects were initiated in 2015 and have been completed on 14 projects totaling over 1,700 acres. Full implementation is expected to occur within 10 years of HCC license issuance. IPC will continue to remove aquatic vegetation and debris at the Swan Falls project at least through 2042.

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Table 1
2013 drain and tributary load summary. Summary limited to drains and tributaries located on the south-side of the Snake River identified for inclusion in the Grand View Sediment Reduction Program. Loads were calculated using data collected from April 17, 2013, to October 17, 2013, and represent daily and seasonal loads for a typical 183-day growing season.

		Average Daily Loads (kg/day)		
Drain RM*	**River Position**	**Orthophosphorus**	**TP**	**TSS**
476.3	Left Bank	1.17	2.25	657
476.8	Left Bank	0.11	0.29	156
477	Left Bank	0.20	7.67	11,633
477.5	Left Bank	0.13	1.78	1,239
477.55	Left Bank	0.09	2.29	1,519
477.7	Left Bank	0.01	0.14	563
478	Left Bank	0.10	1.61	1,043
478.1	Left Bank	0.49	2.38	1,312
478.9	Left Bank	1.56	6.14	4,272
479.1	Left Bank	1.02	1.37	179
479.7	Left Bank	0.01	0.36	387
479.9	Left Bank	0.08	1.20	1,017
480.1	Left Bank	0.29	0.64	166
483.1	Left Bank	0.46	2.04	1,212
485.3	Left Bank	2.33	3.22	738
486.5	Left Bank	0.32	0.35	33
490.4	Left Bank	4.00	9.33	6,054
Cumulative Average Daily Load (kg/day)		**12**	**43**	**32,181**
Cumulative Average Daily Load (lbs/day)		**27**	**95**	**70,946**
Total Seasonal Load (lbs/day*183 days)		**4,988**	**17,374**	**12,983,101**

* Site location described in Snake River miles at point of inflow to river

Table 2
Summary of sediment annual load estimates derived from measured data and produced by the SISL model from full implementation of the Grand View Sediment Reduction Program.

	Load Estimate (lbs/year)	
	Measured Data	**SISL**
Sediment	12,983,101	21,474,000
Load Reduction Efficiency (total*90%)		19,326,600*
Load Reduction at Program Buildout (90% adjusted load*80%)		15,461,280**

* Reflects conservative assumption of 90% efficiency from pressurized irrigation.

** Reflects program load reduction potential at full implementation based on 80% conversion of furrow-irrigated acres in the program area.

Table 3
Number of truckloads of aquatic vegetation and debris removed at the Swan Falls project annually between April 15 and October 15 and the resulting TP removed from the Snake River.

	Number of Truckloads	**TP (lbs)**
2012	56	384
2013	227	1,557
2014	417	2,860
2015	308	2,112
2016	209	1,433
2017	136	933
	Average	1,547

Table 4
Snake River TP samples collected, mean, standard deviation, and median concentration from 2003 to 2006 at Swan Falls Reservoir inflow (Inflow), Swan Falls Reservoir outflow (Outflow), Celebration Park.

	Count	Mean	Standard Deviation	Median
2003				
Inflow	17	0.081	0.063	0.067
Outflow	17	0.080	0.017	0.076
Celebration Park	17	0.074	0.015	0.071
2004				
Inflow	23	0.078	0.021	0.076
Outflow	23	0.083	0.020	0.078
Celebration Park	23	0.088	0.020	0.081
2005				
Inflow	25	0.072	0.015	0.070
Outflow	25	0.079	0.025	0.074
Celebration Park	25	0.080	0.032	0.068
2006				
Inflow	20	0.077	0.022	0.070
Outflow	20	0.093	0.038	0.076
Celebration Park	20	0.089	0.026	0.082

Table 5
TP, DO, and organic matter (OM) stoichiometric ratios.

Stoichiometry or Load	W2	Brwn '02	Brwn '95	SR '95	Proposed
TP/OM	0.005	0.01	0.01	0.02	0.01
DO/OM	1.4	1.7	1.4	1.4	1.5
TP/DO	0.36%	0.59%	0.71%	1.43%	0.67%

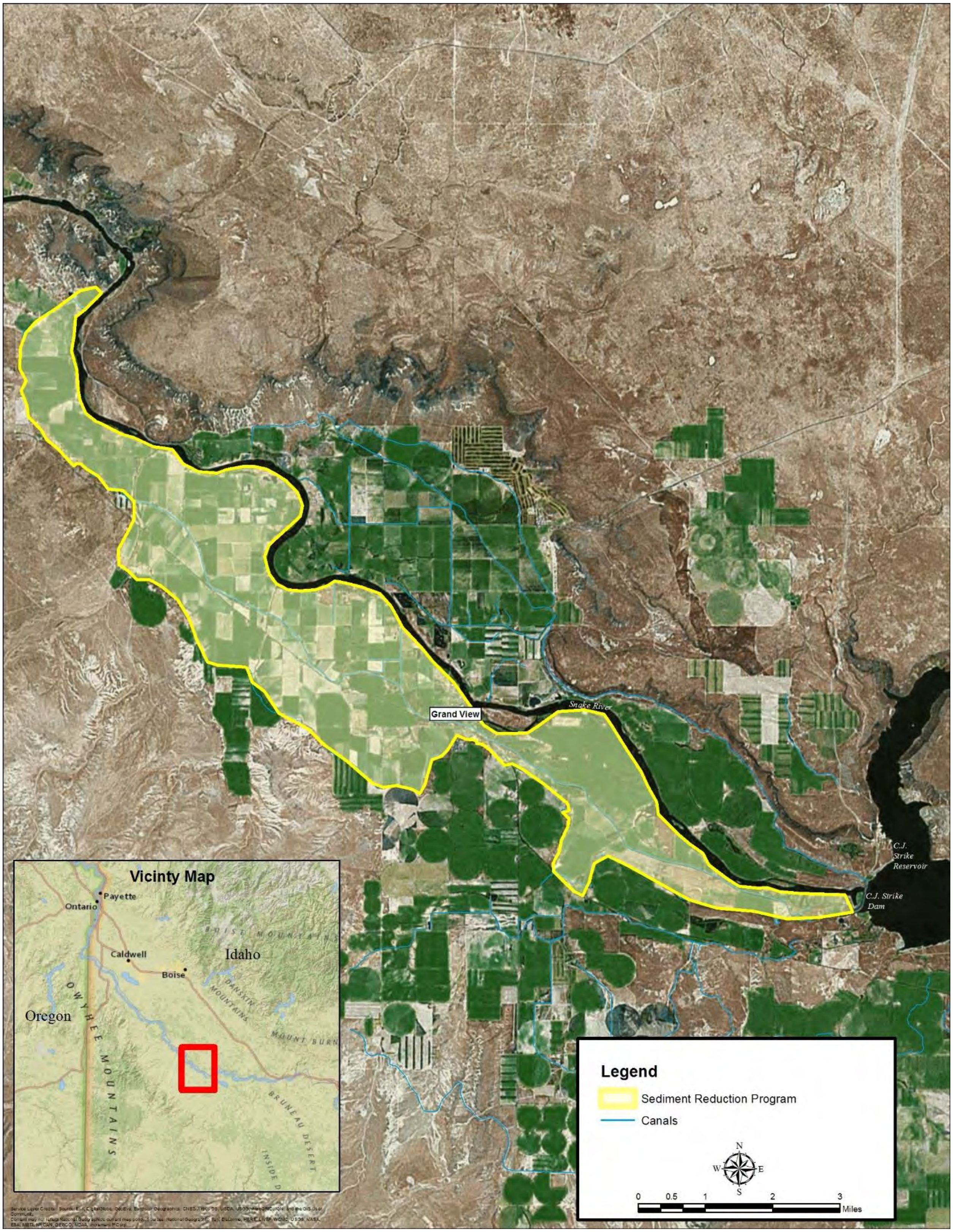
***Notes:** Ratios obtained from Harrison et al., 2014
W2: Stoichiometry are modeled default values per Cole and Wells 2002.
Brwn ’95: Stoichiometry are optimized model values used in the 1995 Brownlee model application.
SR ’95: Stoichiometry are optimized model values used in the 1995 Snake River model application.
Brwn ’02: Based on data collected in upper end of reservoir.
Proposed: Recommended for conversion of DO allocation to TP reduction.

Table 6
IPC DO load allocation per SR–HC TMDL, with conversion to TP equivalent using stoichiometric ratios proposed by IPC. TP load reduction with OM and DO equivalents resulting from the Grand View Sediment Reduction Program and Swan Falls project.

TMDL	**Annual Load**
DO Load Allocation per SR-HC TMDL (tons/yr)	1,125
OM Load Allocation Equivalent (tons/yr)	750
TP Load Allocation Equivalent (tons/yr)	7.5
TP Load Allocation Equivalent (lbs/yr)	15,000
Grand View Sediment Reduction Program	**Annual Load**
TP Reduction via SISL (lbs/yr)	12,060
TP Reduction via SISL (tons/yr)	6.03
OM Reduction Equivalent (tons/yr)	603
DO Demand Reduction Equivalent (tons/yr)	905
Swan Falls project aquatic vegetation and debris removal	**Annual Load**
TP Reduction (lbs/yr)	1,547
TP Reduction (tons/yr)	0.77
OM Reduction Equivalent (tons/yr)	77
DO Demand Reduction Equivalent (tons/yr)	116

Example TP to DO equivalent calculation method:

- TP lbs to tons: 12,060 lbs TP/(2,000 lbs/1 ton) = **6.03 tons TP/yr**
- TP tons to OM tons: 6.03 tons TP/0.01 TP:OM ratio = **603 tons OM/yr**
- OM tons to DO tons: 603 tons OM/1.5 DO:OM ratio = **905 tons DO/yr**



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Figure 1
Grand View Sediment Reduction Program area map

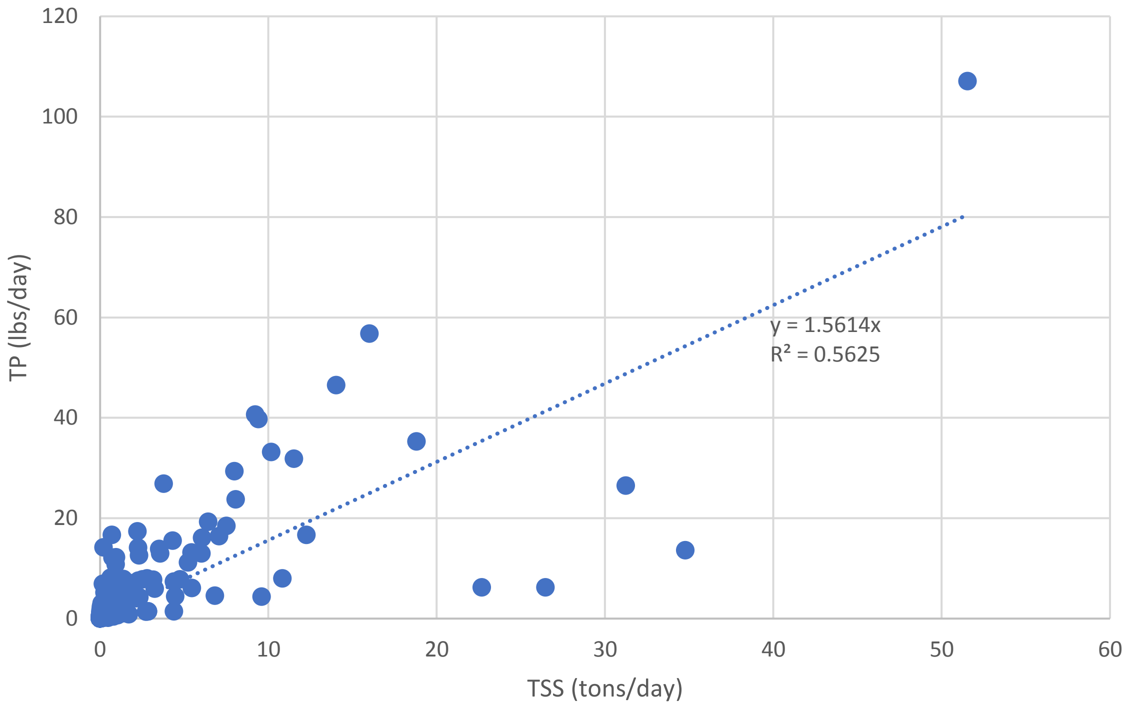


Figure 2
TP and TSS regression analysis for south-side drains and tributaries. Analysis indicates there are 1.56 lbs of phosphorus per ton of TSS.

Figure 3
Sampling location map. From left to right, sampling locations are at Celebration Park (river mile [RM] 447.6), Swan Falls Reservoir outflow (RM 457.6), and Swan Falls Reservoir inflow (RM 472.0).

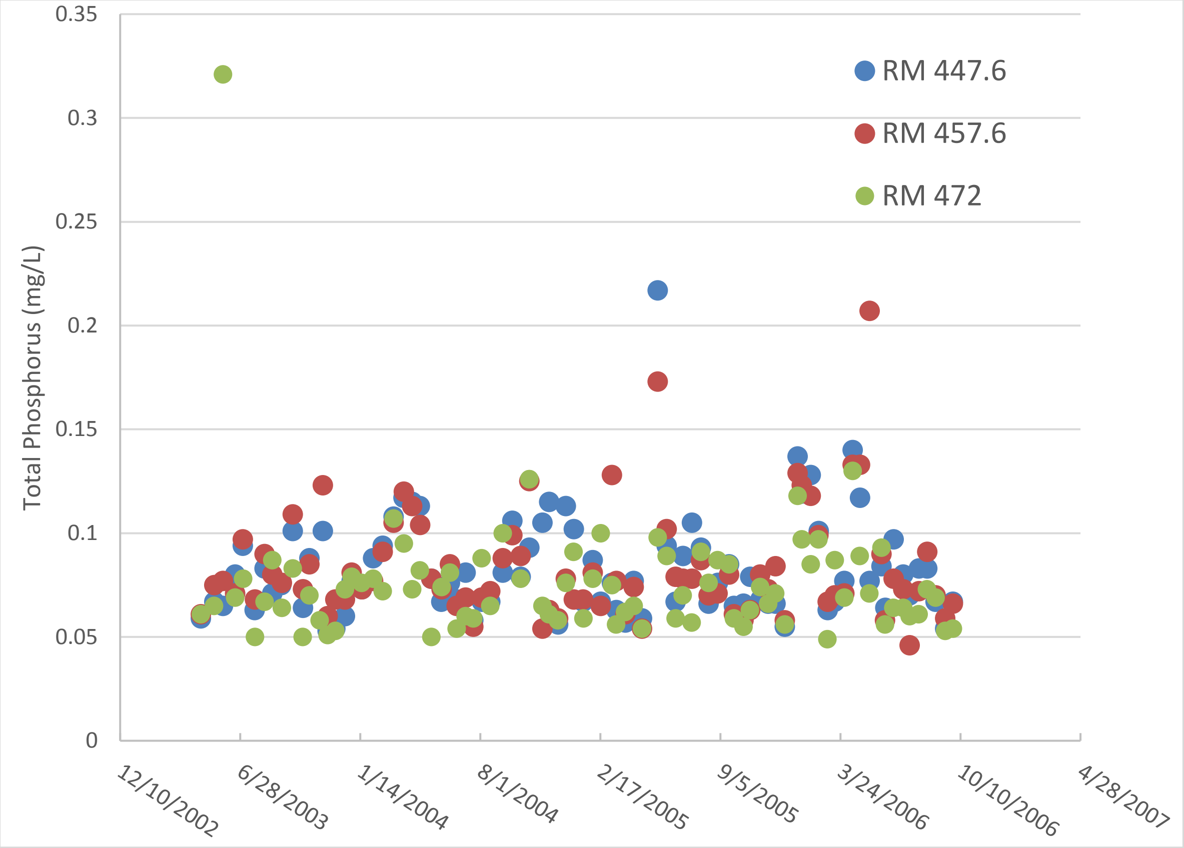


Figure 4
Snake River TP concentrations at Swan Falls Reservoir inflow (river mile [RM] 472.0), Swan Falls Reservoir outflow (RM 457.6), and Celebration Park (RM 447.6).

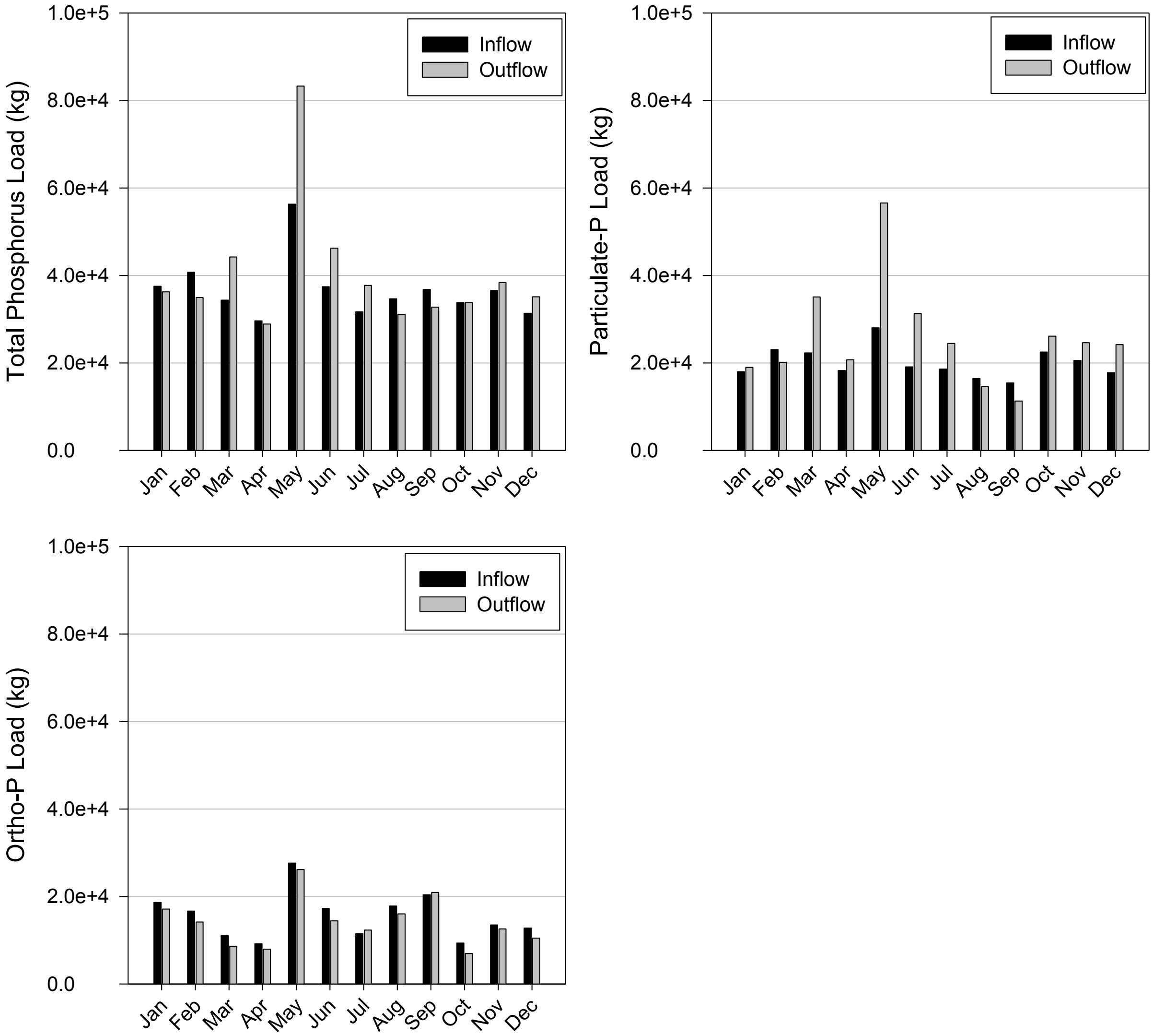


Figure 5
Monthly 2005 total, orthophosphorus, and particulate phosphorus loads. Note: Estimated phosphorus loads from drains and tributaries are not included in plots (Naymik and Hoovestol 2008).

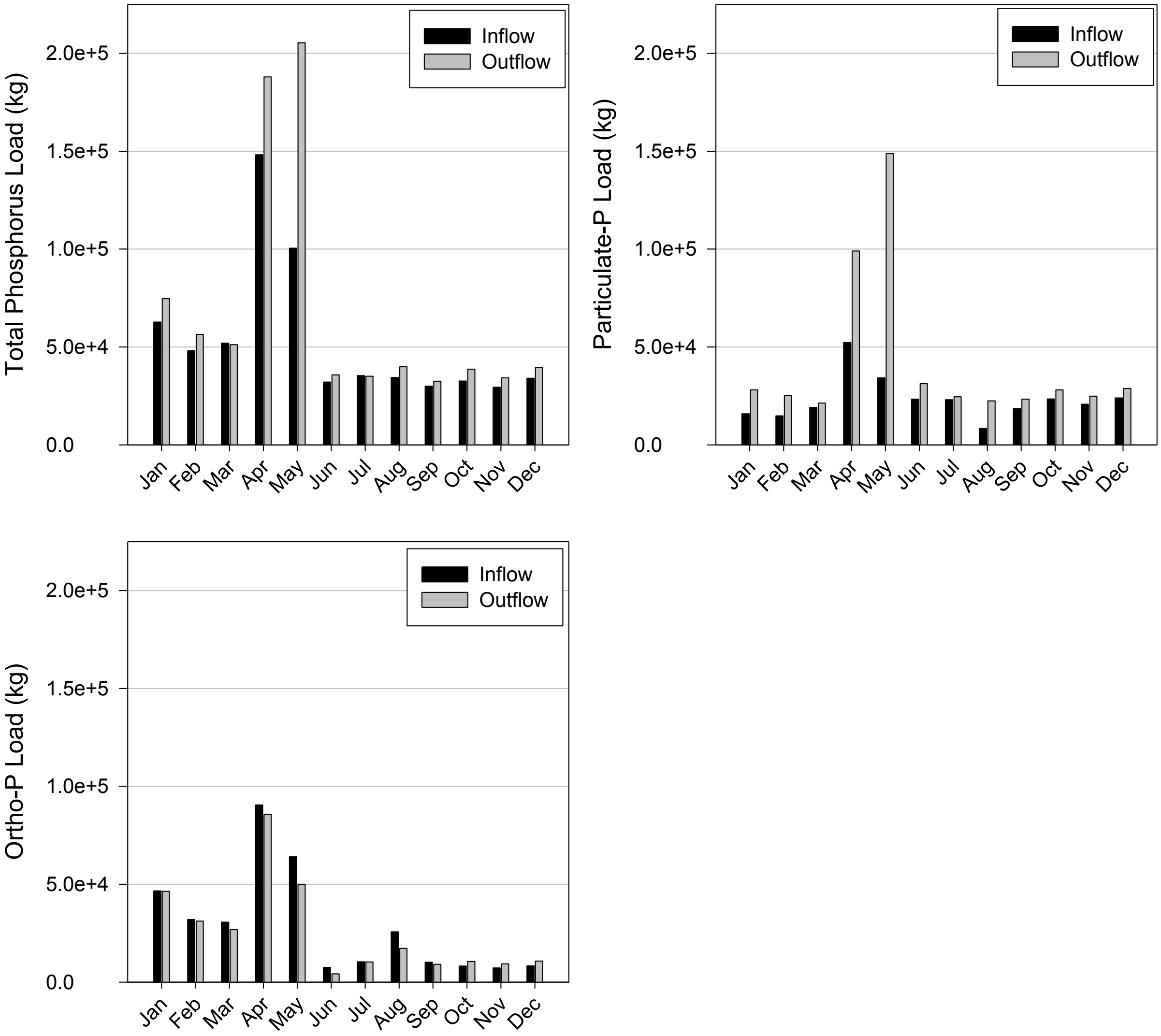


Figure 6
Monthly 2006 total, orthophosphorus, and particulate phosphorus loads. Note: Estimated annual TP loads from drains and tributaries are not included in these plots (Naymik and Hoovestol 2008).

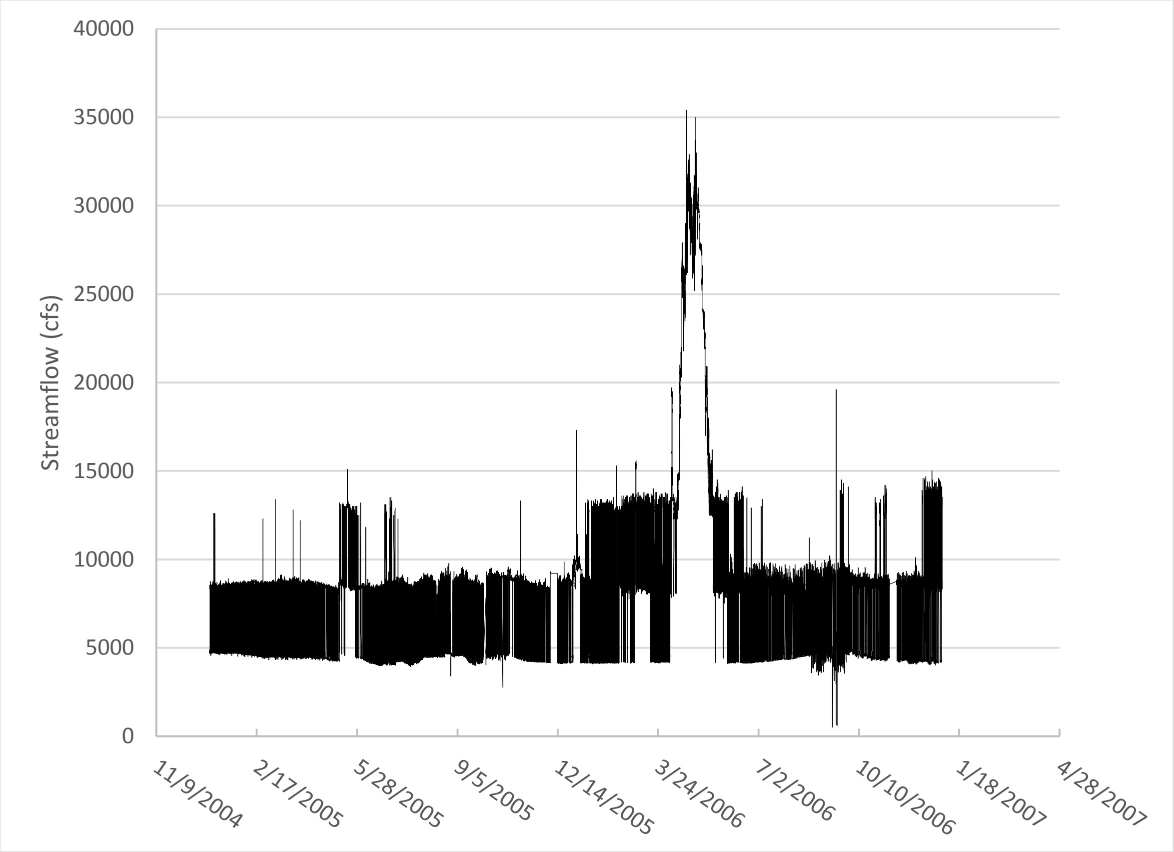


Figure 7
2005 and 2006 streamflow below C.J. Strike Reservoir.

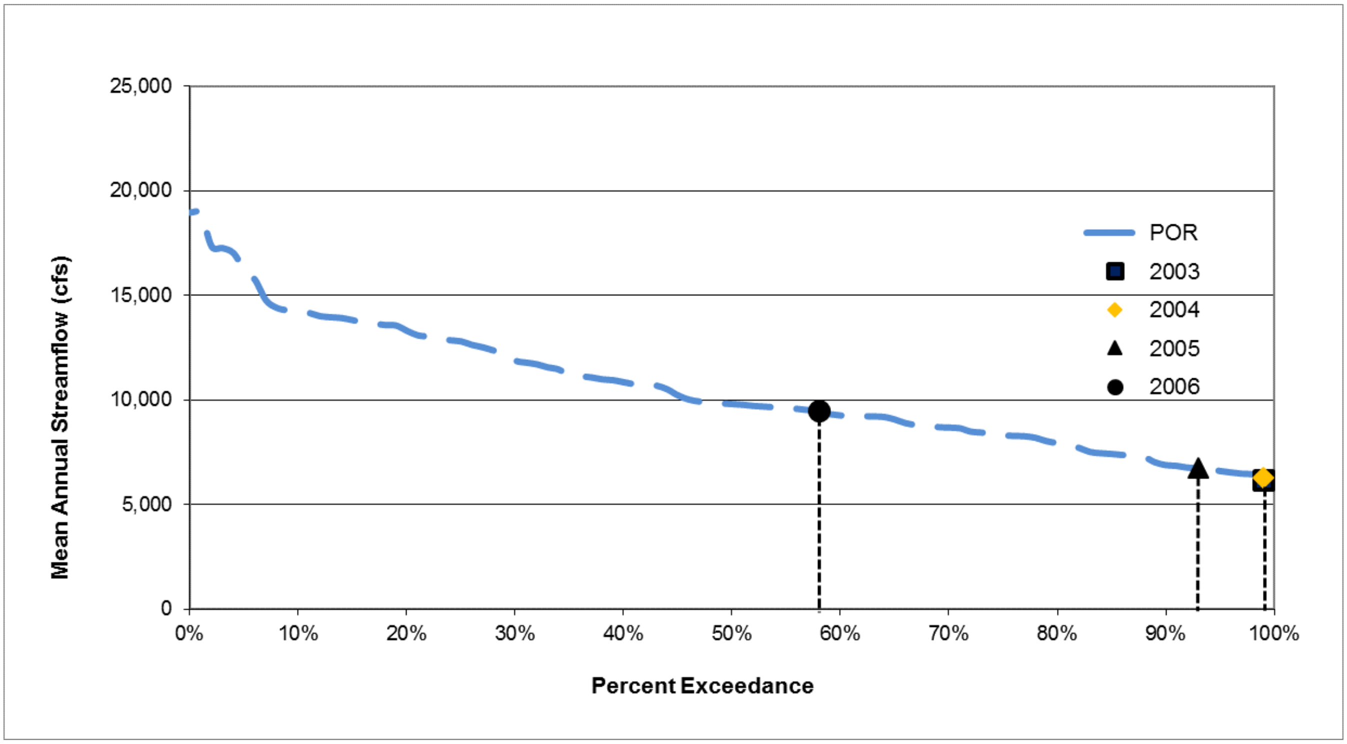


Figure 8
1912 through 2017 Snake River near Murphy, Idaho, period of record (POR) average annual flow exceedance curve. Streamflow percent exceedance for 2003 through 2006 average annual flows.

Exhibit 7.2-9
Brownlee Dam: dissolved oxygen enhancement report

VOITH	Idaho Power Company (IPC)	
Brownlee Dam: Dissolved Oxygen Enhancement Report	**BRWN-TEN60-0201**	
	PDM Name 2TEN60-0201-240742	**Rev.** A

Brownlee Dam: Dissolved Oxygen Enhancement Report

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Rev. Index	Page N°	Description	Executed by:	Approved by:	Date:
A		Revision to include TDG calculation results	foustj	YOR_RDON	12/05/2013
B					
C					

Execution OU:	**Executed by:**		**Checked by:**		**Approved by:**		**Date:**
VHEC	Name Jason Foust	Sign. foustj	Name Rich Donelson	Sign. YOR_RDON	Name Rich Donelson	Sign. YOR_RDON	**Issue Date** **12/03/2013**

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1.0 Introduction

Idaho Power Company's (IPC) Brownlee Dam is located on the Snake River between Idaho and Oregon, and together with the Hells Canyon and Oxbow Dams, make up the Hells Canyon Complex. During the warmer months of late summer, Brownlee is subject to low dissolved oxygen levels in the water discharging into the tailrace. At times, these dissolved oxygen levels can fall below 2 mg/l. To mitigate these low tailrace dissolved oxygen levels, Voith Hydro has designed four 4.8 meter inlet diameter (D1a) replacement Francis runners for the plant that provide distributed aeration from the blade discharge edges during turbine operation. Note that the distributed aeration at Brownlee will draw air into the turbines naturally (without the use of a supplemental compressor or blower) for the tailwater range specified by IPC. Details of the expected aeration characteristics of the replacement runners are provided in the current report, including:

(1) Predicted maximum air flow vs. turbine discharge through the modified turbine for tailwater levels at Elevations 1801.0 Ft (minimum), 1805.0 ft (normal average) and 1808.0 ft (maximum during periods of expected aeration requirements) at Net Heads of 274.0 ft, 250.0 ft, 235.0 ft and 204.0 ft respectively.

(2) Documentation of air friction loss analysis through the proposed modified turbine and all components (i.e., piping, valves) for predicted air flows.

(3) Documentation of predicted dissolved oxygen increase in the turbine discharge for the design basis inlet level of 0 mg/l and 2 mg/l, with a temperature of 23.0° given the current configuration of the Brownlee station/turbines and predicted maximum air flows.

(4) Predicted turbine efficiency curves with maximum air flow added to the turbine discharge for tailwater levels at Elevations of 1801.0 ft (minimum), 1805.0 ft (normal average) and 1808.0 ft (maximum) at Net Heads of 274.0 ft, 250.0 ft, 235.0 ft and 204.0 ft.

Over the past two decades, Voith Hydro has gained extensive experience with the auto-venting technique of distributed aeration for improving tailrace water quality. During this time, Voith has studied distributed aeration over a wide range of applications, turbine operation and site conditions (Foust et al. 2008). These investigations have aided in the development of in-house aeration prediction tools that are used to evaluate aeration capabilities and develop custom aeration solutions that meet specified water quality requirements. In the following sections, a general description of distributed aeration is provided, including the driving factors for aeration performance and the link with local flow characteristics at the air inlet locations within the water passage. This discussion will then be used as a basis to substantiate the distributed aeration predictions for Brownlee Dam.

2.0 Turbine Aeration Overview

Francis turbine operation often leads to the development of sub-atmospheric pressures immediately downstream of the runner. If available, these low pressure regions can be vented to the atmosphere to create a natural flow of air into the water passage during low dissolved oxygen periods. The incorporation of atmospheric air into the turbine is known as auto-venting turbine (AVT) aeration and is a particularly cost effective method for obtaining large dissolved oxygen uptakes within the turbine discharges. Auto-venting turbine aeration generally consists of three different aeration options, including distributed, central and peripheral aeration. Each aeration methodology utilizes a unique piping system to transport air from outside the turbine to the inlet location located within the water passage. These aeration techniques, along with representative air delivery systems, is given below in Figure 1.

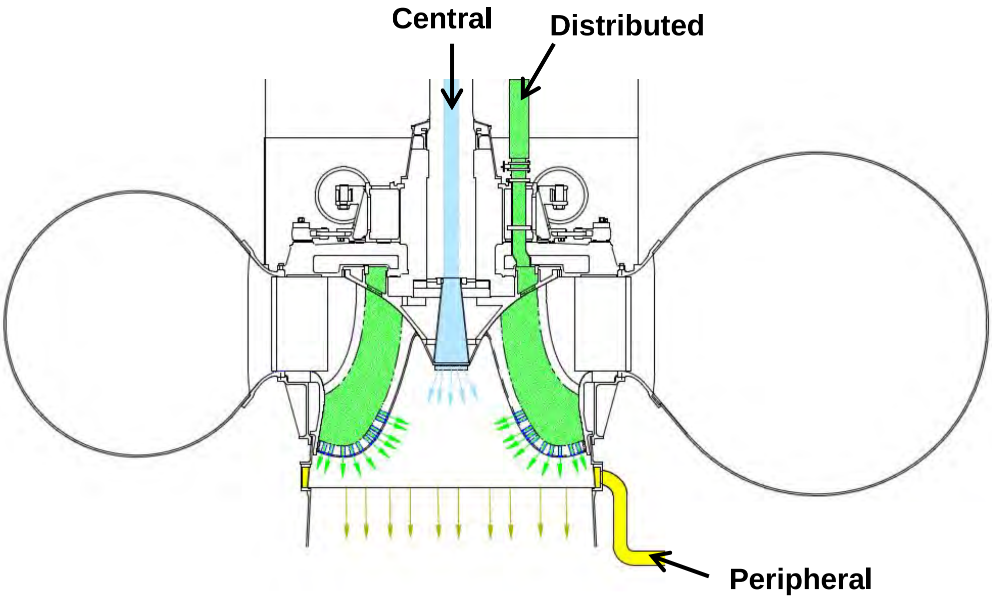


Figure 1 - Representative distributor section of a Francis turbine showing distributed (green), central shaft (blue), and peripheral (yellow) aeration.

Distributed aeration (green) draws air from several pipes positioned above the headcover (typically within the wheelpit), where it is collected in a continuous chamber above the runner crown. The air then passes into the hollow runner blades before entering the water passage through a series of slots positioned along the discharge edges of the blades. The hollow blade design is one of the keys to distributed aeration. Early versions of Voith's aerating runner featured narrow channels to transport the air from the crown to the blade trailing edges. Comparison of the air paths through the blades for the early design with those of the current concept are given below in Figure 2.

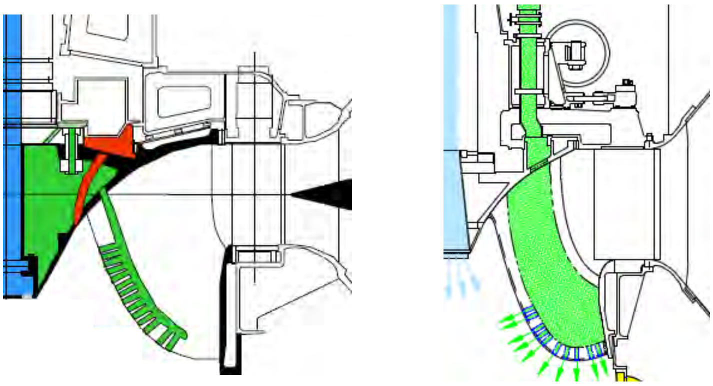
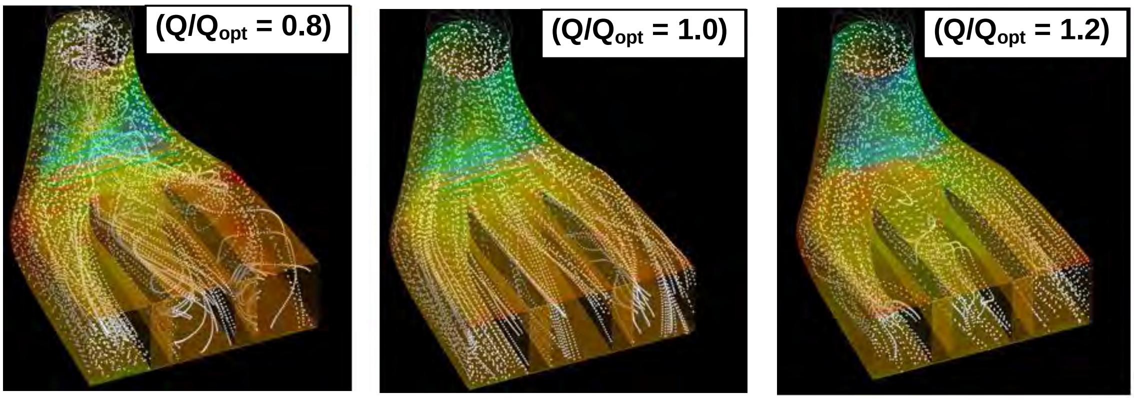

(i) (ii)

Figure 2 - Distributed aeration system showing (i) air channels of the early designs and (ii) the hollow blades of the modern design.

The channels of the early design were shown to have a significant amount of head loss that limited the air flow into the turbine. Advances in hollow blade manufacturing techniques developed at Voith over the past twenty years allow for much larger air flow paths that minimize the head loss through this portion of the distributed aeration system. During the hydraulic design of replacement runners, aeration impacts are considered, along with turbine performance, when defining the blade thickness profile and shape. To accommodate the aeration slots on the blade trailing edges, the blades feature thicker trailing edges when compared to conventional Francis turbine designs.

Central aeration (blue) transports air from the region above the headcover via the turbine shaft to one larger opening at the tip of the deflector. Peripheral aeration (yellow) occurs further downstream, near the entrance to the draft tube. Peripheral air is collected in a manifold system that distributes the flow around the outside of the water passage. Air exits the manifold through a configuration of slots or holes positioned along the inside of the draft tube cone.

Aeration starts with inducing air flow into the water passage during turbine operation. Once the air is drawn into the water passage, aeration performance depends on how well the air mixes with the surrounding water. Evenly distributed bubbles that are smaller in diameter provide a more efficient transfer of oxygen, so higher uptakes can be achieved for a given amount of air flow. These bubble distributions are influenced by (i) the aeration method and air inlet location and (ii) the operating condition when aeration is occurring. Voith has performed CFD calculations to determine the bubble distributions and overall air/water mixing that occurs during distributed aeration from the blade trailing edges across a range of turbine discharges. Illustrations of these distributions are given below in Figure 3.



Part Load **Peak (best) Efficiency** **Full Load**

Figure 3 - Calculated bubble distributions for distributed aeration at conditions of part load (left image), peak efficiency (middle image) and full load (right image).

The air inlet locations along the blade discharge edges, in combination with the rotation of the runner, create uniform bubble mixing within the draft tube across the range of discharges investigated (EPRI, 2002). The slot locations at the blade trailing edges are also characterized by high levels of shear which help to keep the incoming air bubbles small. The finer bubbles that result mix uniformly within the draft tube cone, providing enhanced mixing that facilitates the transfer of oxygen from the air to the surrounding water. Although distributed aeration is capable of producing large air flows, the efficient oxygen transfer provides more dissolved oxygen uptake with less air within the unit. These aeration characteristics are important for the Brownlee project, where the turbine setting is deep with respect to tailwater elevation. In fact, minimum tailwater elevations for the plant are only 3 ft below the distributor centerline elevation of 1804 ft.

The uniform air/water mixing is one of the key features of distributed aeration. The finer bubble sizes help to minimize the disturbances within the draft tube, keeping the turbine operating efficiencies high. Other forms of turbine aeration have a much larger impact on runner-draft tube interaction, resulting in significant turbine efficiency loss during aeration (March, 2011).

3.0 Brownlee Air Flow Predictions

Each aeration method utilizes the pressure difference across the piping system to draw air into the turbine. Ultimately, the amount of air flow that passes through the system will increase until the head losses inherent to the piping geometry match the pressure difference between outside (atmospheric) and inside of the water passage. During operation, the pressures at each of the aeration locations are influenced by the operating condition and the local flow patterns that develop within the turbine. These pressures, under non-aerating conditions, can be predicted with state-of-the-art Computational Fluid Dynamic (CFD) calculations. An illustration of the calculated pressure distributions on the water passage surfaces of the Brownlee replacement runner operating near the peak (best efficiency) load is given below in Figure 4.

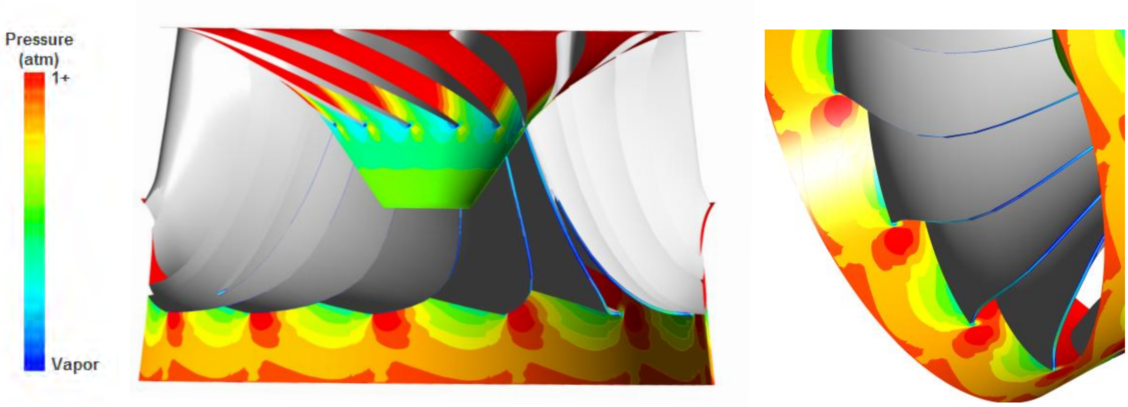


Figure 4 - Calculated pressure distributions on the water passage surfaces for the Brownlee replacement runner operating near peak (best) efficiency.

The dark blue contours illustrated in Figure 2 indicate that lower pressure regions are present along the blade discharge edges where the aeration slots are located. During the Brownlee distributed aeration investigation, static pressures were determined at flow rates corresponding to Q/Q_{opt} = 0.57, 0.62, 0.79, 0.94, 0.98, 1.02, 1.07 and 1.12 for tailwater elevations of 1801.0, 1805.0 ft and 1808.0 ft. These static pressures at the blade trailing edges are summarized in Table 1.

Turbine Discharge [cfs]	Q/Q_{opt} [-]	Predicted Static Pressures Under Non-Aerating Conditions [psia]		
		TWE = 1801.0 ft	TWE = 1805.0 ft	TWE = 1808.0 ft
3000	0.57	7.2	9.0	10.3
3300	0.62	7.8	9.5	10.8
4200	0.79	8.0	9.8	11.1
5000	0.94	7.0	8.8	10.1
5200	0.98	6.7	8.4	9.7
5430	1.02	6.2	8.0	9.3
5673	1.07	5.8	7.5	8.8
5945	1.12	5.5	7.2	8.5

Table 1 – Calculated static pressures along the trailing edges of the Brownlee replacement runner under non-aerating conditions for tailwater elevations of 1801, 1805 and 1808 ft.

For a given tailwater elevation, the static pressures generally decrease as the turbine discharges increase due to the larger fluid velocities at the slot locations. These static pressures at the air slots are also influenced by changes to tailwater elevation. As the tailwater elevation increases, the back-pressure downstream of the runner increases. The combination of larger discharges and lower tailwaters therefore corresponds to increased suction and larger air flows into the water passage.

The static pressures provided in Table 1 are calculated based on turbine discharge and tailwater elevation and are considered as independent of net head for the Brownlee project. As a result, these static pressures apply to net heads of 274.0, 250.0, 235.0 and 204.0 ft. While the air flow predictions, dissolved oxygen uptakes and total dissolved gas levels are provided in the upcoming sections for the complete turbine discharge range, note that the maximum turbine discharge does vary slightly for the different net head values. These maximum turbine discharges correspond to 5,945 cfs, 5,731 cfs, 5,673 cfs and 5,430 cfs for net heads of 274.0 ft, 250.0 ft, 235.0 ft and 204.0 ft, respectively. These maximum turbine discharges should be considered when applying the predictions for a given net head value.

While bubble size and distribution influences dissolved oxygen uptake efficiency, it also influences the pressures at the air inlet location. As the air flows into the water passage, the lower density of the air has an impact on the drawing pressures during aeration. Air bubbles that are confined to a localized region, such as the steady vortex rope for central aeration at full load (Foust et al. 2008) have a much larger effect on the local pressures when compared the more even bubble distributions of peripheral and distributed aeration. During Voith's initial distributed aerating runner development, the first prototype runners at Tennessee Valley Authority's (TVA) Norris Dam were capable of providing central, peripheral and distributed aeration separately or in combination. Pressure transducers were placed at each of the three air inlet locations and data were collected for various operating conditions and air flows for each of the aeration methods. An overview of the Norris pressure transducer locations is given below in Figure 5.

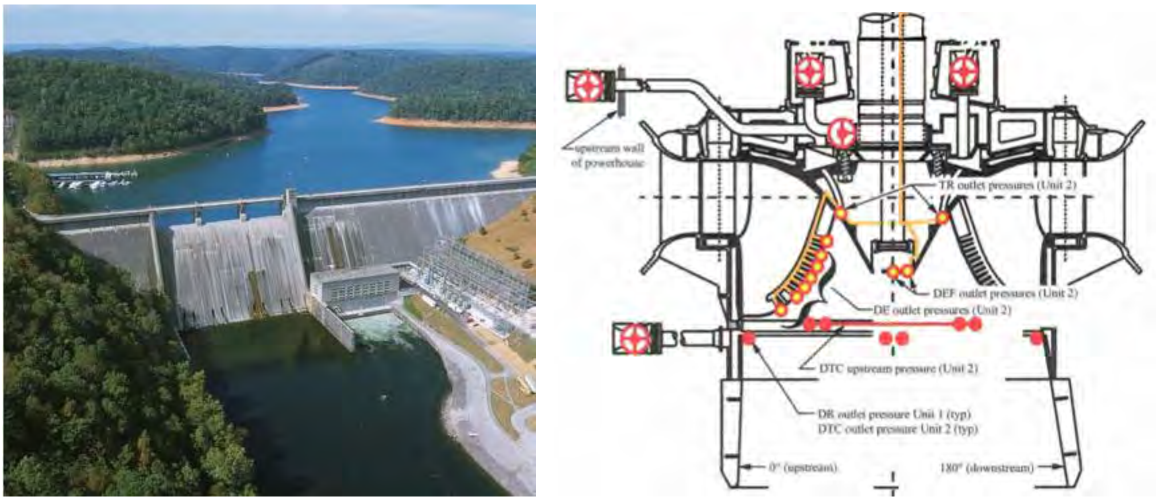


Figure 5 - Pressure transducers (red dots in right image) placed at the air inlet locations for central, peripheral and distributed aeration at Norris Dam.

Overall, distributed aeration shows the lowest impact on the drawing pressures (best condition for achieving large air flows) across the range of discharges investigated. Normalized pressure influences resulting from the two-phase flow at the slot location during distributed aeration are sh

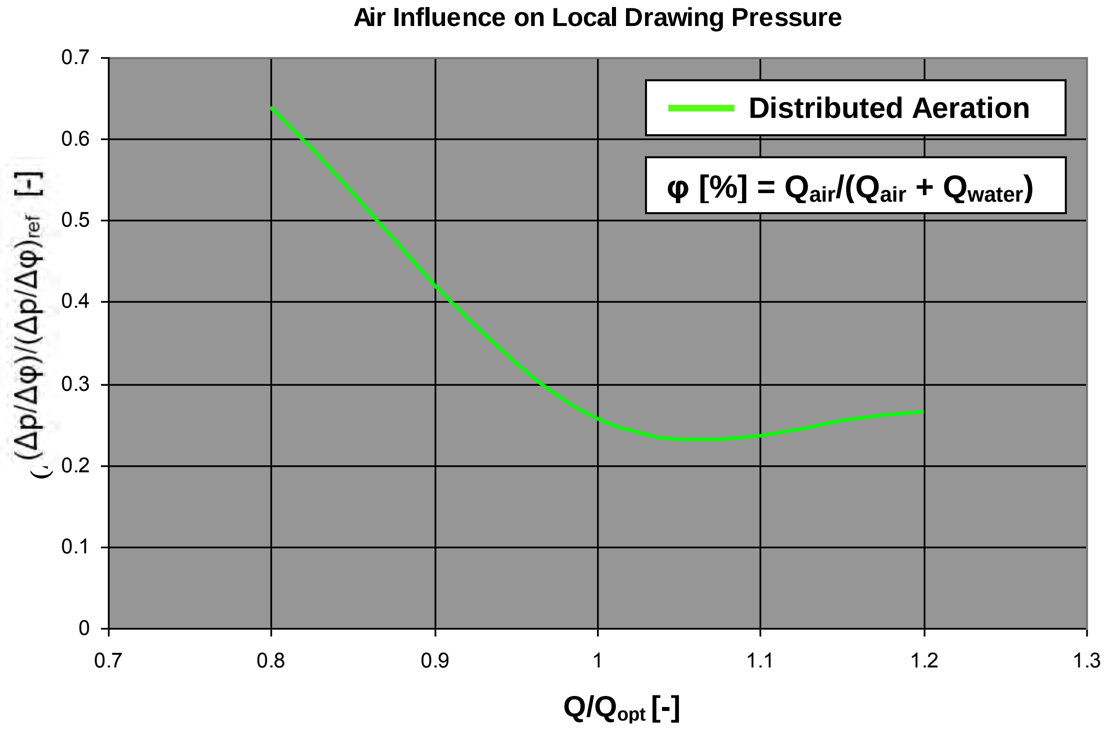


Figure 6 - Influence of air flow on inlet static pressure (Δp/Δφ) during distributed aeration.

Although the pressure change values provided in Figure 6 are normalized by a reference value, the trend in the data is clear. At smaller discharges, changes in φ have a bigger impact on local drawing pressures when compared to larger discharges. Note that φ represents the void fraction occurring during aeration and is calculated according to:

$$\varphi = Q_{air}/\left(Q_{air} + Q_{water}\right) \qquad \text{Eq. (1)}$$

This two-phase influence minimizes near the optimum discharge ($Q/Q_{opt} = 1$) for distributed aeration. Note that this factor *Δp/Δφ* is significantly smaller for the aerating runner when compared to that of the central and peripheral aeration methodologies (Foust et al. 2008).

The two-phase impacts on the local drawing pressures during aeration must be considered when making accurate air flow predictions. The Norris pressure measurements, in addition to other measurements conducted both in Voith's hydraulic laboratory and other prototype aeration installations, make up an in-house database that is used for Voith's aeration calculations.

The final step in the air flow prediction process involves adjusting the air flows so that the head losses across the piping system match the static pressure at the air inlet location (non-aerating pressures adjusted for the two-phase influence). These head losses can be categorized into two main divisions; losses caused by skin friction within the inner pipe surface, and losses related to flow patterns, i.e., separation, and component geometry. For each type of loss, a dimensionless loss coefficient K_L can be determined. The head loss for the given component is then computed by multiplying this loss coefficient by the velocity head, or $\frac{V^2}{2g}$. Here V is the average velocity through the component ($\frac{Q}{A}$), and g is the acceleration due to gravity. These losses for each component are then summed to give the total losses for the piping system, and can be expressed as

$$H_L = \frac{1}{2g}\left(\frac{Q}{A}\right)^2 \sum K_{L(i)} \qquad \text{Eq. (2)}$$

where i indicates the individual piping component.

During the Brownlee distributed aeration investigation, air flow values and the corresponding piping losses were determined for turbine discharges of Q = 3,000 cfs, 3,300 cfs, 4,200 cfs, 5,000 cfs, 5,200 cfs, 5,430 cfs, 5,673 cfs and 5,945 cfs. The Brownlee air piping will consist of five intake pipes located within the turbine wheelpit. Each intake pipe is eight inches in diameter and is comprised of a bellmouth nozzle and silencer. A butterfly value is used to regulate the air flow through each pipe. The air then collects in a chamber located above the crown before continuing into the individual blades.

As previously described, these air flow predictions are independent of net head, but the maximum turbine discharge for each head value should be considered when reviewing the current Brownlee aeration predictions. The predicted static pressures at the blade discharge edges (under non-aeration conditions) and the corresponding air flows for the aforementioned Brownlee operating conditions are given in Tables 2a (TWE = 1801.0 ft), 2b (TWE = 1805.0 ft) and 2c (TWE = 1808.0 ft).

Discharge [cfs]	Q/Q_{opt} [-]	Predicted Static Pressures Under Non-Aerating Conditions [psia]	Predicted Air Flows [scfs]	Predicted *Φ* [%]
3000	0.57	7.2	201	6.3
3300	0.62	7.8	204	5.8
4200	0.79	8.0	235	5.3
5000	0.94	7.0	275	5.2
5200	0.98	6.7	283	5.2
5430	1.02	6.2	293	5.1
5673	1.07	5.8	301	5.0
5945	1.12	5.5	308	4.9

Table 2a: Predicted Brownlee distributed air flows for TWE = 1801.0 ft

Discharge [cfs]	Q/Q_{opt} [-]	Predicted Static Pressures Under Non-Aerating Conditions [psia]	Predicted Air Flows [scfs]	Predicted *Φ* [%]
3000	0.57	9.0	168	5.3
3300	0.62	9.5	170	4.9
4200	0.79	9.8	197	4.5
5000	0.94	8.8	239	4.6
5200	0.98	8.4	250	4.6
5430	1.02	8.0	260	4.6
5673	1.07	7.5	269	4.5
5945	1.12	7.2	275	4.4

Table 2b: Predicted Brownlee distributed air flows for TWE = 1805.0 ft

Discharge [cfs]	Q/Q_{opt} [-]	Predicted Static Pressures Under Non-Aerating Conditions [psia]	Predicted Air Flows [scfs]	Predicted *Φ* [%]
3000	0.57	10.3	138	4.4
3300	0.62	10.8	139	4.0
4200	0.79	11.1	164	3.8
5000	0.94	10.1	209	4.0
5200	0.98	9.7	221	4.1
5430	1.02	9.3	233	4.1
5673	1.07	8.8	242	4.1
5945	1.12	8.5	250	4.0

Table 2c: Predicted Brownlee distributed air flows for TWE = 1808.0 ft

For the lowest tailwater elevation of 1801.0 ft, the predicted φ values generally fall between 5% and 6%. As the tailwater increases to 1805.0 ft, the range of calculated φ values drops to 5.3 % to 4.4 %. When the tailwater reaches the highest level of 1808.0 ft, φ remains near 4.0 across the majority of discharges reported.

Summaries of the calculated piping losses for each of the main components are provided in Tables 3a (TWE = 1801.0 ft), 3b (TWE = 1805.0 ft) and 3c (TWE = 1808.0 ft).

Piping Component [-]	Head loss for 201 scfs air flow [psi]	Head loss for 275 scfs air flow [psi]	Head loss for 308 scfs air flow [psi]
Bellmouth Nozzle	0.0	0.0	0.0
Muffler	0.1	0.2	0.3
Butterfly Valve	0.1	0.3	0.3
Straight Pipe	0.0	0.0	0.0
Mitre Bend	0.0	0.0	0.0
Mitre Bend	0.0	0.0	0.0
Straight Pipe	0.0	0.0	0.0
Expansion Into Air Box	0.2	0.3	0.4
Air Box	0.2	0.3	0.4
Contraction into blades	0.0	0.1	0.1
Blade	0.9	1.6	2.0
Contraction into Slot	0.6	1.0	1.3
Slot	0.4	0.7	0.8
Expansion into Draft Tube	1.1	2.1	2.6
Total	**3.6**	**6.7**	**8.4**

Table 3a: Brownlee distributed aeration piping losses for TWE = 1801.0 ft

Piping Component [-]	Head loss for 168 scfs air flow [psi]	Head loss for 250 scfs air flow [psi]	Head loss for 275 scfs air flow [psi]
Bellmouth Nozzle	0.0	0.0	0.0
Muffler	0.1	0.2	0.2
Butterfly Valve	0.1	0.2	0.3
Straight Run	0.0	0.0	0.0
Mitre Bend	0.0	0.0	0.0
Mitre Bend	0.0	0.0	0.0
Straight Pipe	0.0	0.0	0.0
Expansion Into Air Box	0.1	0.3	0.3
Air Box	0.1	0.3	0.3
Contraction into blades	0.0	0.1	0.1
Blade	0.6	1.3	1.6
Contraction into Slot	0.4	0.9	1.0
Slot	0.3	0.6	0.7
Expansion into Draft Tube	0.8	1.7	2.1
Total	**2.5**	**5.6**	**6.7**

Table 3b: Brownlee distributed aeration piping losses for TWE = 1805.0 ft

Piping Component [-]	Head loss for 138 scfs air flow [psi]	Head loss for 221 scfs air flow [psi]	Head loss for 250 scfs air flow [psi]
Bellmouth Nozzle	0.0	0.0	0.0
Muffler	0.1	0.1	0.2
Butterfly Valve	0.1	0.2	0.2
Straight Run	0.0	0.0	0.0
Mitre Bend	0.0	0.0	0.0
Mitre Bend	0.0	0.0	0.0
Straight Pipe	0.0	0.0	0.0
Expansion Into Air Box	0.1	0.2	0.3
Air Box	0.1	0.2	0.3
Contraction into blades	0.0	0.0	0.1
Blade	0.4	1.0	1.3
Contraction into Slot	0.3	0.7	0.9
Slot	0.2	0.4	0.6
Expansion into Draft Tube	0.5	1.3	1.7
Total	**1.7**	**4.3**	**5.6**

Table 3c: Brownlee distributed aeration piping losses for TWE = 1808.0 ft

4.0 Brownlee Dissolved Oxygen Uptake Predictions

Over the past decades, the topic of mass transfer within a two-phase mixture has received considerable attention and the insights gained from these investigations have been employed to develop various mass transfer models for aeration (Wuest et al., 1992; Burris and Little, 1998; McGinnis and Little, 1998; Burris et al., 2002; McGinnis and Little, 2002). One of the more recent techniques is known as Discrete Bubble Modelling (DBM) and has been successfully applied to predict dissolved oxygen during turbine aeration. As bubbles travel through the solution domain after being introduced into the water passage, the mass flux equations for oxygen and nitrogen are solved using Euler's method of numerical integration to obtain the dissolved oxygen and total dissolved gas uptake that occurs along the bubble paths (see McGinnis and Ruane (2007) for more details on the DBM). During auto-venting turbine aeration, the calculations begin at the air inlet location at the discharge edge of the runner, continue through the draft tube and finish when the bubbles reach the tailwater surface. A representation of the calculation domain is given in Figure 7.

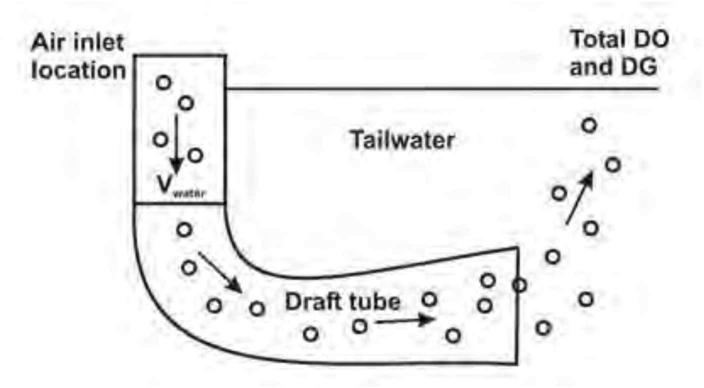


Figure 7 - *Bubble transit during turbine aeration.*

The primary model input parameters include air quantity, turbine discharge, barometric pressure, initial dissolved oxygen and nitrogen concentrations, initial bubble radius, bubble distribution, discharge temperature, turbine geometry, and tailwater elevation. At each evaluation point in the domain, local changes in pressure, bubble radius, transfer coefficients and dissolved gas are reflected in the mass transfer calculations. Once the bubbles reach the tailwater surface, final DO and total dissolved gas concentrations are determined.

Turbine geometry is a critical element of the discrete bubble model. Once the air leaves the runner, the bubble transit time is governed by the surrounding water velocities. In an effort to account for the changing water velocities within the draft tube, as well as the elevation influence on hydrostatic pressure, the draft tube geometry is incorporated into the dissolved oxygen predictions. An overview of the Brownlee draft tube area curve is given in Figure 8.

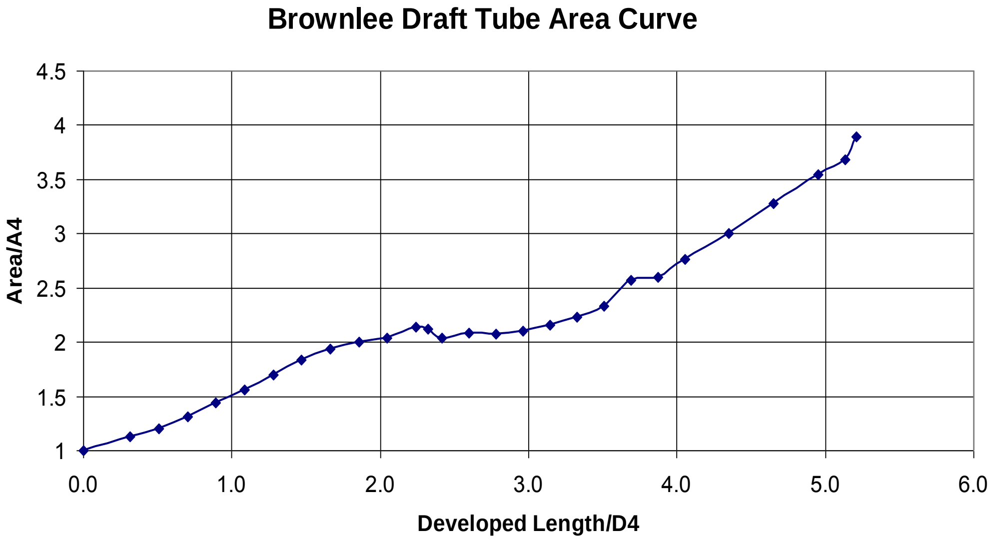
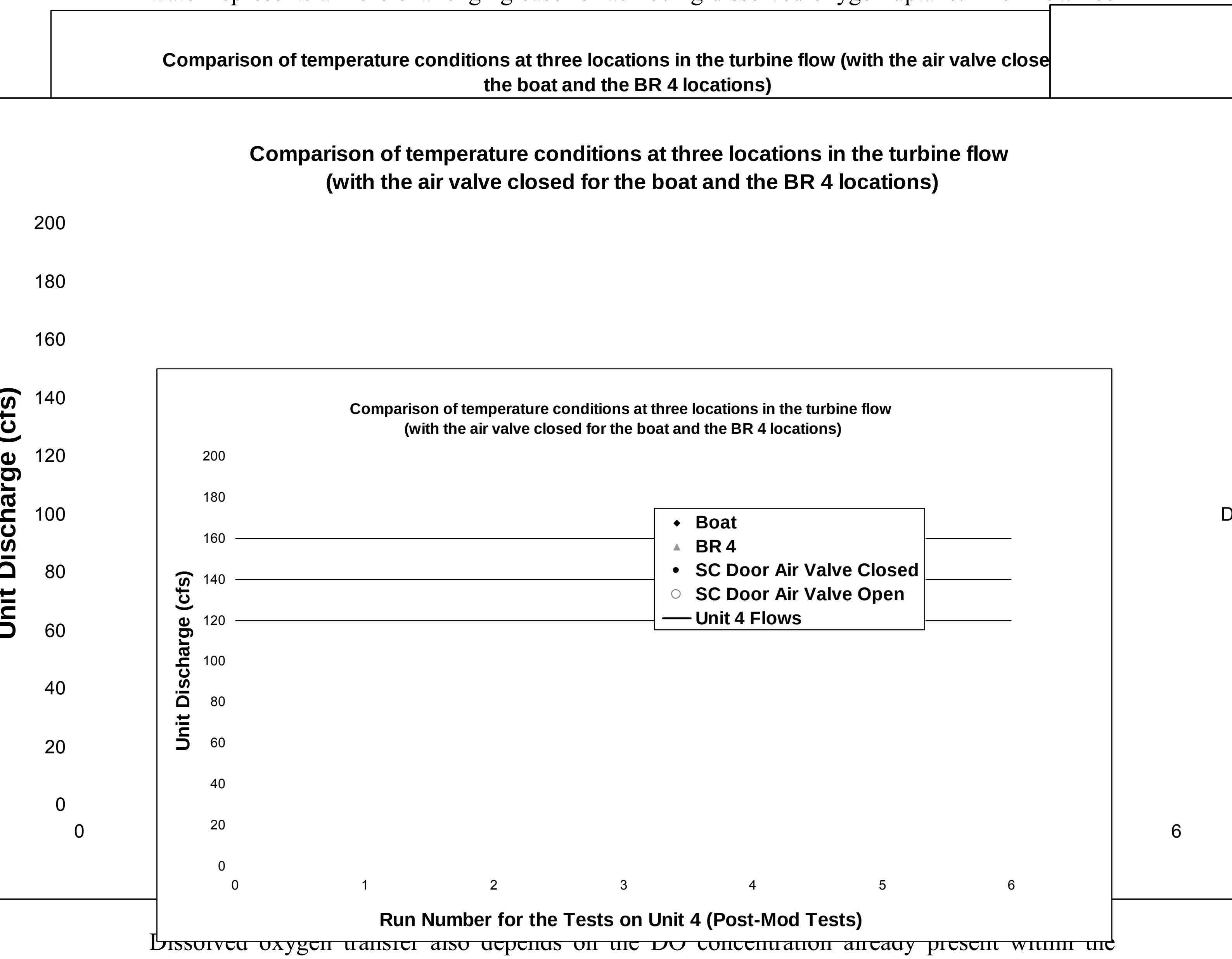
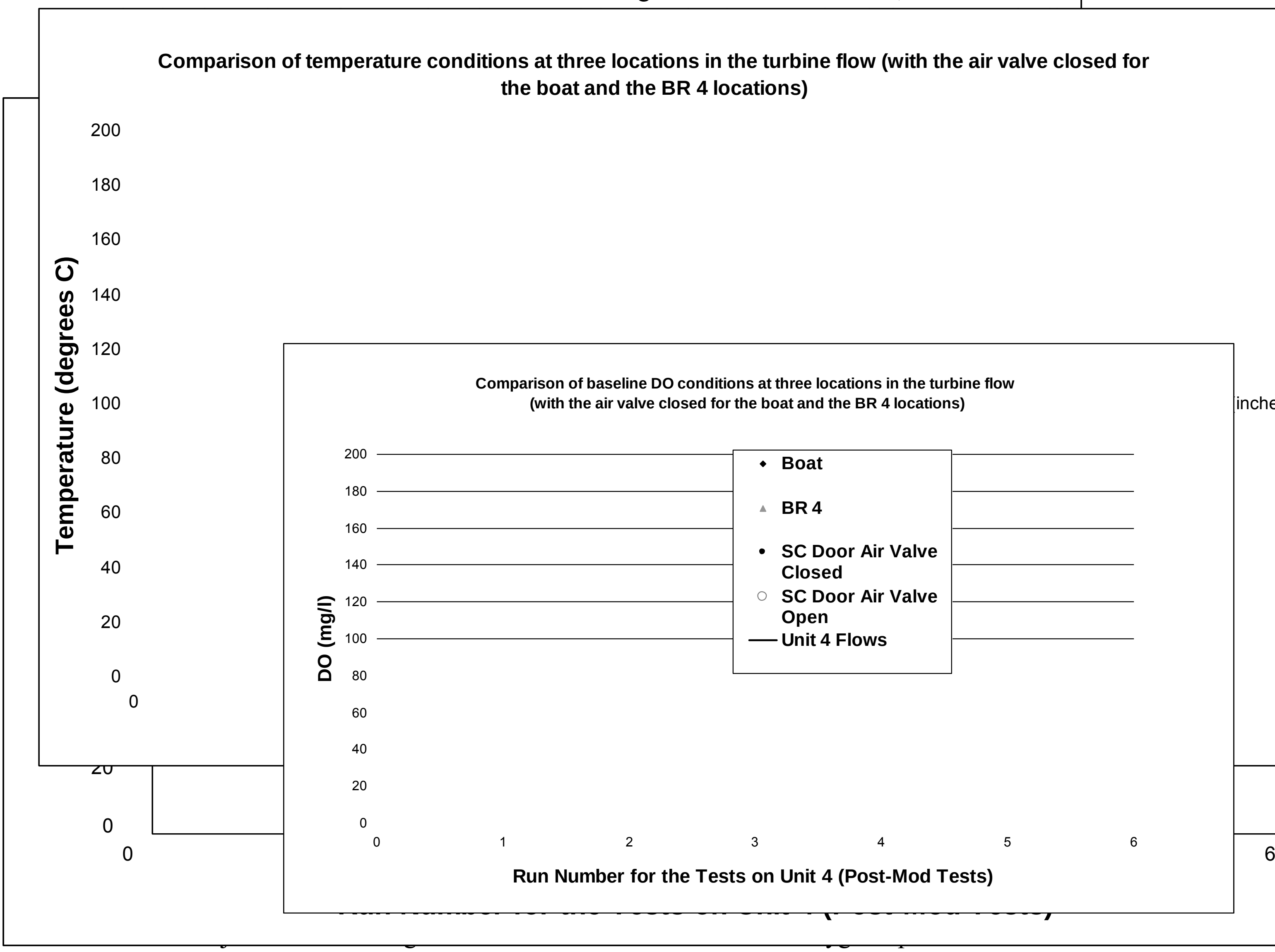


Figure 8 - *Brownlee draft tube area curve showing cross sectional area as a function of developed length.*

The mass transfer calculations performed for current Brownlee aeration assume that air is comprised entirely of oxygen and nitrogen. Other gases, typically making up about 1.0% of the air, are neglected. Once the gases of interest are identified, the mass transfer (Henry) coefficients are determined for each gas. These values are inversely proportional to temperature, so warmer water represents a more challenging case for achieving dissolved oxygen uptake. The Brownlee



Dissolved oxygen transfer also depends on the DO concentration already present within the turbine intakes. At Brownlee, the intakes are positioned 18 ft above the intake channel floor, with the intakes spanning between elevations of 1938 to 1961 ft. Although dissolved oxygen levels within the reservoir can fall below 1.0 mg/l at various elevations, the water enteri



performed with the aforementioned intake dissolved oxygen level of 2.0 mg/l, in addition to the extreme condition of 0.0 mg/l within the Brownlee turbine intakes.

Once the Brownlee turbine geometry and site conditions were incorporated into the discrete bubble model, the updated dissolved oxygen uptake predictions were determined for tailwater elevations of 1801.0, 1805.0 and 1808.0 ft. Summaries of the tailrace dissolved oxygen predictions across the range of turbine discharges are provided in Tables 4a (TWE = 1801.0 ft, intake dissolved oxygen level = 2.0 mg/l), 4b (TWE = 1805.0 ft, intake dissolved oxygen level = 2.0 mg/l), and 4c (TWE = 1808.0 ft, intake dissolved oxygen level = 2.0 mg/l).

Discharge [cfs]	Q/Q_{opt} [-]	Predicted Air Flows [scfs]	Predicted Φ [%]	Predicted Dissolved Oxygen Uptake [mg/l]	Predicted Tailrace Dissolved Oxygen [mg/l]
3000	0.57	201	6.3	4.3	6.3
3300	0.62	204	5.8	3.4	5.4
4200	0.79	235	5.3	3.1	5.1
5000	0.94	275	5.2	3.2	5.2
5200	0.98	283	5.2	3.2	5.2
5430	1.02	293	5.1	3.2	5.2
5673	1.07	301	5.0	3.3	5.3
5945	1.12	308	4.9	3.3	5.3

Table 4a: Brownlee predicted dissolved oxygen uptakes and tailrace levels for TWE = 1801.0 ft and an intake dissolved oxygen level of 2.0 mg/l.

Discharge [cfs]	Q/Q_{opt} [-]	Predicted Air Flows [scfs]	Predicted Φ [%]	Predicted Dissolved Oxygen Uptake [mg/l]	Predicted Tailrace Dissolved Oxygen [mg/l]
3000	0.57	168	5.3	4.1	6.1
3300	0.62	170	4.9	3.2	5.2
4200	0.79	197	4.5	3.0	5.0
5000	0.94	239	4.6	3.1	5.1
5200	0.98	250	4.6	3.2	5.2
5430	1.02	260	4.6	3.2	5.2
5673	1.07	269	4.5	3.3	5.3
5945	1.12	275	4.4	3.3	5.3

Table 4b: Brownlee predicted dissolved oxygen uptakes and tailrace levels for TWE = 1805.0 ft and an intake dissolved oxygen level of 2.0 mg/l.

Discharge [cfs]	Q/Q_{opt} [-]	Predicted Air Flows [scfs]	Predicted Φ [%]	Predicted Dissolved Oxygen Uptake [mg/l]	Predicted Tailrace Dissolved Oxygen [mg/l]
3000	0.57	138	4.4	3.8	5.8
3300	0.62	139	4.0	3.0	5.0
4200	0.79	164	3.8	2.7	4.7
5000	0.94	209	4.0	2.9	4.9
5200	0.98	221	4.1	3.0	5.0
5430	1.02	233	4.1	3.1	5.1
5673	1.07	242	4.1	3.2	5.2
5945	1.12	250	4.0	3.3	5.3

Table 4c: Brownlee predicted dissolved oxygen uptakes and tailrace levels for TWE = 1808.0 ft and an intake dissolved oxygen level of 2.0 mg/l.

Overall, the predicted dissolved oxygen uptake and tailrace dissolved oxygen levels are generally similar for each tailwater. At lower turbine discharges, dissolved oxygen uptakes are approximately 4 mg/l before decreasing to approximately 3 mg/l at the intermediate and larger discharges. For each tailwater level, the tailrace dissolved oxygen levels are expected to approach or exceed 5.0 mg/l.

Summaries of the tailrace dissolved oxygen predictions across the range of turbine discharges are provided in Tables 5a (TWE = 1801.0 ft, intake dissolved oxygen level = 0.0 mg/l), 5b (TWE = 1805.0 ft, intake dissolved oxygen level = 0.0 mg/l), 4c (TWE = 1808.0 ft, intake dissolved oxygen level = 0.0 mg/l).

Discharge [cfs]	Q/Q_{opt} [-]	Predicted Air Flows [scfs]	Predicted Φ [%]	Predicted Dissolved Oxygen Uptake [mg/l]	Predicted Tailrace Dissolved Oxygen [mg/l]
3000	0.57	201	6.3	5.2	5.2
3300	0.62	204	5.8	4.2	4.2
4200	0.79	235	5.3	3.8	3.8
5000	0.94	275	5.2	3.8	3.8
5200	0.98	283	5.2	3.8	3.8
5430	1.02	293	5.1	3.9	3.9
5673	1.07	301	5.0	3.9	3.9
5945	1.12	308	4.9	4.0	4.0

Table 5a: Brownlee predicted dissolved oxygen uptakes and tailrace levels for TWE = 1801.0 ft and an intake dissolved oxygen level of 0.0 mg/l.

Discharge [cfs]	Q/Q_{opt} [-]	Predicted Air Flows [scfs]	Predicted Φ [%]	Predicted Dissolved Oxygen Uptake [mg/l]	Predicted Tailrace Dissolved Oxygen [mg/l]
3000	0.57	168	5.3	4.8	4.8
3300	0.62	170	4.9	3.9	3.9
4200	0.79	197	4.5	3.5	3.5
5000	0.94	239	4.6	3.6	3.6
5200	0.98	250	4.6	3.7	3.7
5430	1.02	260	4.6	3.8	3.8
5673	1.07	269	4.5	3.8	3.8
5945	1.12	275	4.4	3.9	3.9

Table 5b: Brownlee predicted dissolved oxygen uptakes and tailrace levels for TWE = 1805.0 ft and an intake dissolved oxygen level of 0.0 mg/l.

Discharge [cfs]	Q/Q_{opt} [-]	Predicted Air Flows [scfs]	Predicted Φ [%]	Predicted Dissolved Oxygen Uptake [mg/l]	Predicted Tailrace Dissolved Oxygen [mg/l]
3000	0.57	138	4.4	4.4	4.4
3300	0.62	139	4.0	3.5	3.5
4200	0.79	164	3.8	3.1	3.1
5000	0.94	209	4.0	3.4	3.4
5200	0.98	221	4.1	3.5	3.5
5430	1.02	233	4.1	3.6	3.6
5673	1.07	242	4.1	3.7	3.7
5945	1.12	250	4.0	3.8	3.8

Table 5c: Brownlee predicted dissolved oxygen uptakes and tailrace levels for TWE = 1808.0 ft and an intake dissolved oxygen level of 0.0 mg/l.

For Tables 5a, b and c, the lower intake dissolved oxygen of 0.0 mg/l results in larger dissolved oxygen uptakes when compared to Tables 4a, b and c. For this extreme condition of high water temperature (23ºC) and low intake dissolved oxygen, the tailrace dissolved oxygen levels are expected to fall between 3 and 4 mg/l for each of the three tailwater levels of interest.

5.0 Brownlee Influence of Aeration on Turbine Performance

One of the costs associated with aeration relates to the impact that the air flows have on draft tube performance. As the draft tube flow characteristics become altered during aeration, turbine efficiency levels generally decline. These aeration impacts are dependent on several parameters, including draft tube design, air flow quantities, bubble size, aeration method, and point of turbine operation. Although efficiency impacts during aeration are difficult to accurately predict, distributed aeration from an aerating runner has proved to have the smallest influence on draft tube flow characteristics as high fluid shear at the blade discharge edge creates a well distributed cloud of small bubbles downstream of the runner (Foust et al., 2008). A summary of the performance impacts ($\eta_{\text{non aerating}} - \eta_{\text{aerating}}$) associated with distributed aeration at Brownlee is given below in Tables 6a, b, c and d for net heads of 204.0 ft, 235.0 ft, 250.0 ft and 274.0 ft.

Discharge [cfs]	Q/Q_{opt} [-]	Predicted Efficiency Impact during Aeration [%]		
		TWE = 1801.0 ft	TWE = 1805.0 ft	TWE = 1808.0 ft
3000	0.57	4.8	3.5	2.2
3300	0.62	4.1	2.9	1.6
4200	0.79	3.2	2.4	1.7
5000	0.94	2.9	2.6	2.2
5200	0.98	2.9	2.6	2.3
5430	1.02	2.8	2.5	2.3

Table 6a: Brownlee predicted aeration influence on turbine efficiency for Net Head = 204.0 ft.

Discharge [cfs]	Q/Q_{opt} [-]	Predicted Efficiency Impact during Aeration [%]		
		TWE = 1801.0 ft	TWE = 1805.0 ft	TWE = 1808.0 ft
2500	0.47	5.4	4.1	2.6
3000	0.57	4.0	2.8	1.8
3300	0.62	3.3	2.3	1.5
4200	0.79	2.7	2.0	1.5
5000	0.94	2.5	2.2	1.8
5200	0.98	2.5	2.2	1.9
5430	1.02	2.4	2.2	1.9
5673	1.07	2.3	2.1	1.9

Table 6b: Brownlee predicted aeration influence on turbine efficiency for Net Head = 235.0 ft.

Discharge [cfs]	Q/Q_{opt} [-]	Predicted Efficiency Impact during Aeration [%]		
		TWE = 1801.0 ft	TWE = 1805.0 ft	TWE = 1808.0 ft
2500	0.47	4.9	3.7	2.3
3000	0.57	3.7	2.5	1.9
3300	0.62	3.0	2.1	1.9
4200	0.79	2.5	2.0	1.9
5000	0.94	2.4	2.1	1.8
5200	0.98	2.4	2.1	1.9
5430	1.02	2.3	2.1	1.8
5673	1.07	2.2	2.0	1.8
5731	1.08	2.2	2.0	1.8

Table 6c: Brownlee predicted aeration influence on turbine efficiency for Net Head = 250.0 ft.

Discharge [cfs]	Q/Q_{opt} [-]	Predicted Efficiency Impact during Aeration [%]		
		TWE = 1801.0 ft	TWE = 1805.0 ft	TWE = 1808.0 ft
2500	0.47	4.1	2.9	1.6
3000	0.57	2.9	1.9	1.4
3300	0.62	2.4	1.5	1.4
4200	0.79	2.0	1.6	1.5
5000	0.94	2.0	1.8	1.6
5200	0.98	2.1	1.8	1.7
5430	1.02	2.0	1.8	1.7
5673	1.07	2.0	1.8	1.6
5945	1.12	2.0	1.8	1.6

Table 6d: Brownlee predicted aeration influence on turbine efficiency for Net Head = 274.0 ft.

For each of the given operating conditions, the air flows are expected to lower turbine efficiencies by approximately 2 to 3%. Further illustration of the predicted efficiency impact during distributed aeration at Brownlee Dam are provided in Figure 10, 11, 12 and 13 for net heads of 204.0 ft, 235.0 ft, 250.0 ft and 274.0 ft, respectively.

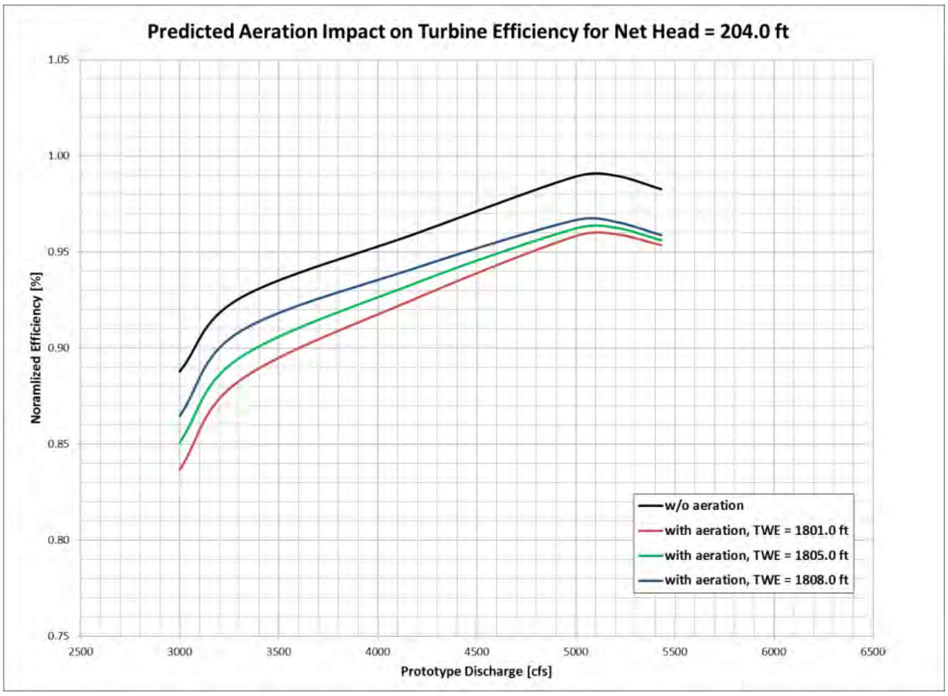


Figure 10 – Predicted Brownlee distributed aeration impact on turbine efficiency for net head = 204.0 ft.

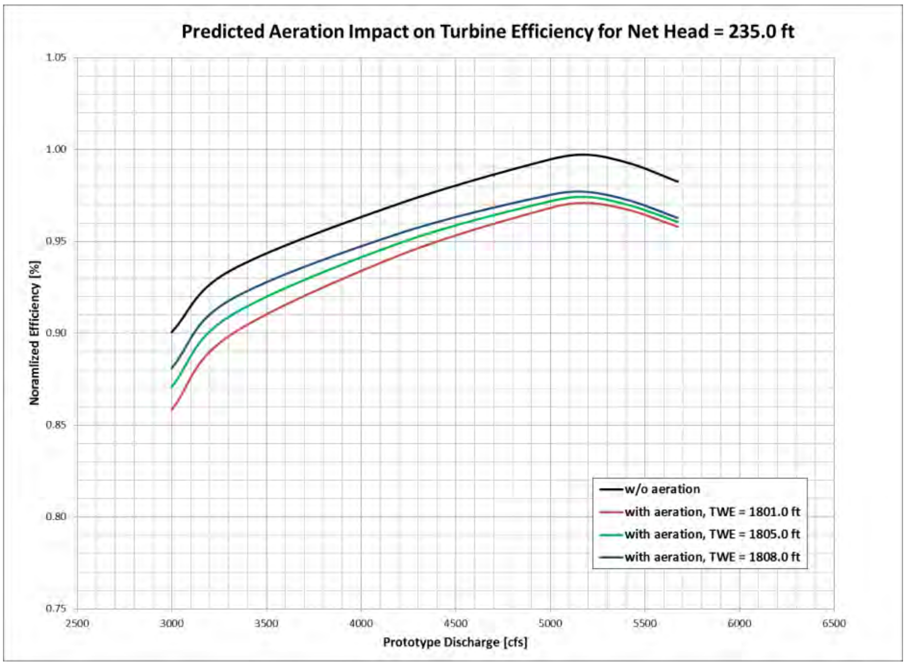


Figure 11 – Predicted Brownlee distributed aeration impact on turbine efficiency for net head = 235.0 ft.

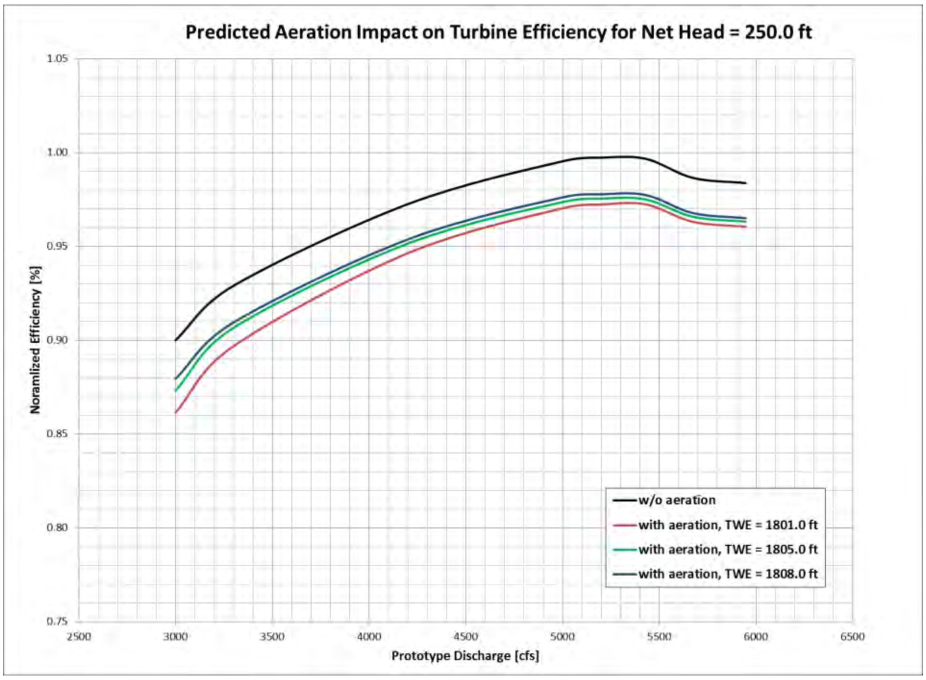


Figure 12 – Predicted Brownlee distributed aeration impact on turbine efficiency for net head = 250.0 ft.

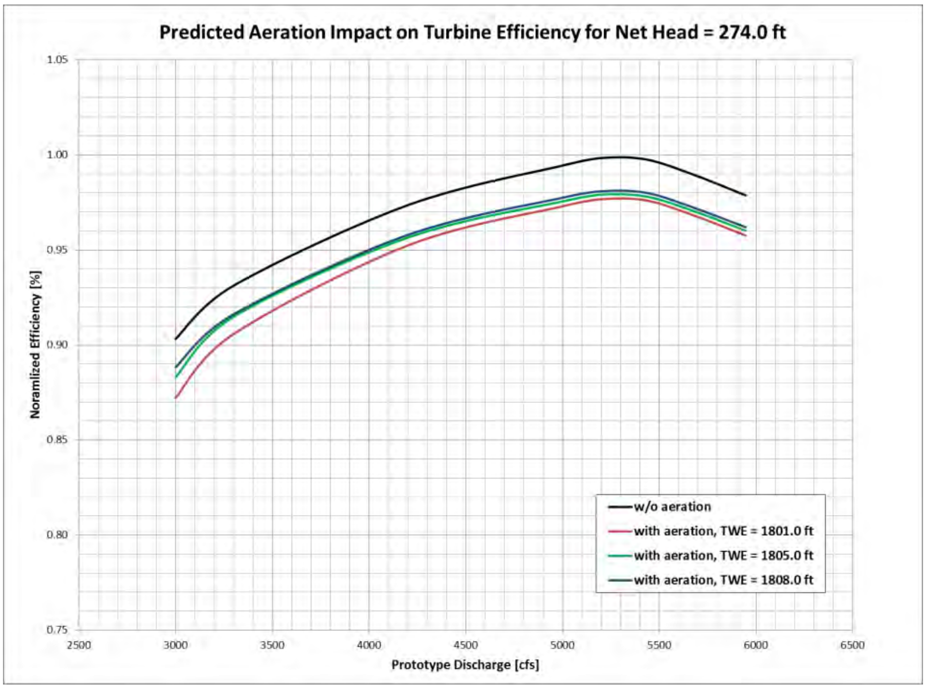


Figure 13 – Predicted Brownlee distributed aeration impact on turbine efficiency for net head = 274.0 ft.

7.0 Total Dissolved Gas Predictions

As the two-phase flow develops within the draft tube, a concentration gradient develops between the gases present within the air and those within the surrounding water. This gradient causes mass to transfer from the air to the water, giving rise to DO uptake. During this process, nitrogen transfer also occurs. While dissolved oxygen uptake generally enhances water quality, too much dissolved gas can also be harmful to fish. Total dissolved gas, or TDG, is defined as

$$TDG[\%] = \frac{Partial\ Pressure_O + Partial\ Pressure_N}{Atmospheric\ Pressure} \qquad \text{Eq. (3)}$$

The DBM methodology can also be utilized to estimate total dissolved gas (oxygen and nitrogen) levels for the Brownlee distributed aeration investigations. The transfer of oxygen and nitrogen is primarily influenced by three factors, including water temperature, intake dissolved oxygen concentration and intake dissolved nitrogen concentration. In the analysis that follows, incoming dissolved oxygen and nitrogen were varied to determine the overall influence of distributed aeration on TDG levels for tailwater levels of 1801.0 ft, 1805.0 ft and 1808.0 ft. For these simulations, the water temperature was held at a constant 20ºC and represents an average temperature that can be expected in the Brownlee turbine intakes during operation when aeration is occurring. These results are summarized in Tables 7a (TWE = 1801.0 ft), 7b (TWE = 1805.0 ft), 7c (TWE = 1808.0 ft) for an incoming dissolved oxygen level of 0.0 mg/l.

	Incoming DO = 0.0 mg/l				
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 18 mg/l	0	0	0.0	18.0	90.5
	3000	201	5.5	20.4	114.8
	4200	235	3.9	19.7	107.7
	5000	275	4.0	19.7	107.9
	5945	308	4.2	19.9	109.2
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 20 mg/l	0	0	0.0	20.0	100.6
	3000	201	5.5	21.1	118.1
	4200	235	3.4	20.8	113.4
	5000	275	4.0	20.8	113.4
	5945	308	4.2	20.9	114.3
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 22 mg/l	0	0	0.0	22.0	110.7
	3000	201	5.5	21.7	121.3
	4200	235	3.9	21.9	118.8
	5000	275	4.0	21.9	118.8
	5945	308	4.2	21.9	119.3
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 24 mg/l	0	0	0.0	24.0	120.7
	3000	201	5.5	22.4	124.6
	4200	235	3.9	23.0	124.5
	5000	275	4.0	22.9	124.2
	5945	308	4.2	22.9	124.3

Table 7a – *TDG predictions for incoming DO = 0.0 mg/l, water temperature = 20ºC and TWE = 1801.0 ft.*

	Incoming DO = 0.0 mg/l				
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 18 mg/l	0	0	0.0	18.0	90.5
	3000	168	5.2	21.2	118.2
	4200	197	3.7	20.1	109.3
	5000	239	3.8	20.2	110.0
	5945	275	4.1	20.5	112.0
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 20 mg/l	0	0	0.0	20.0	100.6
	3000	168	5.2	22.0	122.3
	4200	197	3.7	21.4	115.5
	5000	239	3.8	21.4	116.0
	5945	275	4.1	21.6	117.5
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 22 mg/l	0	0	0.0	22.0	110.7
	3000	168	5.2	22.9	126.4
	4200	197	3.6	22.6	121.7
	5000	239	3.8	22.6	121.9
	5945	275	4.1	22.7	123.0
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 24 mg/l	0	0	0.0	24.0	120.7
	3000	168	5.1	23.7	130.3
	4200	197	3.6	23.8	127.8
	5000	239	3.8	23.7	127.8
	5945	275	4.1	23.8	128.4

Table 7b – *TDG predictions for incoming DO = 0.0 mg/l, water temperature = 20ºC and TWE = 1805.0 ft.*

	Incoming DO = 0.0 mg/l				
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 18 mg/l	0	0	0.0	18.0	90.5
	3000	138	4.7	21.7	119.6
	4200	164	3.3	20.3	109.6
	5000	221	3.8	20.6	112.1
	5945	250	4.0	21.0	114.4
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 20 mg/l	0	0	0.0	20.0	100.6
	3000	138	4.7	22.7	124.4
	4200	164	3.3	21.7	116.3
	5000	221	3.7	21.9	118.3
	5945	250	4.0	22.2	120.3
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 22 mg/l	0	0	0.0	22.0	110.7
	3000	138	4.7	23.7	129.4
	4200	164	3.3	23.0	123.1
	5000	221	3.7	23.1	124.6
	5945	250	4.0	23.4	126.2
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 24 mg/l	0	0	0.0	24.0	120.7
	3000	138	4.7	24.7	134.4
	4200	164	3.3	24.4	129.8
	5000	221	3.7	24.4	130.8
	5945	250	4.0	24.5	132.1

Table 7c– *TDG predictions for incoming DO = 0.0 mg/l, water temperature = 20°C and TWE = 1808.0 ft.*

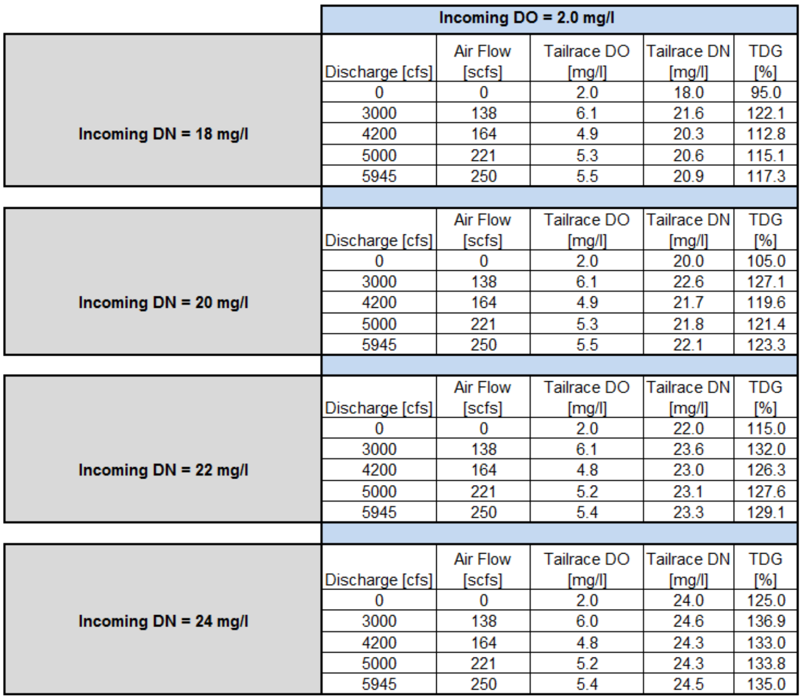
To establish a baseline for comparison purposes, Tables 7a, b and c provide TDG predictions when the Brownlee turbines are not operating. For each of the three tailwater elevations, the resulting TDG levels are influenced significantly by the amount of dissolved nitrogen already present the water. In general, part load operation at a discharge of 3000 cfs produces the largest TDG levels. For intermediate discharges, the TDG values decrease before climbing slightly at the highest turbine discharge of 5945 cfs. Corresponding TDG predictions for an incoming dissolved oxygen level of 2.0 mg/l are provided in Tables 8a (TWE = 1801.0 ft), 8b (TWE = 1805.0 ft), 8c (TWE = 1808.0 ft).

	Incoming DO = 2.0 mg/l				
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 18 mg/l	0	0	2.0	18.0	95.0
	3000	201	6.7	20.3	116.8
	4200	235	5.4	19.7	110.7
	5000	275	5.4	19.6	110.7
	5945	308	5.6	19.8	111.8
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 20 mg/l	0	0	2.0	20.0	105.0
	3000	201	6.6	21.0	119.9
	4200	235	5.3	20.8	116.2
	5000	275	5.4	20.7	116.1
	5945	308	5.5	20.8	116.8
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 22 mg/l	0	0	2.0	22.0	115.0
	3000	201	6.6	21.6	123.2
	4200	235	5.3	21.9	121.8
	5000	275	5.4	21.8	121.5
	5945	308	5.5	21.8	121.8
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 24 mg/l	0	0	2.0	24.0	125.0
	3000	201	6.6	22.2	126.3
	4200	235	5.3	23.0	127.2
	5000	275	5.3	22.9	126.8
	5945	308	5.5	22.8	126.8

Table 8a– *TDG predictions for incoming DO = 2.0 mg/l, water temperature = 20°C and TWE = 1801.0 ft.*

	Incoming DO = 2.0 mg/l				
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 18 mg/l	0	0	2.0	18.0	95.0
	3000	168	6.5	21.1	120.4
	4200	197	5.2	20.1	112.4
	5000	239	5.3	20.1	113.0
	5945	275	5.5	20.4	114.8
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 20 mg/l	0	0	2.0	20.0	105.0
	3000	168	6.4	21.9	124.5
	4200	197	5.1	21.3	118.5
	5000	239	5.3	21.3	118.9
	5945	275	5.5	21.5	120.3
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 22 mg/l	0	0	2.0	22.0	115.0
	3000	168	6.4	22.7	128.5
	4200	197	5.1	22.5	124.6
	5000	239	5.2	22.5	124.8
	5945	275	5.5	22.6	125.7
	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 24 mg/l	0	0	2.0	24.0	125.0
	3000	168	6.4	23.6	132.5
	4200	197	5.1	23.8	130.8
	5000	239	5.2	23.7	130.7
	5945	275	5.5	23.7	131.1

Table 8b– *TDG predictions for incoming DO = 2.0 mg/l, water temperature = 20°C and TWE = 1805.0 ft.*



Incoming DO = 2.0 mg/l

	Discharge [cfs]	Air Flow [scfs]	Tailrace DO [mg/l]	Tailrace DN [mg/l]	TDG [%]
Incoming DN = 18 mg/l	0	0	2.0	18.0	95.0
	3000	138	6.1	21.6	122.1
	4200	164	4.9	20.3	112.8
	5000	221	5.3	20.6	115.1
	5945	250	5.5	20.9	117.3
Incoming DN = 20 mg/l	0	0	2.0	20.0	105.0
	3000	138	6.1	22.6	127.1
	4200	164	4.9	21.7	119.6
	5000	221	5.3	21.8	121.4
	5945	250	5.5	22.1	123.3
Incoming DN = 22 mg/l	0	0	2.0	22.0	115.0
	3000	138	6.1	23.6	132.0
	4200	164	4.8	23.0	126.3
	5000	221	5.2	23.1	127.6
	5945	250	5.4	23.3	129.1
Incoming DN = 24 mg/l	0	0	2.0	24.0	125.0
	3000	138	6.0	24.6	136.9
	4200	164	4.8	24.3	133.0
	5000	221	5.2	24.3	133.8
	5945	250	5.4	24.5	135.0

Table 8c– *TDG predictions for incoming DO = 2.0 mg/l, water temperature = 20°C and TWE = 1808.0 ft.*

The higher initial dissolved oxygen level of 2.0 mg/l results in larger TDG levels in the Brownlee tailrace. The overall TDG trends with respect to turbine discharge are similar to those of Tables 7a, b and c, with higher TDG levels observed at deep part load before decreasing at larger discharges.

6.0 Conclusions

Voith Hydro has performed aeration predictions associated with four replacement runners capable of providing distributed aeration at Brownlee Dam. Geometry and site condition assumptions were incorporated into a mass transfer model which determines the amount of oxygen and nitrogen that passes between the air-water mixture as it continues through the turbine and into the tailrace. These calculations indicate that the proposed replacement runners will be sufficient to raise tailrace dissolved oxygen concentrations from 2 mg/l to approximately 5 mg/l across a range of turbine discharges and tailwater levels. If intake dissolved oxygen levels decrease to 0 mg/l, the proposed distributed aeration is expected to raise tailrace dissolved oxygen levels between 3 and 4 mg/l.

Voith Hydro has also investigated the influence of turbine aeration on total dissolved gas. While distributed aeration results in higher TDG levels in the Brownlee reservoir, these predictions can be used as a guide to avoid problematic thresholds according to dissolved oxygen and nitrogen levels within the turbine intakes. It should be noted that distributed air intake pipes located above the headcover are equipped with butterfly valves that can be used to throttle the air flow into the turbine. The Brownlee distributed aeration system can therefore be used to improve tailrace dissolved oxygen levels while making adjustments to air flow based on the current TDG predictions.

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Exhibit 7.3-1

Hydraulic modeling of Hells Canyon Dam for spillway deflector design: Phase one – deflector design

HYDRAULIC MODELING OF HELLS CANYON DAM FOR SPILLWAY DEFLECTOR DESIGN:
PHASE ONE – DEFLECTOR DESIGN

by

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EXECUTIVE SUMMARY

This report documents hydraulic modeling of Hells Canyon Dam for spillway deflector design. A two-dimensional sectional model was constructed at the Iowa Institute of Hydraulic Research to investigate length, elevation, and lip angle required for optimal performance of sluiceway deflectors at Hells Canyon Dam. These deflectors are designed to redirect plunging spillway jets, reducing total dissolved gas (TDG) produced by spill discharges. Performance curves were used to analyze the hydraulic performance characteristics of various deflectors and develop an effective design. The hydraulic model allowed development of comprehensive rating curves for predicting spillway and sluiceway discharges. This report describes design issues, model structure, experimental procedures, and model results applied to the development of comprehensive rating curves and optimal deflector design for potential TDG reduction at Hells Canyon Dam.

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1. INTRODUCTION

This report provides a complete description of hydraulic model studies performed by the Iowa Institute of Hydraulic Research (IIHR) for spillway deflector design at Hells Canyon Dam The spillway deflectors are designed to reduce air entrainment and total dissolved gas (TDG) at Hells Canyon Dam by redirecting plunging spillway jets. Lowering TDG levels lessens the-risk of injury and death to fish caused by gas bubble disease. A hydraulic model was used to develop performance curves for various deflector designs, enabling optimization for TDG reduction. The hydraulic model was used to develop discharge rating curves for the spillway and sluiceway gates at Hells Canyon Dam.

Chapter 2 describes the basis for the deflector model study, structure of the modeling project, layout and construction of the two-dimensional hydraulic model and initial model operation. Methods and results utilized in development of comprehensive spillway and sluiceway rating curves are described in Chapter 3. Details related to deflector performance testing with the two-dimensional sectional model are contained in Chapter 4. The approach for developing performance curves, general information about deflector design, and the hydraulic performance of specific deflectors tested are discussed. The final chapter summarizes results and conclusions from the hydraulic model studies used to develop comprehensive rating curves and optimal deflector design for TDG reduction at Hells Canyon Dam.

2. EXPERIMENTAL APPROACH

High gas supersaturation levels observed below Hells Canyon Dam persist for miles down the Snake River. IPC contracted IIHR to investigate spillway deflector designs to reduce these TDG levels. The configuration and size of Hells Canyon Dam require unique hydraulic model studies. This chapter describes the deflector model study rationale, project design specifications, layout, construction, and initial operation of the two-dimensional hydraulic model.

2.1 Basis for Hydraulic Model Study

Based on input by the Aquatic Working Group (AWG) as part of the relicensing process, IPC specified gas abatement in the Hells Canyon Complex as a goal (Myers, Pierce, and Stute, 2, 1999). A study plan was developed to evaluate operational procedures and improvement measures to minimize TDG levels.

A series of TDG measurements were taken during spring and summer from 1997 through 1999 at Hells Canyon Dam (Myers, Pierce, and Stute, 3, 1999). This study provides useful information on gas supersaturation. Spill is the primary gas supersaturation source downstream of the dam. Cumulative spill effects at Oxbow or Brownlee dams do not appear to influence TDG levels below Hells Canyon Dam. Spill from the upper and lower gates at Hells Canyon caused only small differences in TDG levels. Spill events of 9,000 and 13,400 cfs produce TDG levels over 110% at all stations 47 miles below the dam (river mile 200). The recommendation that spill releases at Hell Canyon Dam be limited to 3,000 cfs whenever possible is based upon these TDG study findings. The 3,000 cfs spill limit reduces the chance that TDG levels will exceed 110% saturation (Myers, Pierce, and Stute, 9, 1999).

The 1997-1999 TDG field study confirmed previous suspicions that Hells Canyon Dam caused high gas supersaturation levels. The persistence of elevated TDG levels downstream of Hells Canyon Dam, and the associated risk to anadromous fish, demonstrate the need for gas abatement measures. The unique configuration of the dam and design limitations eliminate most TDG reduction alternatives. Spillway deflectors emerge as the most feasible and economic option. Literature describing the application of spillway deflectors at high head projects like Hells Canyon Dam are quite scarce. Variation in hydraulic conditions at given sites and a lack of pertinent research data demanded a specific case study to evaluate potential deflector designs for Hells Canyon Dam. A hydraulic model study was chosen as the most practical method to determine optimum deflector design.

2.2 Structure of Hydraulic Model Study

A project team lead by Dr. Larry Weber of IIHR, Ms. Sharon Parkinson of IPC, and consulting engineer Mr. Duncan Hay directed the model study. The team established scaling parameters and overall design for the Hells Canyon hydraulic model. These provisions reproduce hydraulic conditions required for accurate evaluation of deflector performance.

2.2.1 Similitude and Model Scaling

Ideally, hydraulic models provide accurate scaling and quantitative measurement of the properties investigated. Scaling problems with air bubbles and surface tension prevent direct measurement of air entrainment and TDG levels in the model. Hydrostatic pressures in the model are too small to drive air bubbles into solution, preventing gas supersaturation. Qualitative observation techniques are therefore used to evaluate TDG reduction potential for various deflector designs. Conditions associated with these qualitative methods are primarily single-phase, free-surface flows. Since the Froude number, a ratio of inertial and gravitational forces is the dominant parameter in free-surface flows, Froude scaling determined prototype to model relations (White, 306, 1999). Although Reynolds-number similarity is violated under these circumstances, the model Reynolds-number range (10^5 to 10^7) corresponds to fully turbulent flow based on the Moody diagram, similar to turbulent flow conditions in the field. Froude scaling provides geometric and dynamic similitude, enabling direct velocity and discharge computation from the geometric model ratio. The procedure for obtaining these proper relationships is illustrated below with a geometric scale of 1:48. Subscripts m and p refer to model and prototype values, respectively.

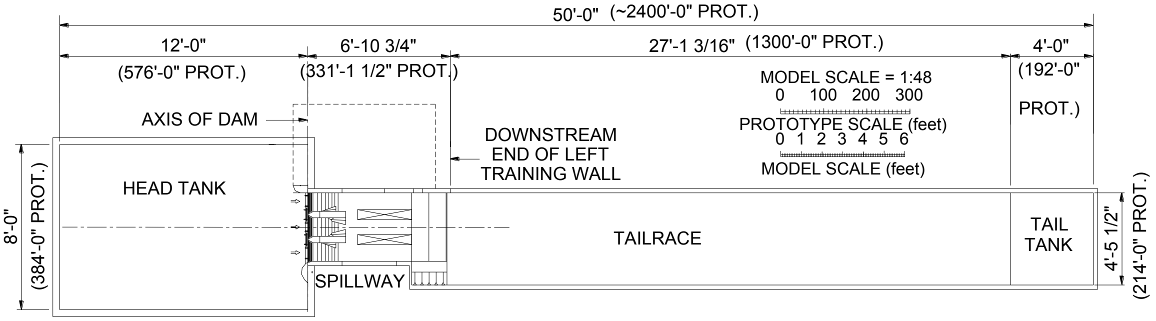
$$\frac{Froude_m}{Froude_p} = \frac{V_m\sqrt{gL_p}}{V_p\sqrt{gL_m}} = \frac{Q_m {L_p}^2\sqrt{gL_p}}{Q_p {L_m}^2\sqrt{gL_m}} = \frac{Q_m}{Q_p}\left(\frac{L_p}{L_m}\right)^{2.5} = \frac{Q_m}{Q_p}(48)^{2.5} = 1 \qquad \text{(Equation 2.1)}$$

Where V_m = model velocity (ft/s)
V_p = prototype velocity (ft/s)
g = gravitational constant (32.17 ft/s^2)
L_m = model length parameter (ft)
L_p = prototype length parameter (ft)
Q_m = model flow rate (ft^3/s)
Q_p = prototype flow rate (ft^3/s)
48 = geometric scale factor (L_p/L_m)

The specification set by the modeling team required simulation of the maximum spillway discharge for Hells Canyon Dam. The maximum prototype spillway flow rate, Qp, is approximately 300,000 cfs. Using Equation 2.1the equivalent model flow rate, Qm, is 18.8 cfs. The model design was therefore required to simulate a flow of approximately 19 cfs.

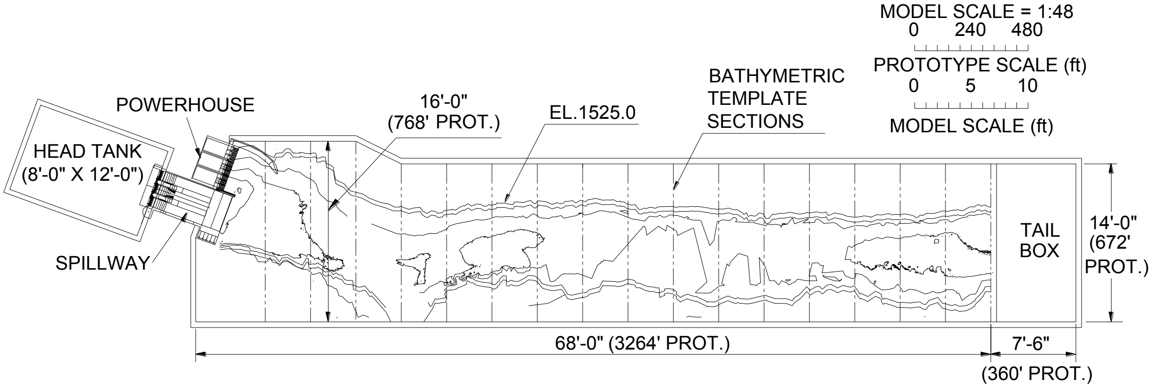
2.2.2 Model Design

The inability to measure air entrainment in Froude scale, single-phase flow requires a qualitative approach (Haug, 2000). Qualitative observation methods developed by USACE provide a basis for assessing air entrainment associated with the potential deflector designs for this model study. Flow characteristics associated with qualitative deflector performance analysis are best observed in larger scale hydraulic models. A larger scale model also provides sufficient distance to reproduce forebay and tailrace boundary conditions. The model scale must be small enough however to be feasible in terms of space and construction cost. These factors guided the design team in the choice of model scale 1:48 for the deflector study. The 1:48-scale maximizes available laboratory space, while maintaining an easy to manage scale factor.



ns.

The large 1:48 scale and dam configuration required construction of a new structure at IIHR. model Annex. The model consists of a large head tank, a spillway section, and an open-channel flume. A Plexiglas wall as one side of the downstream flume permits flow visualization for the various deflector designs. The two-dimensional model was approximately 4.5 feet wide by 50 feet long by 8 feet high. The general layout of this two-dimensional sectional model is shown in Figure 2.1. Section 2.3 and Appendix A contain more model design and layout details. All elev



The two-dimensional sectional model was later modified. into a comprehensive three-dimensional model for investigation of potential erosion impacts and three-dimensional flow characteristics of spillway deflectors. The spillway section, powerhouse units, left and right bank training walls, forebay area, and about 3200 prototype feet of downstream tailrace are included in this 1:48-scale, three-dimensional model, as illustrated in Figure 2.2.

2.3 Two-Dimensional Sectional Model

The primary function of the two-dimensional sectional model was determining optimum length, elevation, transition radius, and lip angle for deflectors. These parameters were investigated for various designs using performance curves obtained from the model. The layout and design of the sectional model provided an ideal visualization of the two-dimensional deflector designs hydraulic performance. Accurate replication of the dam and its hydraulic features required precise construction of the sectional model. Verifications of gate positioning and discharge relationships in the two-dimensional model were imperative for proper deflector design.

2.3.1 Model Layout and Construction

Previous USACE deflector studies provided guidelines for the 1:48-scale sectional model design. Given the likelihood of sectional model expansion to a larger comprehensive model, the 1:48 scale was the largest that could be accommodated in the IIHR Model Annex. The sectional model incorporated an 8 foot wide (384 prototype feet) by 12 foot long (576 prototype feet) by 8 foot high steel framed head tank, lined with high-density overlay plywood and Plexiglas. The size and elements of this tank, shown in Figure 2.3, were established to provide quiescent flow conditions approaching the spillway section. Pipes feeding the head tank terminated with perforated PVC pipe acting as a diffuser. A false wall composed of 16-gauge (0.06 inch thick) perforated plate with 3/16-inch diameter holes was placed inside the head tank to provide uniform flow conditions. The plate has a porosity, or open area, of 32.6%. Covering the lower three feet of perforated plate with a solid sheet of tin prevented flow upwelling within the head tank.

An exact reproduction of the entire spillway section was attached to the head tank. A side view of the stilling basin and spillway section is shown in Figure 2.4. The three upper spillways and two lower sluiceways were constructed from a continuous section of high-density overlay plywood. The spillway and sluiceway tainter gates were metal and controlled individually by rods with setscrews. A metal plate simulated the apron. A PVC wedge positioned on the plate formed the end sill. The entire spillway face, ogee spillway and sluiceway crests, upstream left and right training walls, and pier noses were coveted with tin. Figure 2.5 illustrates these features in a view of the upstream face of the dam from inside the head tank.

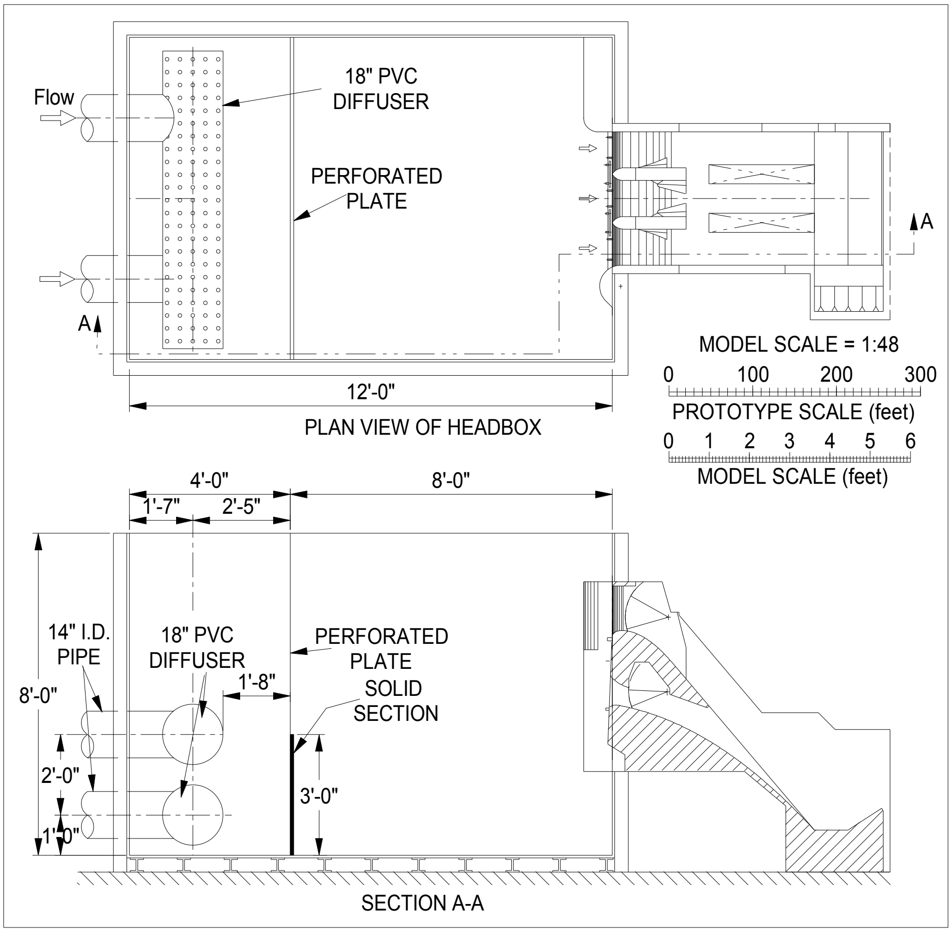


Figure 2.3 Details and Components of 1:48 Model Head Tank

The tailrace of the sectional model was a standard open-channel flume. The channel was constructed of two 4-foot high wood framed walls. One wall was lined with high-density overlay plywood and the other was lined with Plexiglas for flow visualization. A wooden tailgate operated by cable and hand wheel controlled tailwater elevation in the flume, as illustrated in Figure 2.6.

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Figure 2.5 Upstream Face of 1:48 Model Headwall

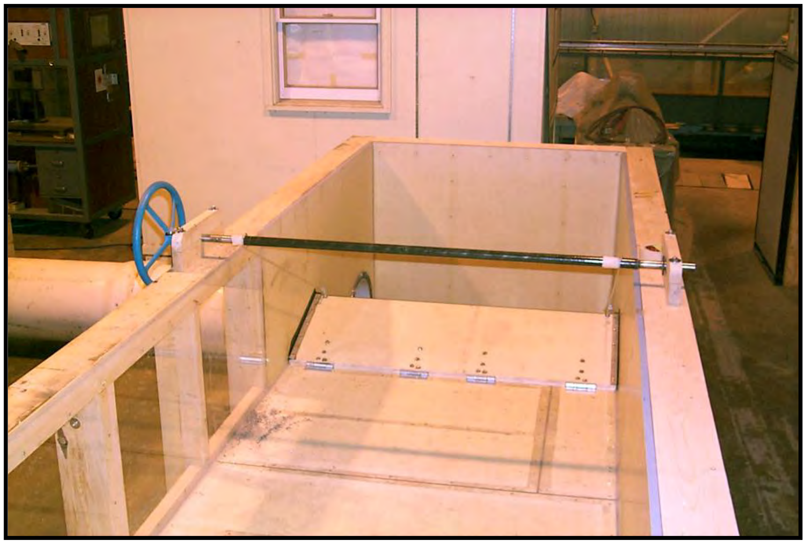


Figure 2.6 Tailgate and Tailrace Flume of 1:48 Sectional Model

2.3.2 Equipment and Initial Operation

A combination of pumps, pipe, and measuring instruments were used in the sectional model. Two low-head pumps supplied flow for the model. A 60-hp pump delivered smaller flows through an 8-inch pipe with a 6-inch orifice. A 75-hp pump supplied larger flows through a 14-inch pipe with a 12-inch orifice. Discharge coefficients for the 6 and 12-inch orifices were C=1.145 and C=5.22, respectively. An 8-foot manometer measured head differential, h, across the orifice allowing computation of prototype discharge from: $Q_p = C(\Delta h)^{0.5}(48)^{2.5}$. Headwater and tailwater elevations were measured using stilling pots with point gages. Point gage elevations were surveyed with an automatic level and referenced relative to the model spillway crest. The headwater elevation was recorded in a calm upstream area near the left training wall. Most water level oscillations were dampened at this location due to distance from the diffuser. Another point gage measured tailwater elevation at approximately 920 prototype feet (19 model feet) downstream of the end sill. A sizeable stilling pot dampened wave fluctuations in the tailrace flume allowing accurate measurement.

Tainter gate positioning requires verification before developing discharge and gate opening relationships. The Gate position relationship was derived from the geometry of individual gates. Various angles and distances obtained from construction drawings or measured on the model. A direct correlation between the positioning rod length and the height of each gate above the gate seal elevation was established. Distances on the metal positioning rods corresponding to each gate opening were marked. The distances between marks provide gate openings every one or two prototype feet. Appendix B presents further details on the geometric relationships for tainter gate rod length positioning.

After gate positioning, discharge and gate opening relationships were developed for the spillway and sluiceway gates. Smaller flows were measured using a 6-inch orifice (C=1.145). A 12-inch orifice (C=5.22) was used for the higher flows. The smaller orifice was calibrated before installation using a weigh tank (Figure C-5 in Appendix C). The larger orifice, used successfully in other model studies, was confirmed with the smaller orifice. The initial operation of the 1:48-scale model displayed a good data overlap for the two orifices (Figures C-2 and C-3). Both orifices were checked after installation using a V-notched weir. Differences between the orifice and weir discharge measurements were about 1% or less (Figure C-4). All flow measurements for these operations were taken at forebay elevation of 1686.0 prototype feet, as specified by IPC. Other details and data of the constant headwater operations are discussed in Section 3.1 of Chapter 3.

2.4 Summary of Modeling Approach

Field tests conducted from 1997 to 1999 reported the persistence of elevated TDG levels below Hells Canyon Dam. Risks to anadromous fish associated with such high gas supersaturation levels revealed the need for gas abatement measures. Spillway deflectors emerged as the most feasible option for TDG reduction because of the high head and distinctive geometry of Hells Canyon Dam. A project team, selected by IPC, established a 1:48-scale hydraulic model as the most valuable method for evaluating potential deflector designs. A two-dimensional sectional model was initially constructed, and various arrangements of equipment and model operations were conducted to prepare the model for evaluation of deflector performance. The two-dimensional sectional model was later rebuilt into a comprehensive three-dimensional model for investigation of erosion impacts and flow characteristics associated with the recommended deflector design.

3. RATING CURVE DEVELOPMENT

Construction of the two-dimensional sectional spillway deflector model presented an opportunity for additional hydraulic model studies of Hells Canyon Dam. IPC considered the hydraulic model as an excellent tool to develop discharge rating curves for the spillway and sluiceway gates. They requested that IIHR perform a complete gate rating analysis. This chapter documents the procedures and results of the gate rating investigation. Comparisons with related experimental research performed by Sutherland and Tinney (1964) at Washington State University (WSU) are included.

3.1 Normal Headwater Condition

Accurate relationships between discharge and gate opening are required for deflector design analysis. Discharges for the normal headwater condition were verified to ensure satisfactory hydraulic conditions during the evaluation of deflector designs. A complete set of rating curves was later developed independently. A correlation between gate opening and discharge per bay was developed for the spillways and sluiceways using a prototype headwater elevation of 1686.0 feet. The spillway gates were set in 2-foot increments from 0.0 feet to12.0 feet and 4-foot increments from 12.0 to 36.0 feet. The sluiceway gates were set in 2-foot increments from 0.0 to 26.0 feet. The headwater elevation was set to 1686.0 feet for each gate opening through pump and valve adjustment. After allowing the model to stabilize for 15 minutes, a manometer reading was taken. The manometer reading was then converted into a discharge value by the simple expression:

$$Q_p = Q_m (48)^{2.5} = C(\Delta h)^{0.5} (48)^{2.5} \qquad \text{(Equation 3.1)}$$

Where Q_p = prototype discharge (cfs)
Q_m = model discharge (cfs)
48 = geometric scale factor
C = orifice discharge coefficient
Δh = head difference reading on manometer (model ft)

The discharge values recorded were taken separately for spillways and sluiceways. Each spillway gate was opened to the same height. The discharge per bay was determined by dividing the total flow by three. The same procedure was used for the two sluiceway gates. Figure 3.1 displays the relationship between discharge per bay and vertical gate opening at a constant headwater elevation of 1686.0 feet for the spillways and sluiceways.

Since two different orifices were required to obtain the minimum and maximum flow rates, several intermediate discharge measurements were recorded using both orifices showing value consistency. As discussed in Section 2.3.2, a V-notch weir verified orifice discharge measurements. These discharge measurements are comparable, as illustrated in Figures C-2 to C-4 of Appendix C.

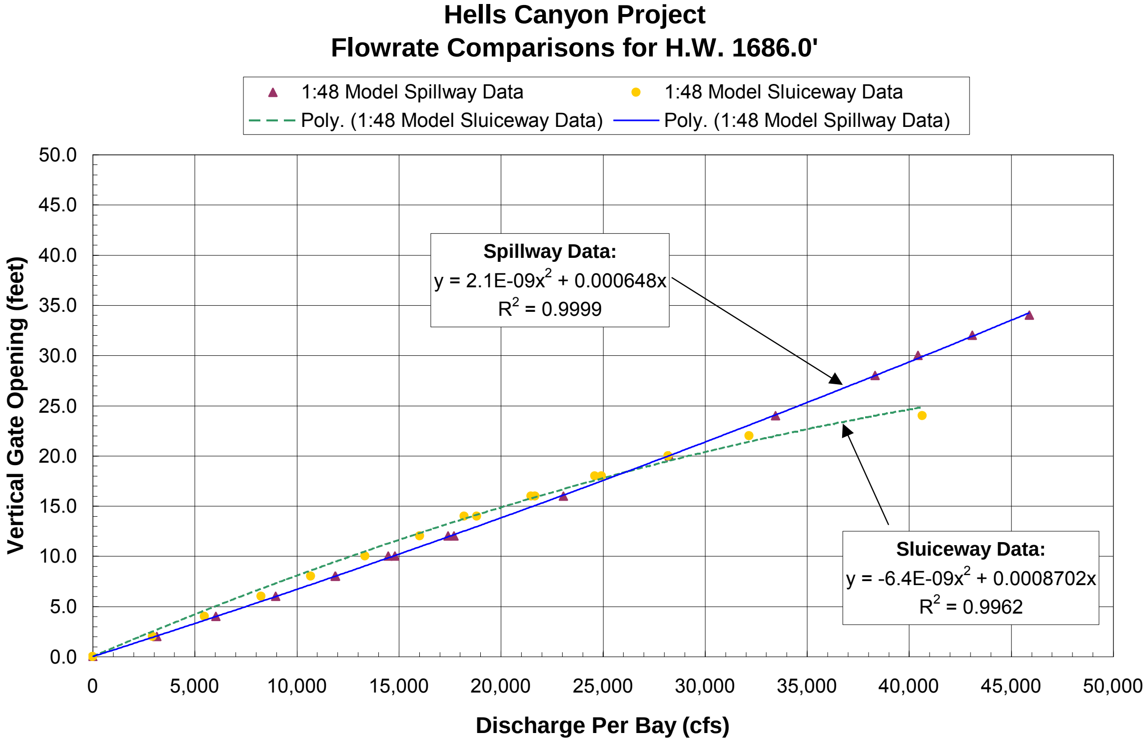


Figure 3.1 Normal Headwater Rating Curves for Spillway and Sluiceway

Spillway data from the 1:48-scale model were compared with USACE experimental results. Sheet 311-1 of Hydraulic Design Criteria gives a relationship for discharge over a spillway with tainter gates (USACE, 1955). According to these design specifications, the discharge coefficient corresponds to an angle measuring the gate opening. Since the Hells Canyon Dam spillway matches Sheet 311-1 design conditions, the angle quantifying gate opening defined by USACE was estimated for Hells Canyon Dam. Discharges per bay were then computed from the Sheet 311-1 empirical relationship (Figure C-6) and were found to be in good agreement with the 1:48-scale model data (Figure C-2).

Empirical submerged outlet discharge data for similar sluiceways is very limited. No direct sluiceway discharge comparisons of normal headwater elevation and with similar experimental results were made for this reason. Detailed discussion of comprehensive rating curves for a range spillway and sluiceway forebay elevations is presented in Section 3.3.

Data obtained by Sutherland and Tinney (1964) from a WSU hydraulic model study of Hells Canyon Dam were consulted throughout this model study. Direct comparisons to Sutherland and Tinney (1964) report are difficult for normal headwater conditions, their data being taken for various forebay elevations, instead of a specific headwater elevation. Data obtained for the sluiceway gate openings, and arbitrary openings were set for several test runs. Direct comparison of IIHR normal headwater discharge relations with results from Sutherland and Tinney (1964) cannot be made. Complete examination of discharge relations obtained by IIHR and Sutherland and Tinney (1964) for the entire forebay elevation range is presented in Sections 3.2 and 3.3.

3.2 No Gate Control Condition

A discharge rating procedure was implemented without gate control of spillways and sluiceways providing further model discharge validation before deflector design investigation. Spillway and sluiceway tests were conducted separately using the 75-hp pump and the 12-inch orifice (C=5.22). Headwater elevations were obtained by adjusting pump and valve settings. After 15 minutes, when the model stabilized, the forebay elevation value was confirmed and the corresponding flow rate obtained from the manometer reading. Prototype headwater elevations for the sluiceway investigation varied from 1568.0 to 1688.0 feet in 10-foot increments. The spillway tests were performed for prototype forebay elevations of 1648.0 to 1693.0 feet in 5-foot increments.

Data obtained by IIHR for the full open condition was compared with empirical data and results from the Sutherland and Tinney model study (1964). USACE (1955) specifies a discharge relationship over an ogee-shaped weir in Sheet 111 of Hydraulic Design Criteria (HDC). This empirical formulation accounts for the geometry of the crest, piers, and abutments. Figure D-2 of Appendix D includes details to compute ungated spillway discharges from

USACE HDC 111 specifications. Figure 3.2 displays IIHR model data, empirical USACE values, and Sutherland and Tinney (1964) model study results for the ungated spillway condition. The plot below shows these values to be in good agreement. Figure 1-3 of Appendix I provides a reference for the data obtained by Sutherland and Tinney (1964) and used for comparison in Figure 3.2.

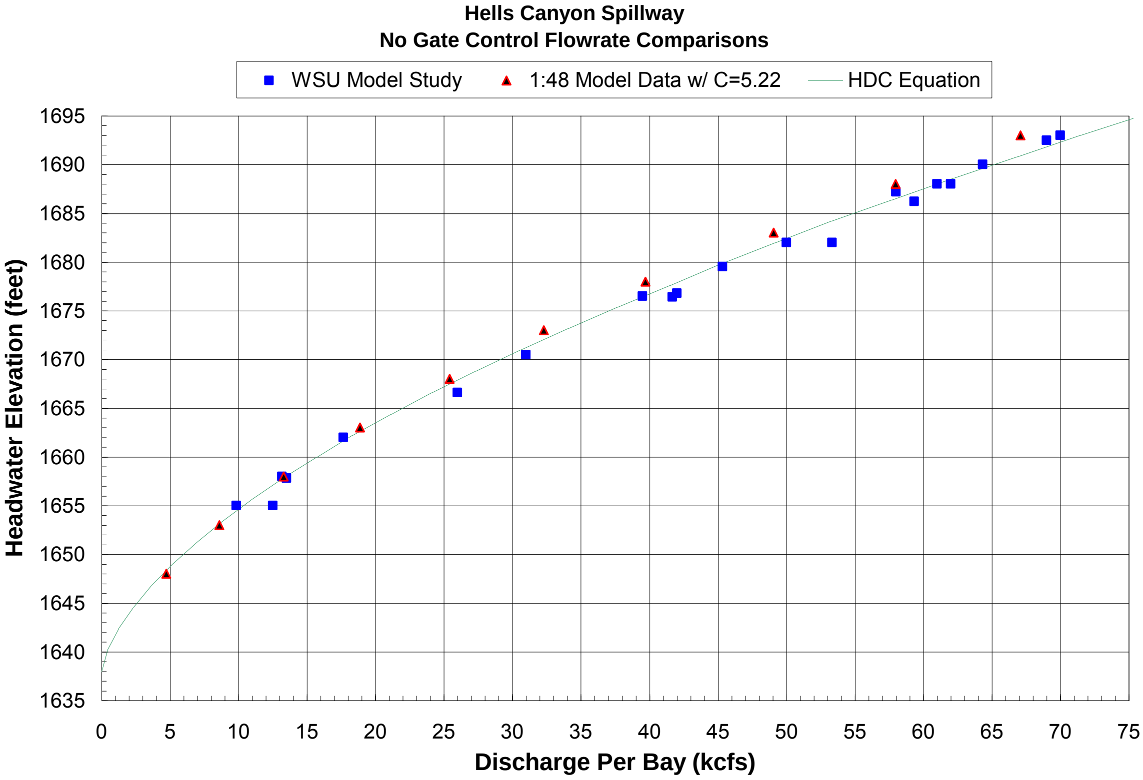


Figure 3.2 Rating Curves for Full Open Spillway Condition

The unique position and configuration of sluiceways prevented use of the USACE HOC 111 relation to compute sluiceway discharges. The sluiceway outlets function as submerged orifices and cannot be treated as typical overflow weirs. Zipparro and Hasen (1993) give expressions for discharge through submerged orifices for a high head and a low head case. The procedure for applying these relations to the sluiceways is provided in Figure D-4. Comparing results from these two formulas (Figure D-4) reveals nearly the same discharge values for low head case, Q_1, and high head case, Q_2. Given the similarity between Q_1 and Q_2 values and the focus on higher head discharges, only the Q_2 discharge values were used for comparisons. Empirical Q_2 values, IIHR model data, and Sutherland and Tinney (1964) model study results are illustrated in Figure 3. 3. IIHR model data compares favorably with calculated Q_2 discharge values, but Sutherland and Tinney (1964) model results deviate from these other two. Although a general pattern is evident from the Sutherland and Tinney (1964), these values differ significantly from empirical and IIHR model results, especially for higher headwater elevations. A reference for the full open sluiceway data obtained by Sutherland and Tinney (1964) is given in Figure I-4.

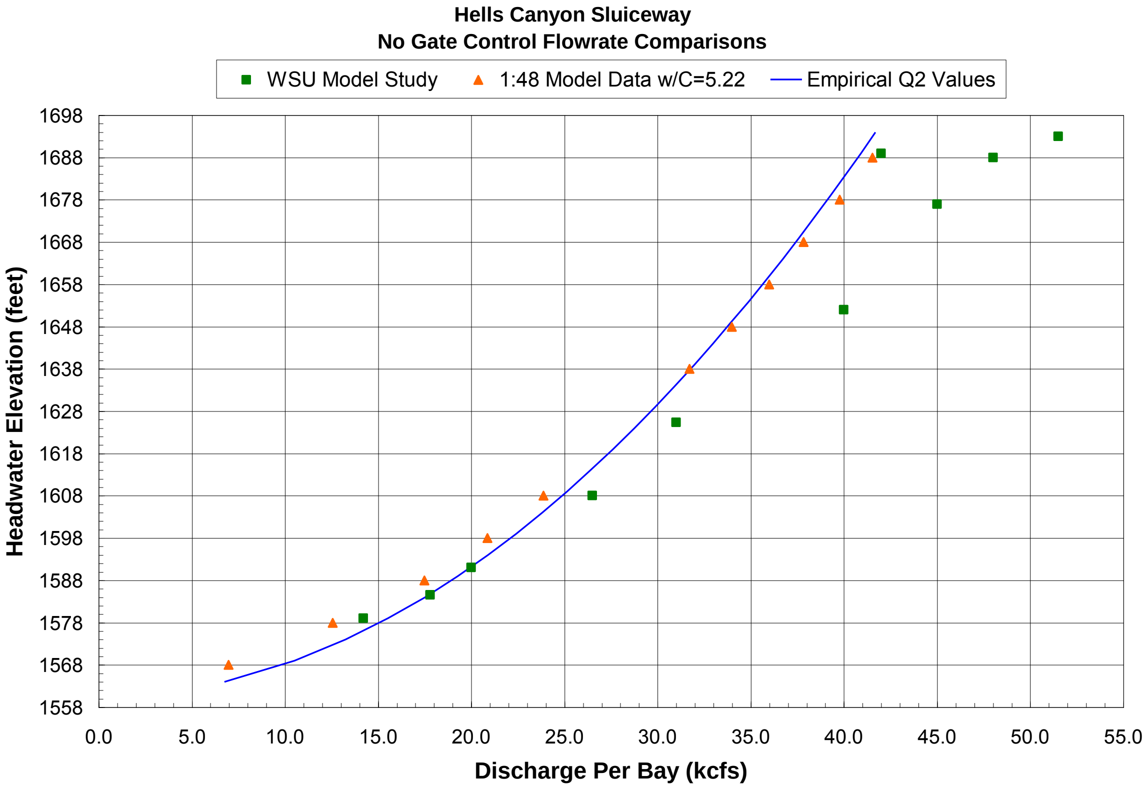


Figure 3.3 Rating Curves for Full Open Sluiceway Condition

IIHR model results for full open spillway and sluiceway conditions generally agree with the corresponding empirical values. A few discrepancies, primarily in sluiceway values, are apparent between IIHR model results and Sutherland and Tinney data. Section 3. 3.4 describe the variations between IIHR and Sutherland and Tinney (1964) in more detail. Despite these differences, the similarity of IIHR model data to published information suggests that IIHR findings are reasonable.

3.3 Comprehensive Rating Curves

Information obtained from the IIHR hydraulic model on conditions of normal headwater without gate control provide a sound basis for discharge relationships required in the evaluation of deflector designs for Hells Canyon Dam. Considerable additiop.al data was required to develop complete rating curves for the spillways and sluiceways. Experimental discharges at various gate openings over a range of headwater elevations were measured for analysis. A variety of methods were implemented to develop a comprehensive rating curve set. Results documented by IIHR were again compared with the hydraulic model study performed by Sutherland and Tinney (1964).

3.3.1 Experimental Procedure

The spillway and sluiceway gate openings were originally determined from individual gate geometries. Marks were placed on positioning rods corresponding to each gate opening. This gate positioning method provides acceptable accuracy discharge measurement for deflector design. Flow rates for developing rating curves, however, require the highest accuracy possible. For this reason, gate openings for spillway and sluiceway rating curve analysis were set using Plexiglas blocks. These blocks were cut and milled to the precise thickness required for each gate opening. The blocks were sized to be placed on the respective spillway or sluiceway crest, with the gate shut onto the block, and the block leveled to provide the proper angle. A 2.0-foot gate openings increment provided sufficient data to generate rating curves, while keeping data collection at an efficient level.

The spillway tests involved positioning all three upper spillway gates to the same opening, beginning with a 2.0-foot prototype opening. The water level in the head tank was brought to prototype elevation 1648.0 feet. The headwater was allowed to stabilize for approximately 15 minutes before forebay elevation and manometer readings were recorded. The headwater was then raised in 5.0-foot increments to 1693.0 feet, with measurements at each interval. The next gate opening was set and measurements taken over the same headwater range. This procedure was used for gate openings from 2.0 feet to 36.0 feet in 2.0-foot increments.

Intervals of 5.0 feet for headwater provide adequate information to develop a rating curve for spillway gate openings. Approximate increments of 5.0 feet were targeted. It was not necessary to obtain headwater elevations exactly 5.0 feet apart. A range of headwaters was needed to develop the relationships between discharge, gate opening, and headwater elevation. The headwater range of needs to be uniformly distributed between 1648.0 and 1693.0 feet to provide consistent representation of the relationship, but exact intervals are not required. Data collection efforts were simplified by adjusting the headwater close to the targeted value, allowing the model to stabilize, and then recording the headwater. This procedure rather was more efficient than adjusting the headwater to exact 5.0-foot increments.

Sluiceway test procedures were very similar to those for the spillways. Intervals of 2.0 feet were used for gate openings from 2.0 to 22.0 feet. The headwaters ranged from 1568.0 to 1688.0 feet at increments of about 10.0 feet. Gate openings were positioned precisely using Plexiglas blocks, similar to those for the spillways. Each headwater elevation was targeted and allowed to stabilize before measurements were made. As with the spillways, exact headwater intervals were not necessary. A general uniform distribution of headwater range obtained the desired trend.

Separate tests, presented in Section 3.2, were conducted for conditions without gate control. Readings were not recorded when gate openings were so large that the headwater level was below the lower spillway or sluiceway gate lip. Measurements were taken only when the gate had an effect on headwater elevation or discharge.

3.3.2 Spillway Rating Curves

A general relationship between discharge, gate opening, and headwater was proposed for the spillways. Regression analysis was performed to determine required parameters. The form of this relationship originates in USACE Hydraulic Design Criteria, Sheet 311-1, (1955); as discussed in Section 3.1. The formula for discharge over a spillway with tainter gates is shown below:

$$Q = CG_oB\sqrt{2gH} \qquad \text{(Equation 3.2)}$$

Where Q = discharge per bay (cfs)
C = discharge coefficient based on gate opening
G_o = effective gate opening (ft.)
B = gate width (ft.)
g = gravity constant (32.17 ft/s^2)
H = head to center of gate opening (ft.)

The spillway at Hells Canyon is of the general shape described in HDC 311-1, so the HDC 311-1 equation was used to describe the relationship between discharge, gate opening, and head:

$$Q = G^{a} H^{b} 10^{c} \qquad \text{(Equation 3.3)}$$

Where Q = discharge per bay (kcfs)
G = vertical gate opening (ft.)
a = gate opening regression coefficient
H = head to center of gate opening (ft.)
b = head regression coefficient
c = regression coefficient for constants

The three regression coefficients, a, b, and c, were obtained through multiple linear regression analysis. The c regression coefficient takes into account all constants, of the USACE HDC 311-1 equation (1955). Several regression analyses were performed with experimental spillway data to determine accurate rating curves.

3.3.2.1 Comprehensive Regression

The simplest regression analysis arranged all experimental spillway data into one set. A single set of regression coefficients was generated for the data. This analysis captured the general trend of the data set. Discrepancies were found, however, between experimental data and values calculated from regression coefficients. The results are displayed in Figure E-1, Appendix E. A goodness-of-fit analysis was performed experimental data and calculated values for each gate opening on all plots. R^2 values obtained for the spillways from this procedure are shown in Figure E-6, Appendix E. The average R^2 value of all gate openings in comprehensive regression analysis was 0.949.

In Figure E-1, and all other spillway and sluiceway rating curve plots, experimental data from the 1:48-scale model is displayed in points. Curves on the plots represent values calculated from regression analysis. Data associated with specific gate openings obtained by Sutherland and Tinney (1964), referenced in Appendix I, is included for comparative. Experimental and empirical data generated by IIHR for full open conditions are incorporated to provide complete rating curves.

3.3.2.2 Consecutive Regressions

A more complex regression analysis was performed to acquire coefficients that more accurately represent experimental data trends. The most comprehensive analysis would produce directly separate coefficients for each gate opening. This procedure is not mathematically feasible. Grouping different combinations of consecutive gate openings together allows separate regression coefficients to be generated for each gate opening. Separate analyses were conducted for sets of two, three, and four consecutive gate openings. Best results were obtained with groups of three consecutive gate openings. Separate regression analysis was performed for each group from 2-6 feet, 4-8 feet, 6-10 feet, and so on up to 32-36 feet. Coefficients for individual gate openings were computed taking the coefficient average from the regression sets containing the respective opening (Figure E-5). The three coefficients obtained for each gate opening were plotted, (Figures E-3 and E-4) to identify trends predicting gate opening coefficients. General patterns were apparent for each of the three regression coefficients. Second order polynomial trend lines (Figure E-4) provide equations predicting values for regression coefficients a, b, and c at any gate opening. Regression coefficients computed from trendlines determine calculated discharge values (Figure 3.4). The average R^2 value (Figure E-6) between experimental data and regression coefficient values calculated for this consecutive regression analysis is 0.975.

Regression analysis for sets of three consecutive gate openings provides a complete and concise set of spillway rating curves. A separate trendline equation predicts each of the three regression coefficients (a, b, and c), allowing direct substitution into the general discharge equation. This procedure produces calculated discharge values very consistent with experimental data obtained in the IIHR 1:48 models. This is evident in Figure 3.4 and from the average R^2 value of 0.975 obtained from the goodness-of-fit analysis between the experimental and calculated values. Trendline equations obtained from this consecutive regression analysis, applied with the general discharge equation, accurately predict spillway discharges for any headwater and gate opening combination.

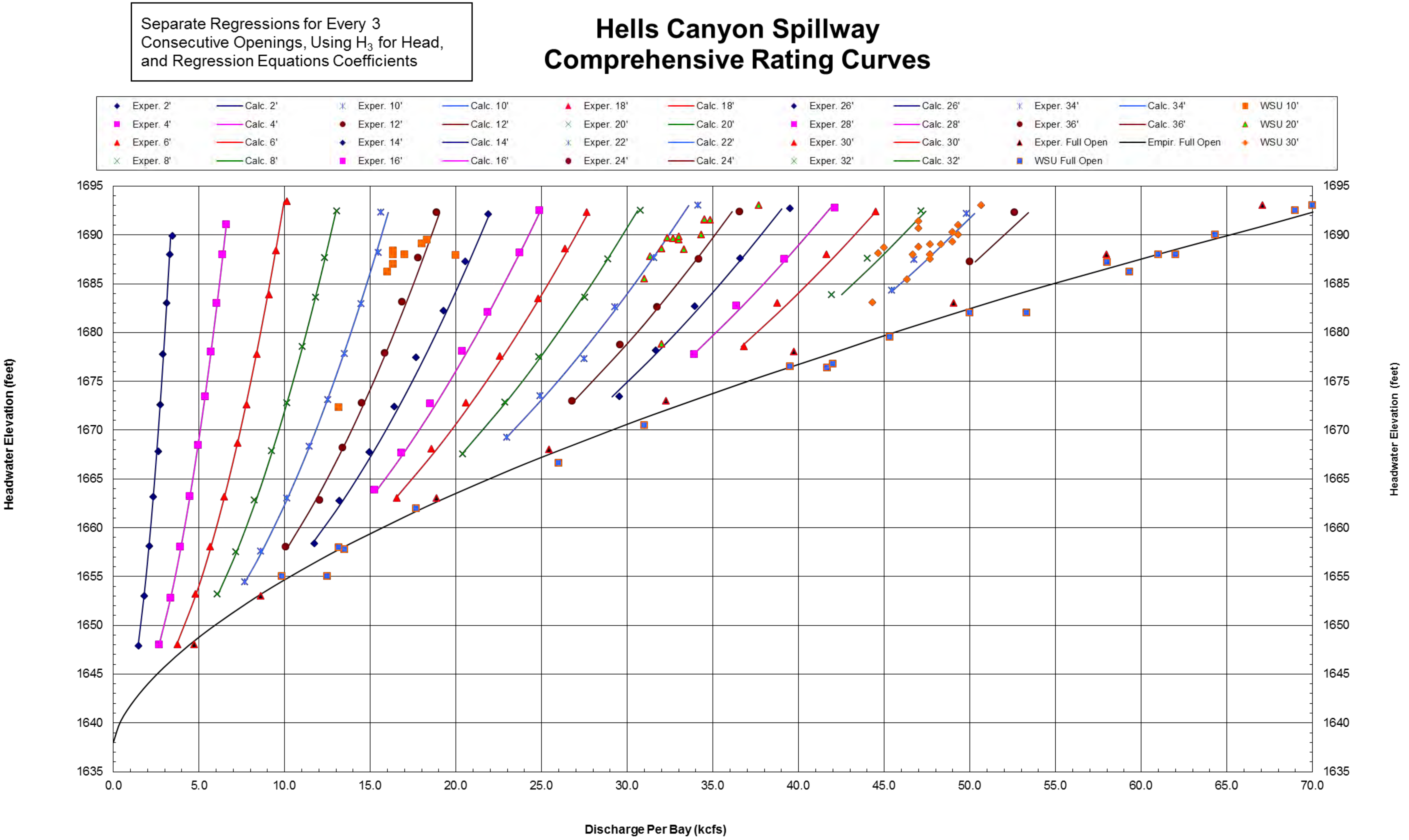


Figure 3.4 Final Comprehensive Spillway Rating Curves

3.3.3 Sluiceway Rating Curves

The basic procedure used for spillways was applied to sluiceways. A general relationship between discharge, gate opening, and headwater was proposed, and regression analysis performed, to determine required parameters. The unique geometry of the sluiceways distinguishes them from traditional gated ogee spillways. They act as submerged orifices. Zipparro and Hasen (1993) present an equation for flow through a submerged orifice when the head is relatively large, compared to the size of the orifice (previously referred to as Q2 in Section 3.2):

$$Q = CA\sqrt{2gH} \qquad \text{(Equation 3.4)}$$

Where Q = discharge per bay (cfs)
C = discharge coefficient based on orifice geometry
A = area of orifice (ft^2)
g = gravity constant (32.17 ft/s^2)
H = head to center of orifice (ft.)

Orifice geometry and head significantly influence discharge coefficients in this equation. The area in this expression can be replaced by the sluiceway gate opening because the sluiceway width remains constant. Based on this, a general submerged orifice equation was used to develop sluiceway discharge rating curves at Hells Canyon Dam:

$$Q = G^a H^b 10^c \qquad \text{(Equation 3.5)}$$

Where Q = discharge per bay (kcfs)
G = vertical gate opening (ft.)
a = gate opening regression coefficient
H = head to center of gate opening (ft.)
b = head regression coefficient
c = regression coefficient for constants

The three regression coefficients, a, b, and c, were obtained through multiple linear regression analysis. The c regression coefficient takes into account all constants, of the original orifice equation. Several regression analyses were performed with experimental sluiceway data to define accurate rating curves.

3.3.3.1 Comprehensive Regression

The first regression analysis grouped all experimental sluiceway data into one set. This produced one set of regression coefficients to fit all data. Although the general trend was captured by these coefficients, errors between the regressed values and experimental data were significant. A plot of this analysis is found in Figure E-7, Appendix E. An average R^2 value of 0.945, as shown in Figure E-13, Appendix E, was computed for the comprehensive regression analysis of sluiceway gate openings.

3.3.3.2 Two Separate Regressions

Upon further examination of the data, it was grouped into two distinct sets. The sluiceway inlet geometry of the sluiceway inlet provides a unique situation. For gate openings up to 16.0 feet, the gate acts as the primary discharge control. For larger gate openings, the upper transition section of the sluiceway orifice may be the primary control. This concept would validate two distinct sets of regression coefficients.

Given these assumptions, error between regressed values and the experimental data was greatly reduced. Figure E-8 illustrates these results. The average R^2 value between the experimental data and the regressed values for this analysis was 0.994, as seen in Figure E-13.

3.3.3.3 Consecutive Regressions

The idea that a shift in control could occur led to further investigation into sluiceway rating curves. Since two sets of regression coefficients were logical for a shift in control, the concept that each gate opening could have its own set of coefficients was analyzed. This procedure is similar to the consecutive regression analysis for spillways in Section 3.3.2.2. Pairs of consecutive gate openings are grouped together for regression analysis. Separate sets of regression coefficients are obtained for each pair from 2-4 feet, 4-6 feet, and so on up to 20-22 feet. Regression coefficients for individual gate openings are computed averaging coefficient values from two different regression sets (Figure E-12). Figures E-10 and E-11 illustrate plots of the three regression coefficients calculated for each gate opening. Basic trends are evident for each regression coefficient, as displayed by the second order polynomial and linear trendlines in Figure E-11. These trendlines allow calculation of regression coefficients a, b, and c at any gate opening. Calculated discharge values shown in Figure 3.5 were determined using regression coefficients computed directly from trendlines. The goodness-of-fit analysis between experimental discharge values and values calculated from consecutive regression analysis (using regression coefficients computed from trendlines in Figure E-11) gave an average R^2 value of 0.989 (Figure E-13).

As in the spillway analysis in Section 3.3.2.2, a complete and concise set of sluiceway rating curves was developed from regression analysis of consecutive gate openings. Each regression coefficient (a, b, and c) is predicted by a separate trendline equation. The combination trendline equations and the basic sluiceway discharge equation accurately predict sluiceway discharges for any gate opening and headwater combination Figure 3.5.

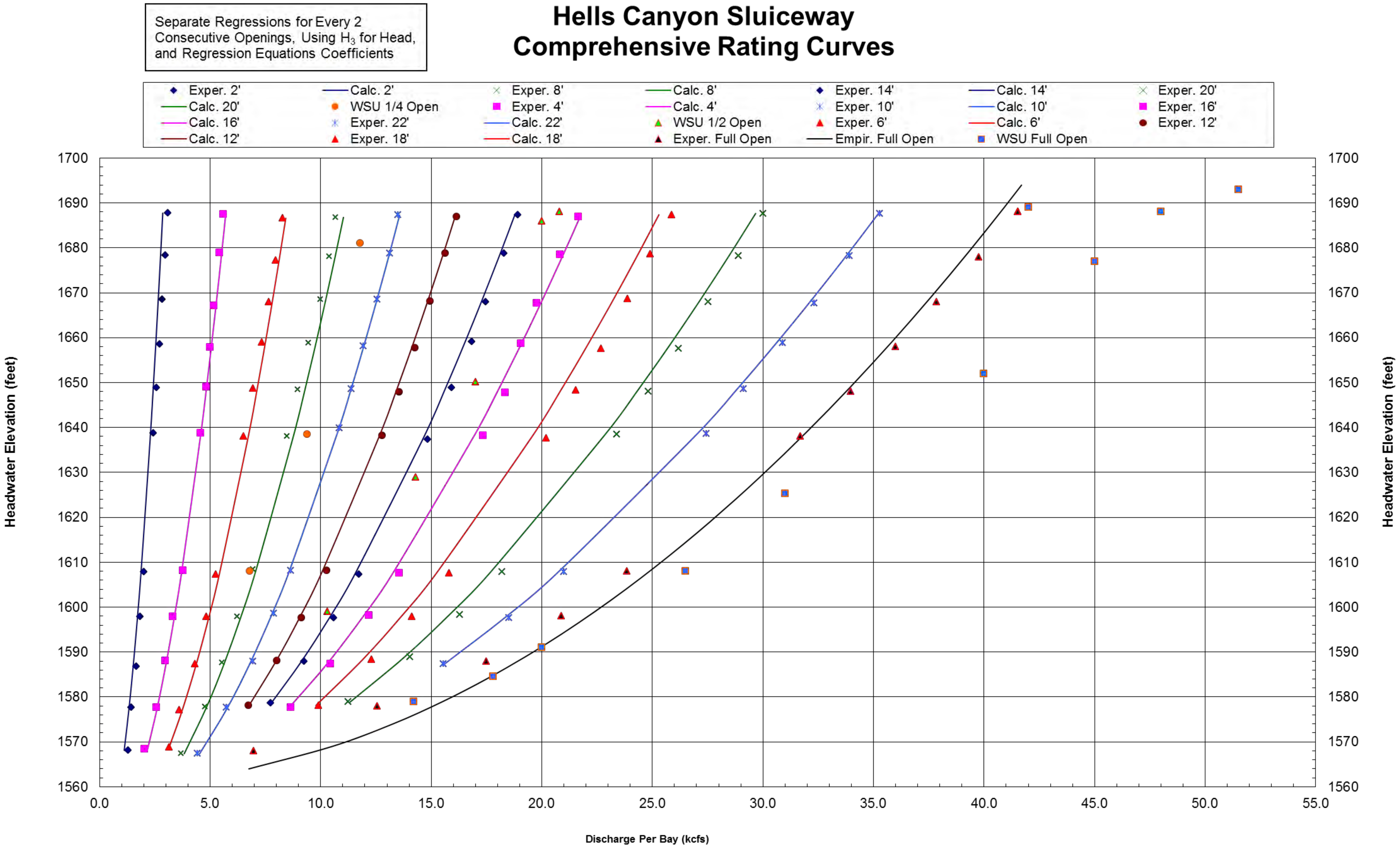


Figure 3.5 Final Comprehensive Sluiceway Rating Curves

3.3.4 Comparison of Results

IIHR results differ from those of Sutherland and Tinney (1964) in a similar model study of Hells Canyon Dam, as shown in the various figures of Appendix E. It is difficult to make direct comparisons to the Sutherland and Tinney (1964) data, especially with the sluiceways. Sutherland and Tinney (1964) acquired minimal data for sluiceway gate openings, and arbitrary openings were used for most test runs performed. Powerhouse flow was assumed to be 27,000 cfs by Sutherland and Tinney (1964) for particular test runs, but no specific values are presented for other trials with the powerhouse in operation. The comparisons illustrated have been adjusted to reflect only total spill flows, which may explain some of the discrepancy. Sutherland and Tinney (1964) present very little information regarding the lab procedures for measuring discharge or water surface elevation. Most variance between Sutherland and Tinney (1964) and IIHR can be attributed to these factors.

As evident from the figures in Appendix E, patterns in the Sutherland and Tinney (1964) data are difficult to discern for various spillway gate openings. Sutherland and Tinney (1964) recorded much data at spillway gate openings of 10, 20, and 30 feet, but inconsistently. A set of rating curves was presented for these gate openings in the report as Exhibit 6, but very few of the test runs documented were used to develop the curves. Another difficulty for sluiceway rating curves comparisons is presented by the ambiguous gate openings of ¼, ½ and ¾ open. These settings correspond to gate openings of 5.75, 11.5, and 17.25 feet based on 23 feet as full open from their report. These rating curves, shown in Exhibit 5 of the Sutherland and Tinney (1964) report, were developed from only a few test runs that were not well documented and have considerably higher discharges than observed by IIHR as shown in Appendix E.

3.4 Summary of Results

Experimental IIHR data to develop spillway and sluiceway rating curves for Hells Canyon Dam is consistent. Experimental data for normal headwater and ungated flow conditions agrees well with the empirical relations presented by USACE (1955) and Zipparro and Hasen (1993). Ungated spillway results also compare well with the Sutherland and Tinney (1964) hydraulic model study (Figure 3.2). The data and rating curve shown by Sutherland and Tinney (1964) for the full open sluiceway condition is consistent, but the discharges reported are considerably higher than those obtained experimentally and empirically by IIHR (Figure 3.3).

Consistent trends were observed in IIHR experimental for developing comprehensive spillway and sluiceway rating curves. The empirical equations developed from consecutive regression analyses accurately predict spillway and sluiceway discharges for given gate openings and headwater elevations (Figures 3.4 and 3.5). Consecutive regression analyses allow great freedom for regression coefficients and provide the most accurate empirical fit to experimental data. Trendlines to predict the three regression coefficients (a, b, and c) for the spillway and sluiceway rating curves provide continuous equations valid for any gate opening (Figures E-4 and E-11). The combination of continuous trendline equations with general discharge relationships provide accurate prediction of spillway and sluiceway discharges for all gate opening and headwater elevation combinations.

4. DEFLECTOR PERFORMANCE TESTING

Following construction and preparation of the two-dimensional sectional model, study was initiated evaluating potential deflector designs for Hells Canyon Dam. Preliminary investigations provided information directing the focus on sluiceway deflectors. Details related to sluiceway flow deflector design using the 1:48 sectional model are included in this chapter. Procedures for developing performance curves are described and background on deflector design is provided. The deflector designs tested and their hydraulic performance are presented with discussion of general velocity patterns obtained from the model. A summary of results and recommendations concludes the section.

4.1 Background and Preliminary Testing

The distinctive geometry of Hells Canyon Dam presents some interesting challenges in developing deflectors for TDG mitigation. The upper nappe deflectors, high head, deep, short stilling basin, lower level sluiceways, and high unit discharge are important factors for effective deflector design at Hells Canyon Dam. After initial model operation, it became apparent that unique flows by the upper nappe deflectors would be problematic for the design of upper spillway deflectors. Flows from the upper spillway gates are deflected away from the concrete spillway surface. The flow becomes a nearly unattached, free-falling jet (Figure 4.1). This flow phenomenon, and the relatively large head, necessitate very large deflectors for the upper spillway gates. Preliminary model tests revealed big problems for large spillway deflectors. Spillway releases above the TDG design discharge impact the riverbed downstream of the stilling basin. This condition poses a threat to dam safety.

Based on these early tests, it was decided that dam operation flexibility could be maintained if an acceptable deflector design could be developed for the lower level sluiceways. The lower level sluiceways could then be operated when TDG levels are important, and the upper spillway gates could be operated for high spill discharges when energy dissipation and dam safety become imperative. Design performance is improved by this sluiceway deflector location due to a flatter surface and sidewall containment. A profile sketch indicating general sluiceway deflector location is shown in Figure 4.2.

Figure 4.1 Unattached Spillway Jet

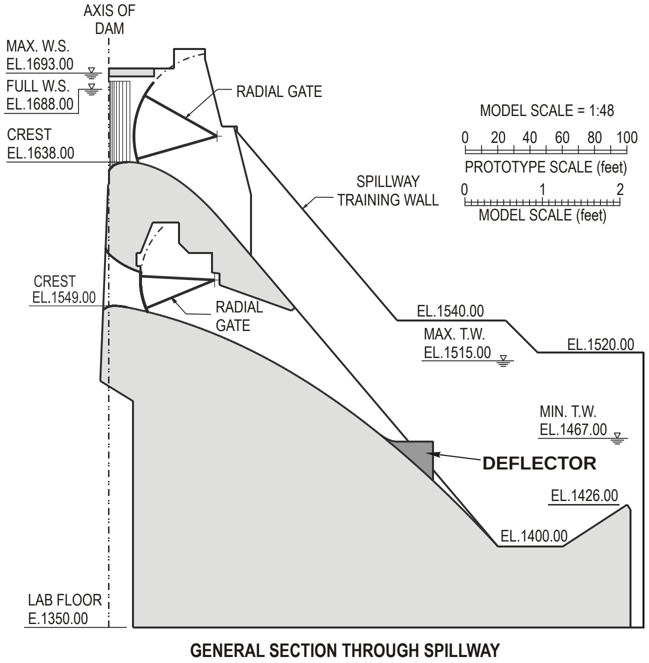


Figure 4.2 Typical Sluiceway Deflector Location

4.2 Baseline Conditions

A balance between energy dissipation and bubble entrainment must be achieved for acceptable flow deflector development. Figure 4.3 illustrates conditions for a 10.0 kcfs discharge through the upper spillway without flow deflectors at Hells Canyon Dam. The stilling basin is the primary means of energy dissipation. It is critical that flow deflectors dissipate enough energy to maintain the structural integrity of the dam.

Figure 4.3 Baseline Condition with No Deflectors

The purpose of flow deflectors is demonstrated in Figure 4.3. Baseline conditions result in large amounts of air entrainment and bubbles brought to depth. Flow deflectors create a more surface-oriented flow regime, decreasing air entrainment and bringing fewer bubbles to depth. This reduction in hydrostatic pressure and air entrainment increases TDG abatement potential.

4.3 Development of Performance Curves

Previous USACE and IIHR research on deflector installations guided this model study. Procedures documented by USACE (1999) and IIHR (Nielsen, Weber, and Haug, 2000) set forth basic methods, but the high head of Hells Canyon Dam posed a unique challenge for the project resulting in a modified performance curve.

A design discharge of 15.0 kcfs per sluiceway bay was used to develop performance curves for various deflector designs. A prototype discharge of 2.5 kcfs was set in each sluiceway, and the forebay was allowed to stabilize at 1686.0 feet for 15 minutes. The tailwater elevation approximately 920 prototype feet downstream from the end sill was set to 1500.0 feet providing deep deflector submergence. The corresponding flow regime for this tailwater was observed and recorded. The tailwater, and submergence, were gradually lowered until a flow regime change was detected. The discharge, tailwater elevation, and flow regime were then recorded. This procedure was repeated until a tailwater corresponding to the plunging flow regime was observed. This process was implemented for prototype flows of 5.0, 7. 5, 10.0, 12.5, and 15.0 kcfs per sluiceway bay. Four distinct flow regime classifications were observed. These regimes are described and illustrated below for a spill discharge of 5.0 kcfs per sluiceway bay using a flow deflector 16.0 feet long with a 5° lip angle set at a prototype elevation 1468.0 feet (see videotape).

a. Surface Jump: The deflector is deeply submerged, and flow rolls back onto the jet within the sluiceway. The jet begins to ramp above the water surface. Very few bubbles are at depth in the stilling basin. A thin shear layer is visible just beneath the jet (Figure 4.4).

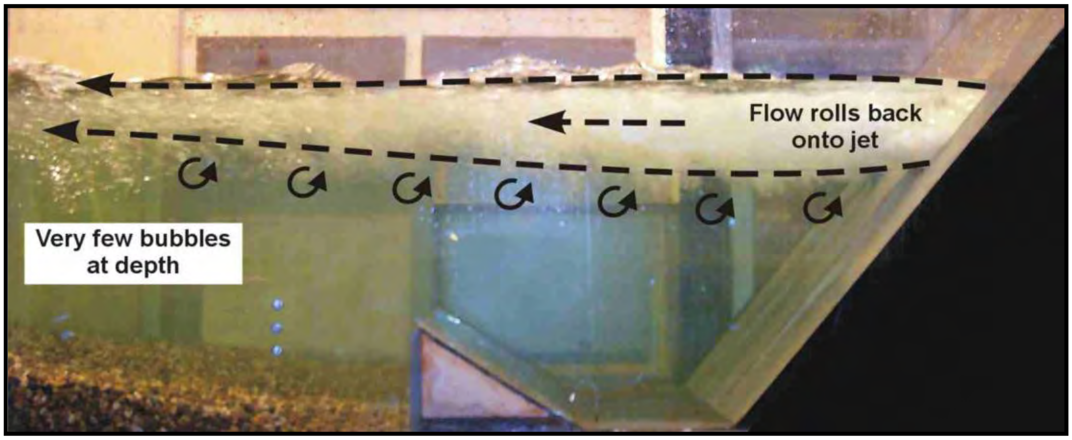


Figure 4.4 Surface Jump Flow Regime

b. Surface Jet: The jet is swept out, and the flow deflected 5-10 degrees above the horizontal. The entire jet is surface oriented and relatively flat. A thin shear layer remains visible beneath the jet (Figure 4.5).

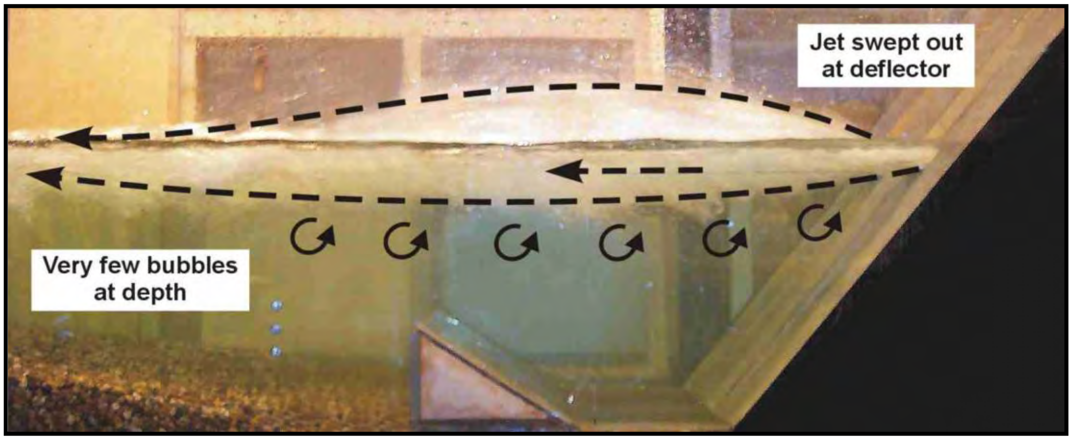


Figure 4.5 Surface Jet Flow Regime

c. Vented Surface Jet: This flow regime begins as submergence is lowered to where the nappe intermittently aerates. The jet is still surface oriented and appears to deflect off the downstream water surface. An area of recirculation develops within the stilling basin (Figure 4.6).

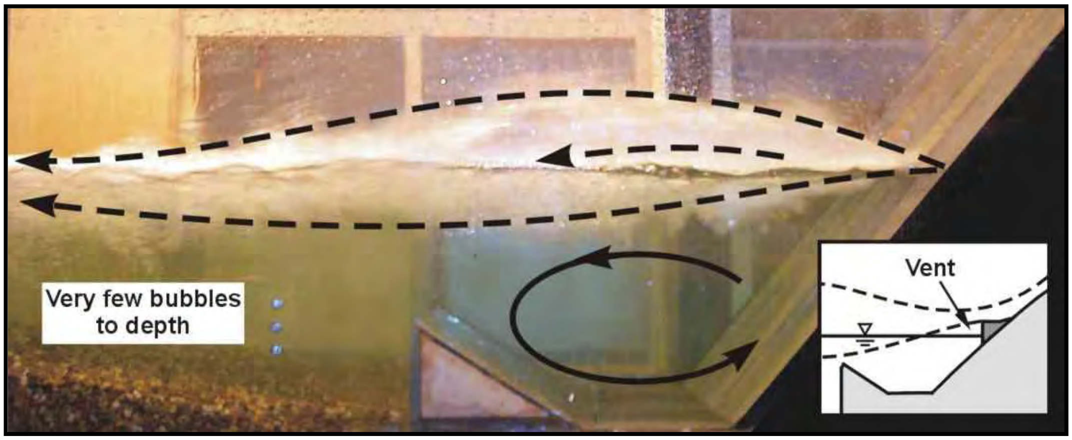


Figure 4.6 Vented Surface Jet Flow Regime

d. Plunging Flow: The jet is consistently aerated and entrains bubbles to depth beyond the stilling basin. A recirculation pattern below the jet occasionally brings bubbles to depth within the stilling basin (Figure 4.7).

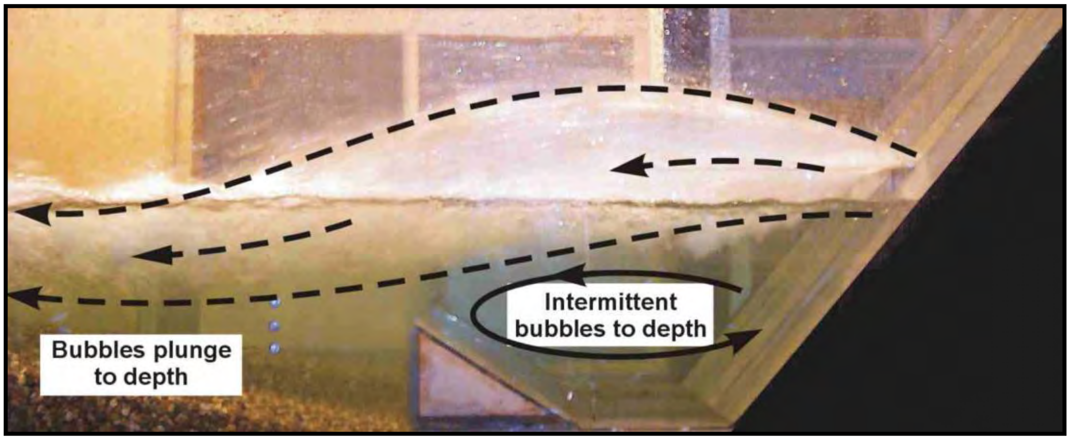


Figure 4.7 Plunging Flow Regime

A performance curve was generated with this method. Tailwater elevations corresponding to a flow regime change classification were plotted against the respective discharge per sluiceway bay. Distinct boundaries between the four flow classifications were apparent and denoted. Included on these plots, were tailwater curves for sluiceway discharges with 0, 1, 2, and 3 powerhouse units operating. A prototype discharge of 10.0 kcfs per powerhouse was used to obtain the curves. The combination of deflector performance and tailwater curves on a single plot creates a powerful analysis tool for deflector design. These plots form a basis for comparison of deflector designs, to optimize normal operating conditions and surface jet flows. Examples of these performance curves are shown in Figures 4.10 and F-1 to F-4.

4.4 Background of Deflector Designs

Primary flow deflector design components include elevation, length, transition radius, and lip angle. These features are interrelated and their reconciliation is complex. Prior IIHR with deflector experience at Wanapum Dam and Rock Island Dam provide a reliable source of information. Variations in head, gate geometry, and tailwater conditions preclude a deflector design based solely on previous research. Close examination of design goals helps to focus on a logical range for these values. Establishing limits for design factors minimizes iteration in design procedure.

4.4.1 Deflector Elevation

Preliminary flow deflector elevation was determined analyzing tailwater curves for total river discharges at or below 60.0 kcfs. This design discharge value is logical as it incorporates over 98% of flows on the Snake River from 1965 to 1999, as recorded by USGS at gauge 13290450 below Hells Canyon Dam. IPC developed an exceedence curve (Figure 4.8), from these discharge records, demonstrating that the total river discharge of 60.0 kcfs has only a 2% probability of being exceeded. With three powerhouse units operating at capacity (10.0 kcfs each), maximum spill discharge is 30.0 kcfs. The flow deflectors were designed to pass as close to 30.0 kcfs as possible. The unique dam geometry favors sluiceway flow deflector rather than in the upper spillways. Analyzing the tailwater curves for discharges of up to 15.0 kcfs per sluiceway bay, an initial deflector elevation was determined. Deflector elevation must remain below the tailwater level to prevent vented surface and plunging flows. These flow regimes result in large amounts of air being carried to depth, increasing the potential for gas supersaturation. Deflector elevation should be high enough to keep performance within the surface jet flow regime for high tailwaters, since the surface jump flow regime may bring about higher TDG levels. Based on this analysis, an initial deflector elevation of 1468.0 feet was proposed.

4.4.2 Deflector Length

Another critical flow deflector design component is length. Deflectors must be long enough to deflect flow, but short enough to minimize construction cost. Cavitation is also a factor of concern in flow deflector length. Sluiceway bay deflectors at Hells Canyon Dam could cause cavitation problems if they extend beyond the spillway face. If the protrusion is severe enough, cavitation damage to deflectors can occur from upper spillway nappe impacts. The model demonstrates that upper spillway nappe flow impact on the recommended sluiceway deflectors is minimized by the upper nappe deflectors. These factors help determine a preliminary design length of 14.3 prototype feet, which extends 6 inches beyond the spillway face.

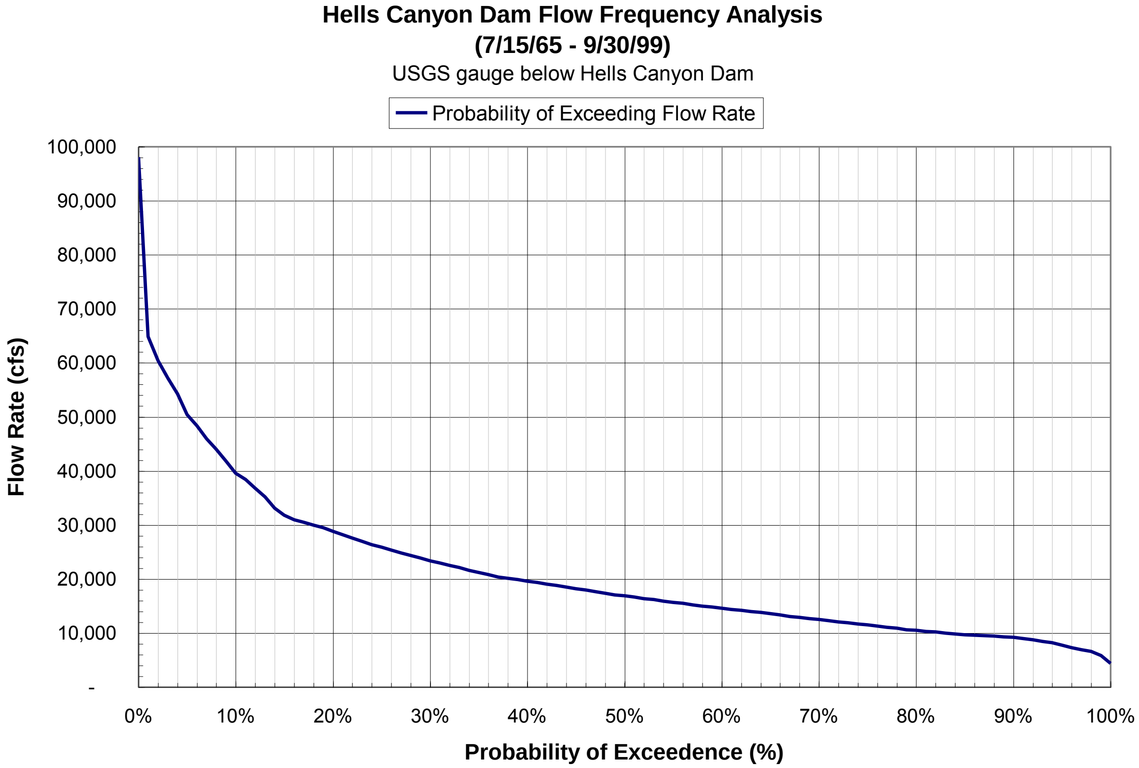


Figure 4.8 Exceedence Curve for Flow Rates at Hells Canyon Dam

4.4.3 Deflector Transition Radius

The transition radius is the radius of an arc connecting the sluiceway face to the horizontal deflector face. Various deflector designs implemented and tested by IIHR, USACE, and other agencies show good results with a 15.0-foot transition radius. This radius was used initially to minimize fish injury. These studies demonstrate that this radius has a positive impact on performance. A base value of 15.0 feet was used for all of deflectors tested in this study.

4.4.4 Deflector Lip Angle

The final element in flow deflector design is lip angle. Several previous deflectors have been designed with the upper face angled slightly upward. The length of the angled portion and the angle degree are critical to Hells Canyon Dam deflector performance. Initially, deflector designs analyzed by IIHR used a 0° lip angle. Several different angles were examined over the course of the model study to optimize performance at Hells Canyon Dam up to 30.0 kcfs.

4.5 Deflector Performance Investigation

The primary analysis method IIHR used for flow deflector design was performance curve development. Procedures outlined in Section 4.3 were utilized to generate curves, allowing evaluation of many sluiceway deflector designs. As discussed in Section 4.1, preliminary testing indicated that sluiceway deflectors to be superior to spillway deflectors for a number of reasons. The study therefore focused on the performance of various sluiceway deflectors. Sluiceway deflector designs were modified until an optimum was attained. This deflector maximizes the overlap, illustrated by the performance curve, of normal operating conditions with the surface jet flow regime, for flows up to the design spill discharge of 30.0 kcfs (15.0 kcfs per sluiceway bay). Table 4.1 summarizes basic design parameters and performance for tested deflectors.

4.5.1 Deflector Design Performance

A deflector design length of 14.3 feet, with elevation 1468.0 feet, was tested. This deflector had a 0° lip angle and a 15.0-foot transition radius. A complete performance curve was generated (Figure F-1, Appendix F). It is clear from analysis that small spill discharges occurring with the three powerhouse units at full capacity fall into the surface jump flow regime. Larger spill flows occurring with only one powerhouse unit at full capacity are in the plunging flow category. These results demonstrate the need for further study. The typical range of operations and conditions do not fall within the surface jet flow regime.

An identical 14.3-foot deflector was tested at elevation 1464.0 feet. This elevation provides a lower boundary for deflector design. A full performance curve was generated for this deflector (Figure F-2, Appendix F). As at the 1468.0 foot case, the 14.3-foot deflector at elevation 1464.0 feet exhibits surface jump flow characteristics at small spill discharges under normal operating conditions. Improvement was seen for higher spill discharges under operating conditions for one or zero powerhouse units at full capacity. These conditions do not produce plunging flow with the 14.3-foot deflector at elevation 1464.0 feet. Evidence of surface jump flow conditions at small spill discharges resulted in further deflector development and performance range expansion.

Length (feet)	**Elevation (feet)**	**Lip Angle (degrees)**	**Performance Comments**
14.3	1468.0	0	Operations fall into surface jump and plunging flow regime
14.3	1464.0	0	Surface jump flow regime exhibited for small discharges
17.3	1468.0	Varying up to 45	Plunging flow at low tailwaters, drastic changes in flow at high angles
18.3	1468.0	5, 10, and 15	Too drastic of change in flow regimes
18.3	1468.0	0	Good for larger spills, surface jump flows for small spills
14.3	1468.0	5 and 10	Cleaner and smoother flows within surface jet regime; bordering plunging flow at high spills
16.0	1468.0	15	High angle borders on surface jump regime for small spills
16.0	1468.0	10	Good overall performance, angle slightly too drastic at low and high spills
16.0	1468.0	5	Cleanest and smoothest flow, minimal amount of aeration, remained in surface jet regime for normal operations with 1, 2, and 3 powerhouse units

Table 4.1 Summary of Deflectors Tested

Analysis of the two preliminary performance curves reveal that flow regimes can be adjusted relative to tailwater elevations by altering deflector elevation. This principle formed a basis for investigating deflector designs with lip angles. If the flow regimes could be shifted slightly relative to the tailwater curves, normal operating conditions could produce surface jets. A few brief experiments were performed with a 17.3-foot deflector at elevation 1468.0 feet with various lip angles up to 45°. A longer deflector was chosen for these tests to prevent plunging flow at lower tailwater elevations.

This concise investigation of 17.3-foot deflectors with various lip angles led to the development of an 18.3-foot deflector at elevation 1468.0 feet with 0°, 5°, 10°, and 15° lip angles. Each design was explored, but the 5°, 10°, and 15° lip angles changed flow too drastically. Not enough energy was dissipated to prevent the jet from reaching or surpassing the end sill of the stilling basin. The 18.3-foot deflector at elevation 1468.0 feet with a 0° lip angle was analyzed for a full performance curve (Figure F-3, Appendix F). This deflector improved performance for larger spill discharges compared to the 14.3-foot deflector at elevation 1468.0 feet and nearly stays within the surface jet flow regime for small spill discharges.

The performance similarity between 14.3 and 18.3-foot deflectors at elevation 1468.0 motivated testing of lip angles for the 14.3-foot deflector. It was postulated that lip angles would produce more reasonable flow regime variations for a the 14.3-foot deflector. Lip angles of 5° and 10° were examined for the 14.3-foot deflector at elevation 1468.0 feet. The advantage of these deflectors over those with no lip angle is not evident through performance curves. The desired flows remained in the surface jet flow regime. Deflector performance for operations within the surface jet regime was much cleaner and smoother with the lip angles. Less aeration occurred deep in the stilling basin, and the jet remained closer to the surface than without a lip angle. Performance did, however, still border on plunging flow for the higher spill discharges at tailwaters that correspond to one and two powerhouse units at full capacity.

These results led to extending the deflectors to between 14.3 and 18.3 feet to remedy the plunging flow at higher spill discharges. Good results were obtained for these flows with the 18.3-foot deflector, but the lip angles performed poorly. A deflector length of 16.0-foot was proposed at elevation 1468.0 feet with lip angles of 0°, 5°, and 10°. Basic testing of these three designs revealed that the 5° lip performed best. A sketch of the 16.0-foot deflector with a 5° lip angle and 15-foot transition radius at elevation 1468.0 feet is illustrated in Figure 4.9. A full performance curve was developed for this deflector (Figure 4.10).

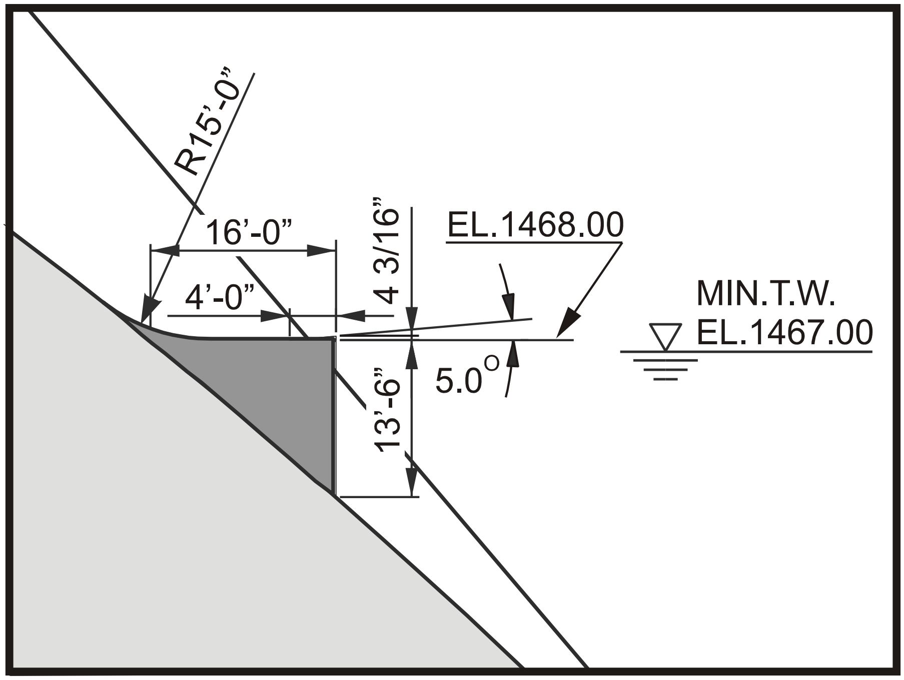


Figure 4.9 Sketch of 16-foot Deflector at Elevation 1468.0 Feet with 5° Lip

Normal tailwater conditions for 1, 2, and 3 powerhouse units at full capacity, with spill discharges ranging from 2.5 kcfs to 15.0 kcfs per sluiceway bay, all remain within the desired surface jet flow regime (Figure 4.10). The 5° lip angle also provides a very smooth, clean flow within the surface jet flow regime. Although tailwater conditions with zero powerhouse flow fall outside desired flow regimes, this operating condition is unlikely in the field. Figures illustrating deflector performance at spill discharges of 2.5, 5.0, 7.5, 10.0, 12.5, and 15.0 kcfs per sluiceway bay, with tailwater conditions for three and no powerhouse units, are included in Appendix G. The videotape accompanying this report also displays the performance of this recommended deflector design. Figure G-13 of Appendix G provides an index to video clips.

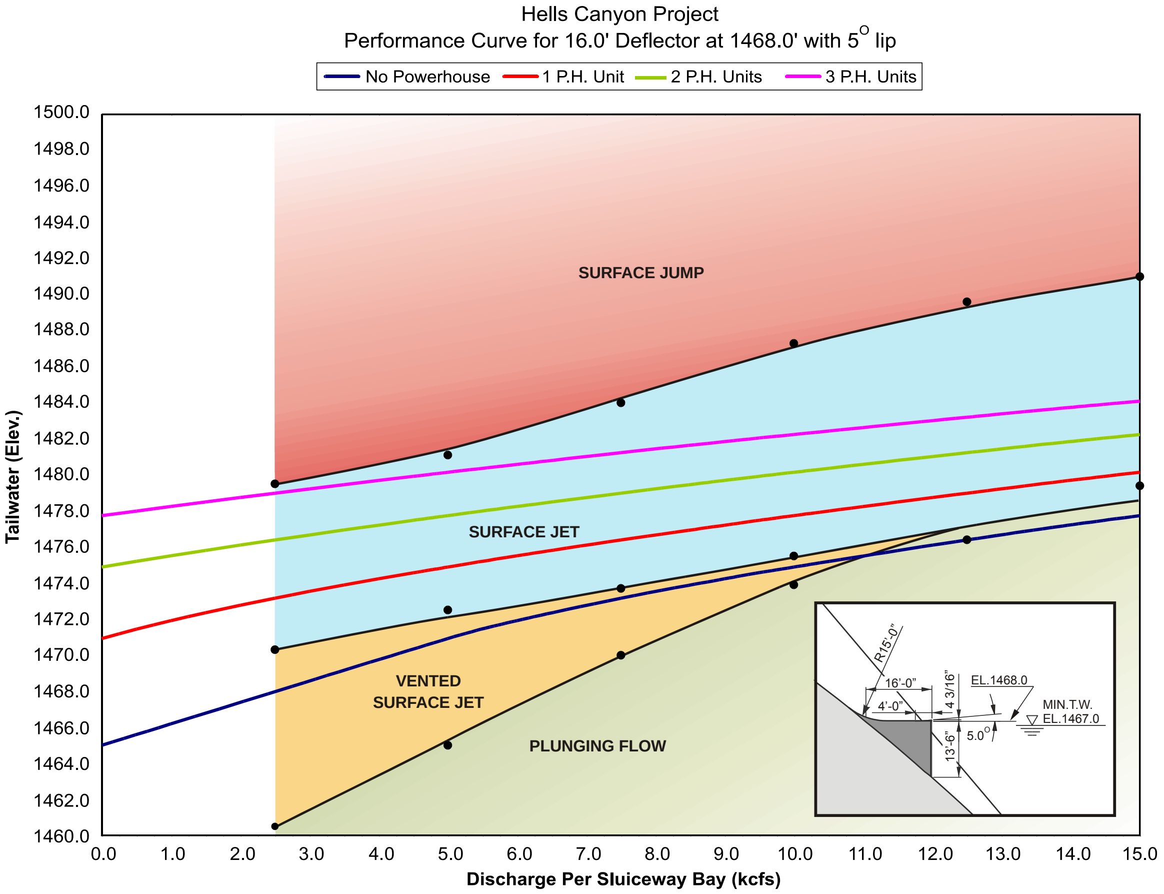


Figure 4.10 Performance Curve for Recommended Deflector Design

4.5.2 Deflector Design Summary

This model study demonstrates that a 16.0-foot deflector at elevation 1468. 0 feet with a 5° lip angle has the highest potential for minimizing TDG. Tailwater curves for normal conditions with 1, 2, and 3 powerhouse units in operation remain in the surface jet flow regime for total discharges of 30.0 kcfs through the sluiceways (up to 60.0 kcfs total river flow with 30.0 kcfs of powerhouse discharge). This satisfies the design criteria of passing 98% of flow conditions within the surface jet flow regime. The potential for cavitation damage is minimized by the 16.0 foot deflector length. This sluiceway deflector design provides flexibility in operating upper spillway gates for total spill discharges exceeding 30.0 kcfs.

4.6 Velocity Profile Measurements

Flow deflectors dramatically change velocity profiles in a river for a short distance downstream of dams due to reduced stilling basin energy dissipation. The current model does not include three-dimensional deflector velocity effects. The two-dimensional sectional model helps to distinguish differences in velocity profiles with and without deflectors.

4.6.1 Experimental Procedure

Velocity measurements in the 1:48-scale sectional model were made using a SonTek Acoustic Doppler Velocimeter (ADV) with a side-looking probe. Three cross sections were positioned at 436, 686, and 936 prototype feet (9.1, 14.3, and 19.5 model feet, respectively) downstream the dam end sill (Figure 4.11). At each of these transects, velocities were measured at five profiles. The left and right-most profiles were each 21.6 prototype feet (0.45 model feet) from the left and right banks (looking downstream), respectively. The left bank wall of the 1:48-scale model flume is parallel to the left spillway guide wall. The right bank wall is 216 prototype feet (4.5 model feet) from the model left bank wall. The three profiles at cross sections were equally spaced between the left and right-most profiles, resulting in a spacing of 43.2 prototype feet (0.9 model feet). Velocity measurements were taken at 0.2, 0.4, 0.6, and 0.8 of the flow depth at all five profiles for each cross section. This procedure was performed for discharges of 2.5, 5.0, 7.5, 10.0, 12.5, and 15.0 kcfs per sluiceway bay with the recommended 16.0-foot deflector with a 5° lip angle at elevation 1468.0 feet in each bay. Baseline velocity measurements were taken without deflectors for spill discharges of 5.0, 10.0, and 15.0 kcfs per sluiceway bay. All tailwater elevations were set for three-powerhouse unit operation at 30.0 kcfs.

4.6.2 Analysis of Results

The profiles for downstream velocity were plotted as shown in Appendix H. The lower baseline condition without deflectors results in a fairly uniform velocity profile for a spill discharge of 5.0 kcfs per sluiceway bay. Spill discharges of 10.0 and 15.0 kcfs per bay exhibit a small amount of recirculation (-1 to -2 ft/s) along the right bank wall with most of the higher positive flows (+8 to +9 ft/s) on the left bank side toward the surface.

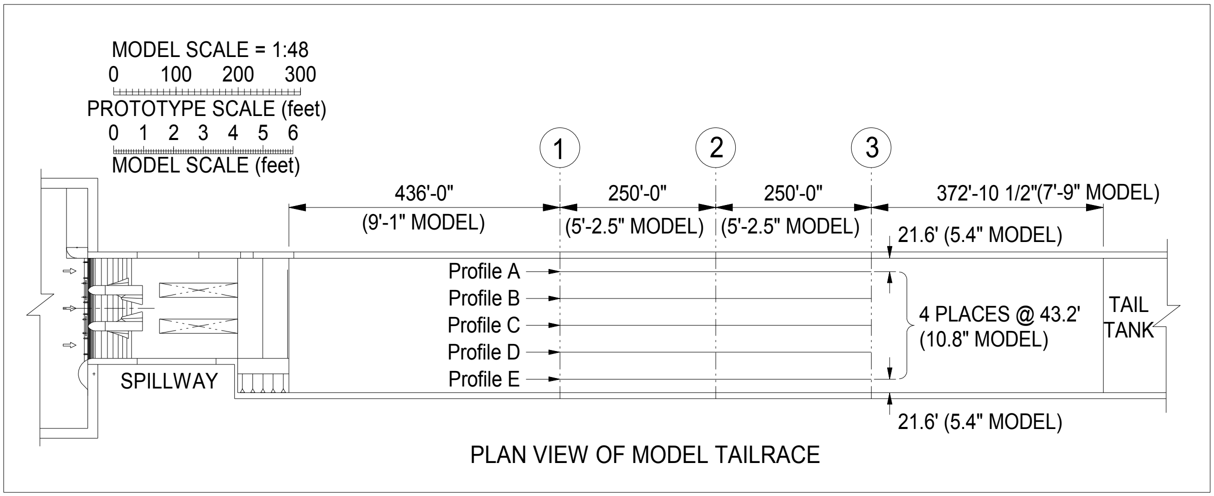


Figure 4.11 Location of Velocity Profiles for 1:48 Sectional Model

Velocity profiles for the recommended 16.0-foot deflector with a 5° lip angle at elevation 1468.0 feet differed from the baseline results. The main discrepancy is the velocity magnitude and the amount of recirculation. Positive velocities as high as 19 ft/s and negative velocities up to -10 ft/s were observed with the deflectors. The condition for a spill discharge of2.5 kcfs per bay did not exhibit the expected right bank recirculation. Spill discharges of 5.0 kcfs per bay displayed a uniform flow profile near the surface with maximum velocity near +6.0 ft/s. Signs of return flow, on the order of -1.5 ft/s, were observed near the channel bed at this discharge. Significant recirculation began along the right bank of the channel for discharges of 7.5 kcfs per bay and higher. This return flow varied from-8 to -10ft/sin the cross section closest to the end sill. The left portion of the first cross section exhibited a similar steady increase in positive velocity from +13 to +19 ft/s for discharges of7.5 to 15.0 kcfs per bay.

The most velocity profile variance occurs in the cross section nearest the end sill. Recirculation diminishes as the flow moves downstream, though small amounts of return flow can be detected along the right bank of the second and third cross sections. Negative velocities up to -4 and -5 ft/s were recorded in these areas for spill discharges ranging from 10.0 to 15.0 kcfs per bay with deflectors. The left portion of the channel displays a uniform velocity profile in the second and third cross sections.

These initial velocity measurements illustrate how the recommended deflectors would change flow patterns below Hells Canyon Dam. Some general patterns are present in the tailrace with or without deflectors. The magnitude of the velocities with deflectors was significantly higher than without deflectors, especially near the water surface. Flow regimes produced by deflectors shift energy dissipation from deep in the stilling basin toward the water surface and farther downstream of the dam. This energy dissipation displacement, coupled with recirculation pockets, is the primary source of concern over velocity profile changes due to the recommended deflectors. These flow characteristic modifications suggest the need for a more extensive, three-dimensional, investigation into the impact of the recommended deflectors on bankline erosion and riverbed scour.

4.7 Summary of Results

The hydraulic model study performed for Hells Canyon Dam produced a recommended deflector configuration that meets the specified design goals. The 16.0-foot deflector with a 5° lip angle at elevation 1468.0 feet has the highest potential minimize TDG levels for sluiceway discharges up to 15.0 kcfs per bay, within the 98% flow exceedence level. This deflector maintains desirable flow performance under typical operating conditions with 1, 2, and 3 powerhouse units. The recommended sluiceway deflectors retain operational flexibility to pass spill flows larger than 30.0 kcfs through the upper spill gates, while dissipating enough energy to maintain the structural integrity of the dam. Preliminary velocity measurements emphasize the need for further exploration of flow deflector effects on general flow patterns, bed scouring, and bankline erosion. A comprehensive three-dimensional model is proposed to investigate potentially adverse effects associated with the recommended deflector design.

5. CONCLUSIONS

Information obtained from IIHR hydraulic model studies is vital for development of a successful Hells Canyon Dam deflector design. Some conclusions can be drawn from background information, experimental procedures, and model study results described in this report. This chapter presents conclusions from hydraulic modeling of Hells Canyon Dam related to rating curve development and deflector performance testing.

5.1 Rating Curve Conclusions

- Experimental data acquired by IIHR for normal headwater and ungated flow conditions are comparable to values computed from empirical relations presented by USACE (1955) and Zipparro and Hasen (1993).
- The comprehensive set of spillway and sluiceway rating curves developed from consecutive regression analyses are the empirical relations that agreed best with experimental data from the 1:48 model.
- The empirical equations developed from consecutive regression analyses provide a complete and accurate method to predict spillway and sluiceway rating curves for any combination of gate openings and headwater elevations.
- Comparing results by Sutherland and Tinney (1964) and those obtained by IIHR is difficult due to differences in data collection and experimental procedure.

5.2 Deflector Performance Testing Conclusions

- The two-dimensional hydraulic model study indicates that a 16.0-foot deflector with a 5° lip angle and 15-foot transition radius at elevation 1468.0 feet has the greatest potential for reducing air entrainment and/or TDG.
- Limiting the recommended deflector length to 16.0 feet minimizes cavitation damage potential.
- The recommended sluiceway deflectors satisfy the design criteria of passing 98% of flow conditions in the surface jet flow regime, while maintaining the operational flexibility for passage of large spill releases.
- The lower level sluiceways are to be operated for flow conditions when TDG levels are important. The upper spillway gates can be operated for high spill discharges

when energy dissipation and dam safety are imperative (spill discharges in excess of 30.0 kcfs).

- Preliminary velocity measurements from the two-dimensional sectional model suggest the need to further explore the impact of the recommended deflectors on general flow patterns, bed scour, and bank erosion.

APPENDIX A

1:48 SECTIONAL MODEL LAYOUT AND CONSTRUCTION DRAWINGS

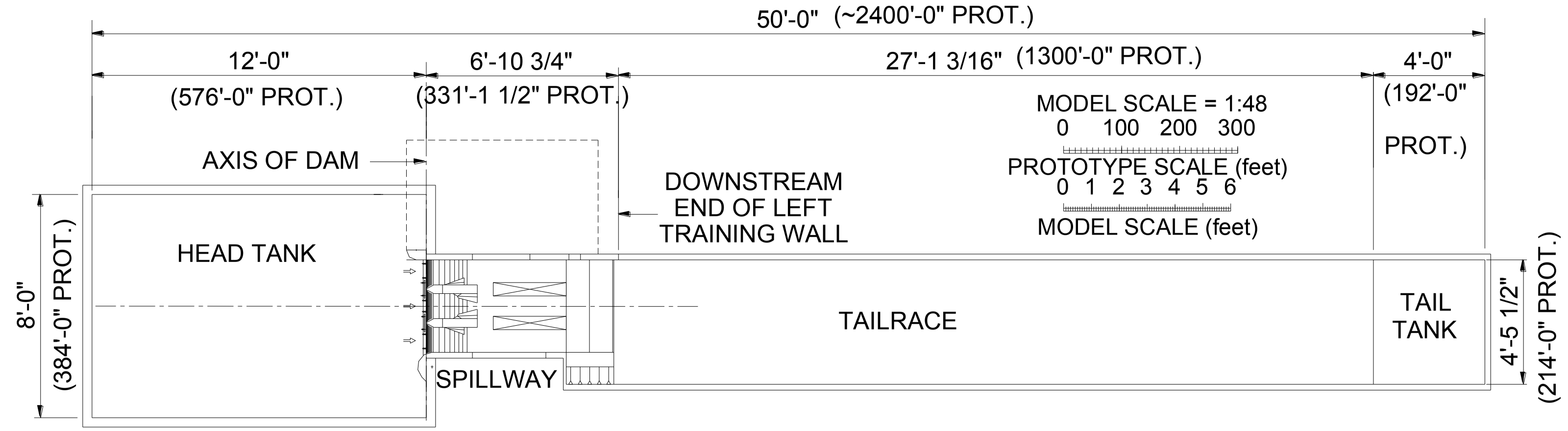


Figure A-1 Plan View of 1:48 Two-Dimensional Sectional Model

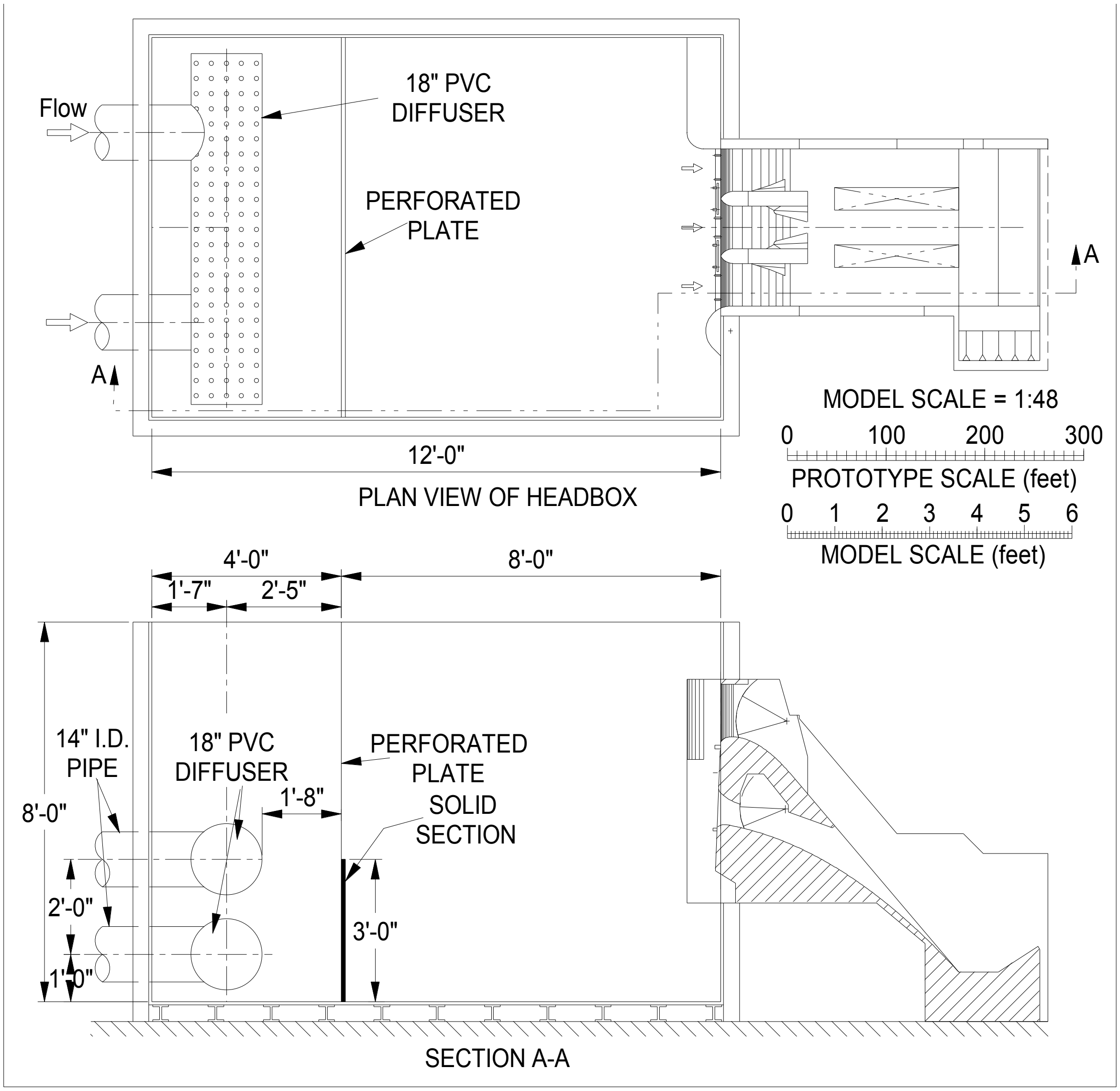


Figure A-2 Plan and Section of Head Tank for 1:48 Sectional Model

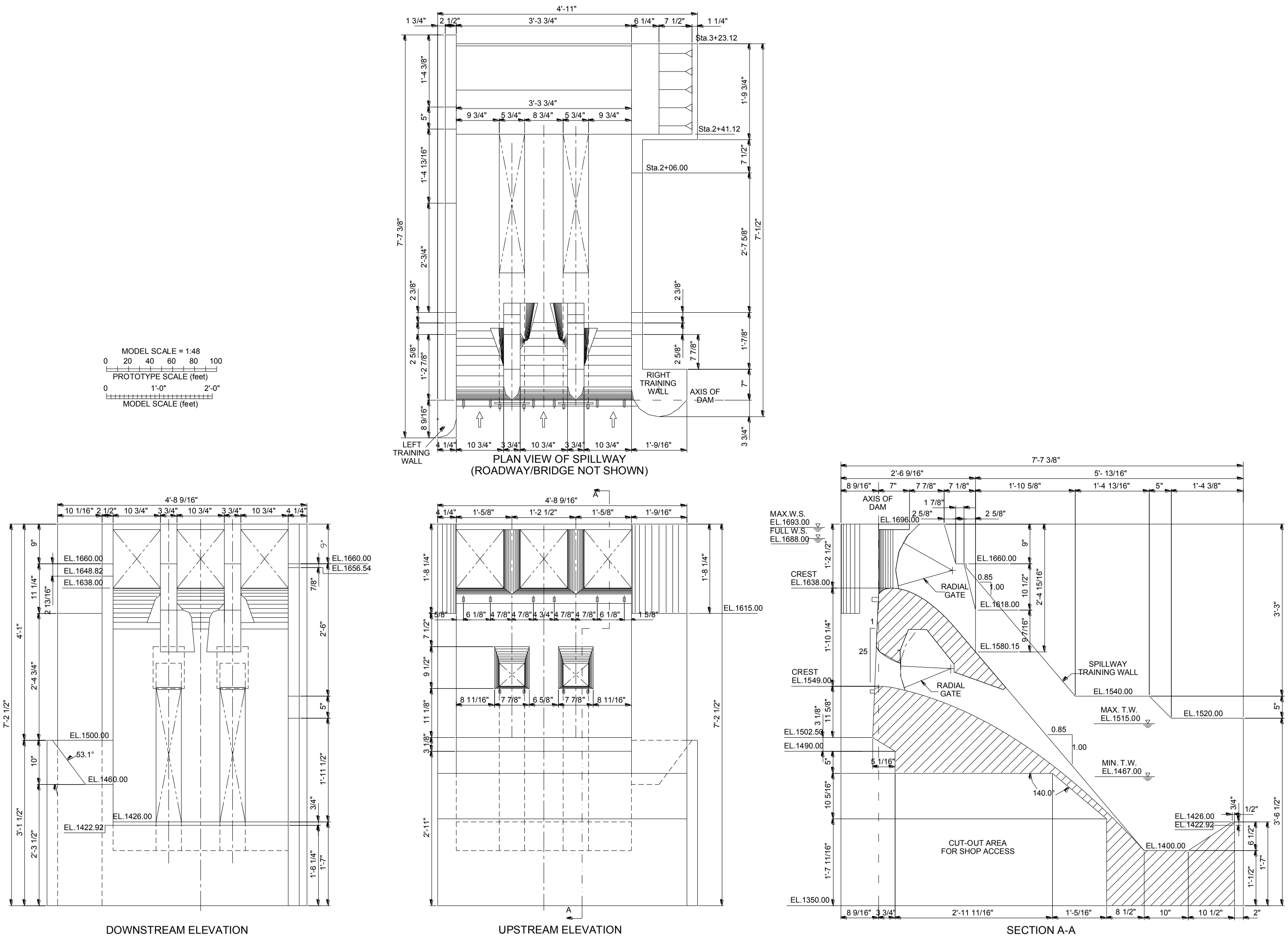


Figure A-3 General Plan, Elevation, and Section Through Spillway of 1:48 Sectional Mode

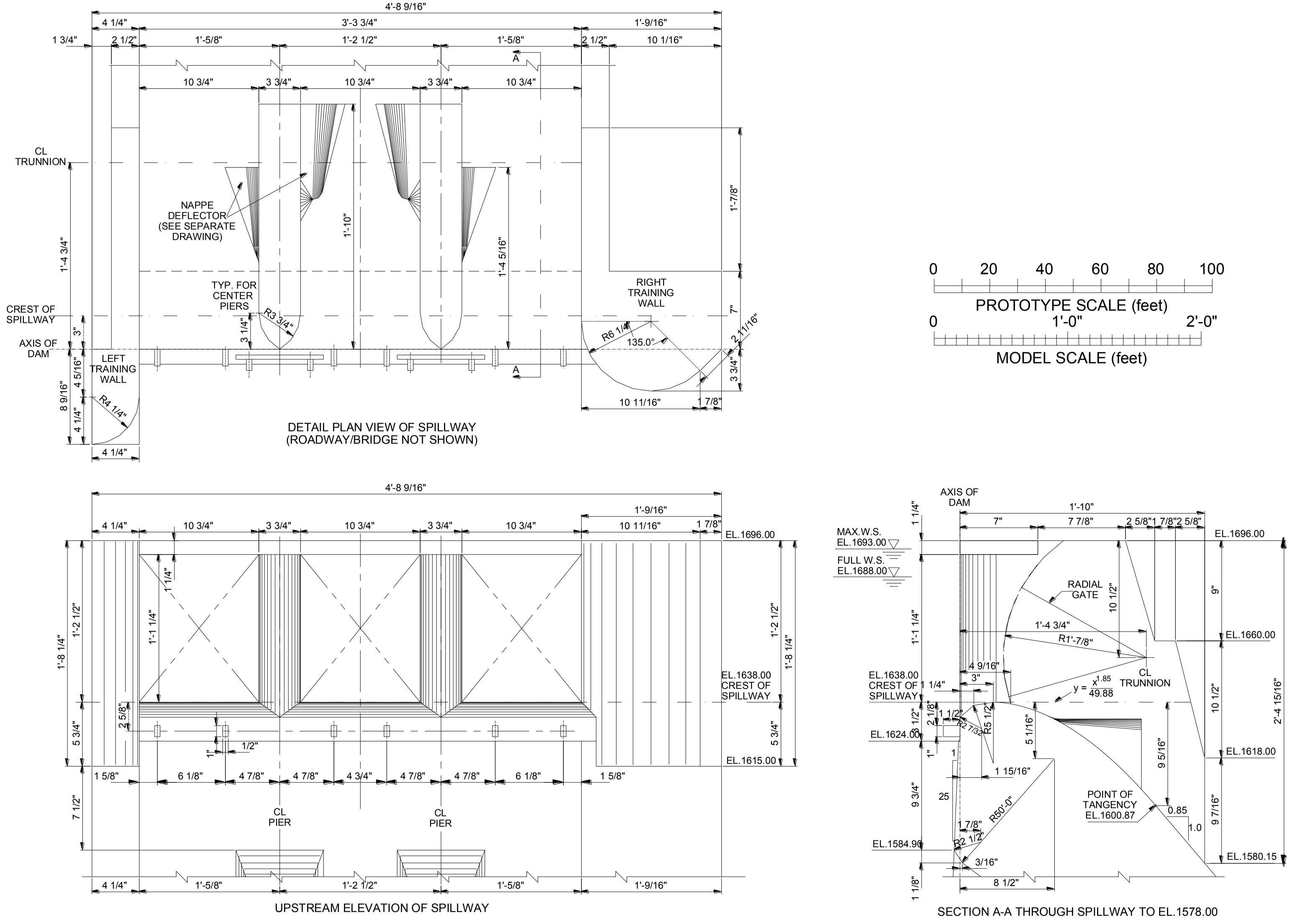


Figure A-4 Plan, Elevation, and Section of Spillway Above El. 1578.0 for 1:48 Sectional Model

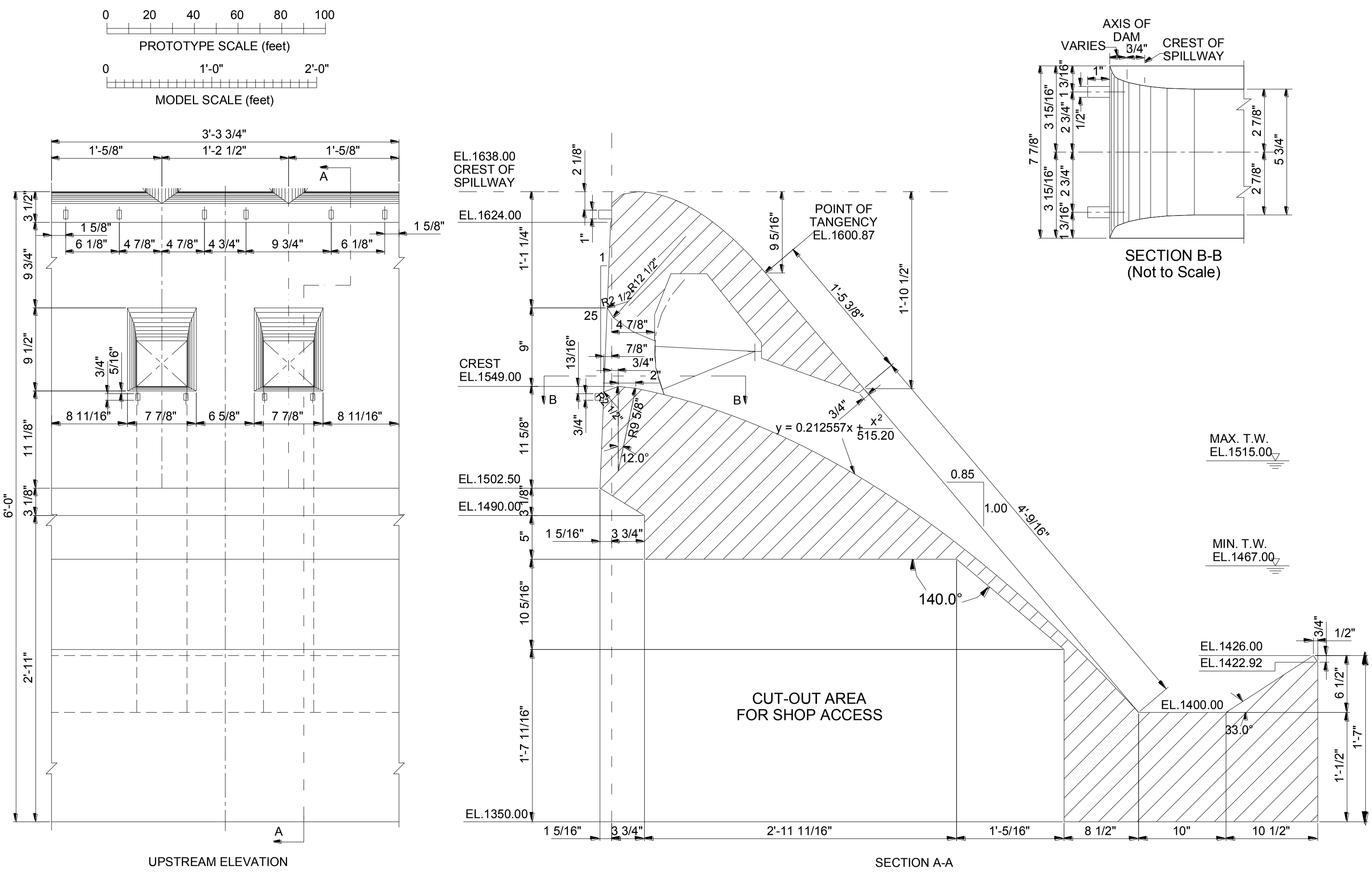


Figure A-5 Upstream Elevation and Section Through Sluiceway of 1:48 Sectional Model

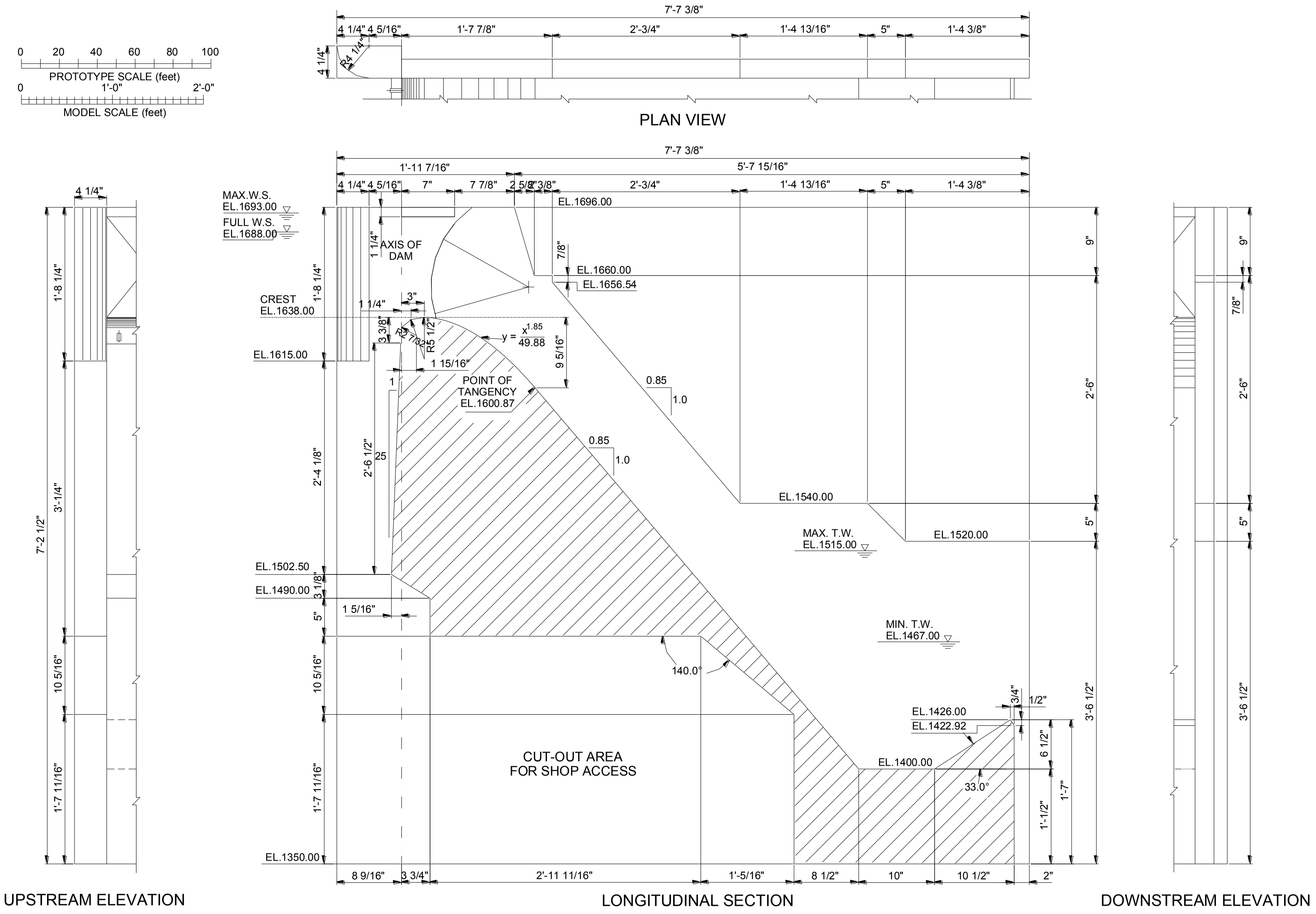


Figure A-6 Plan, Elevation, and Section of Left Guide Wall for 1:48 Sectional Model

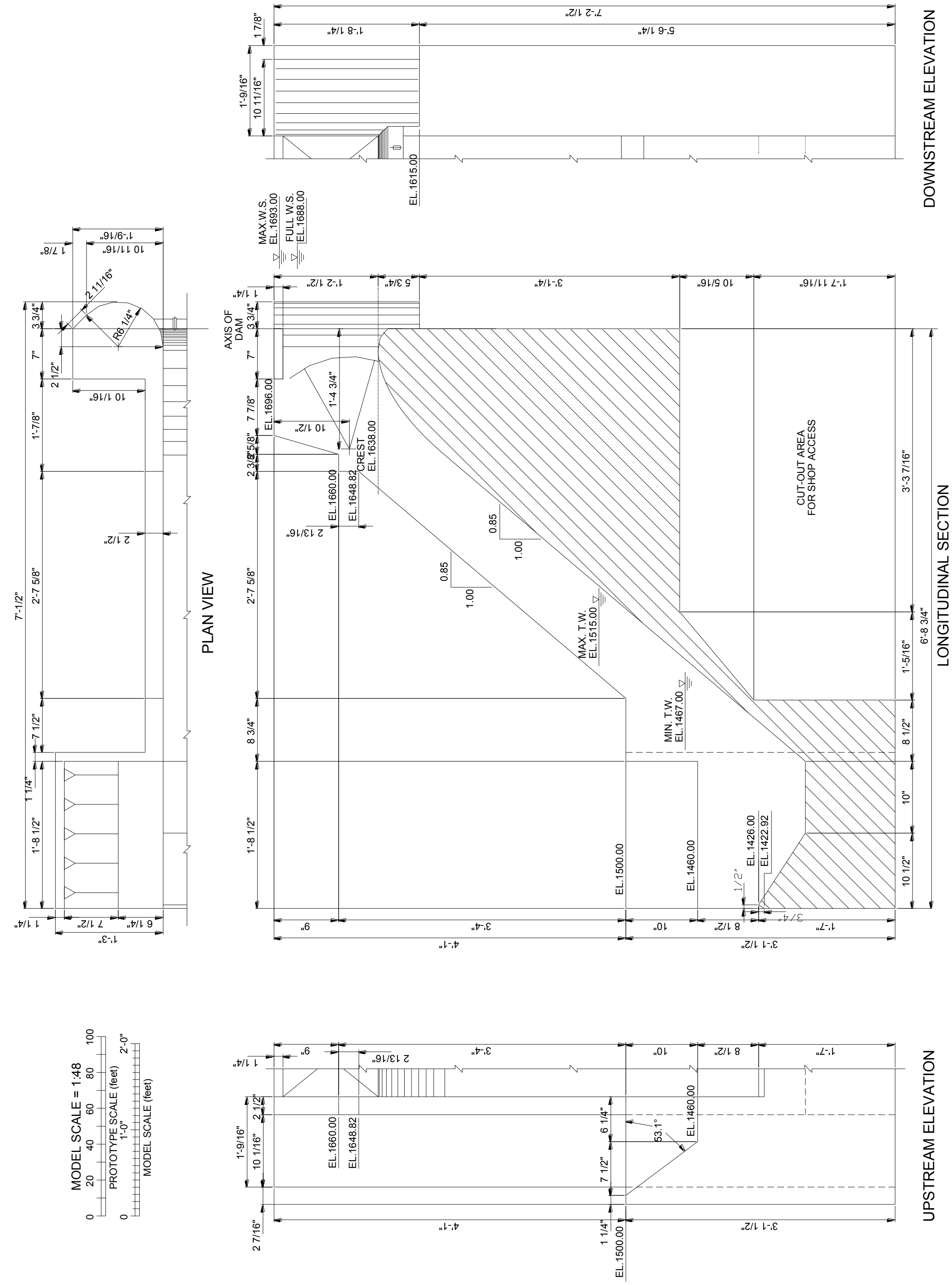


Figure A-7 Plan, Elevation, and Section of Right Guide Wall for 1:48 Sectional Model

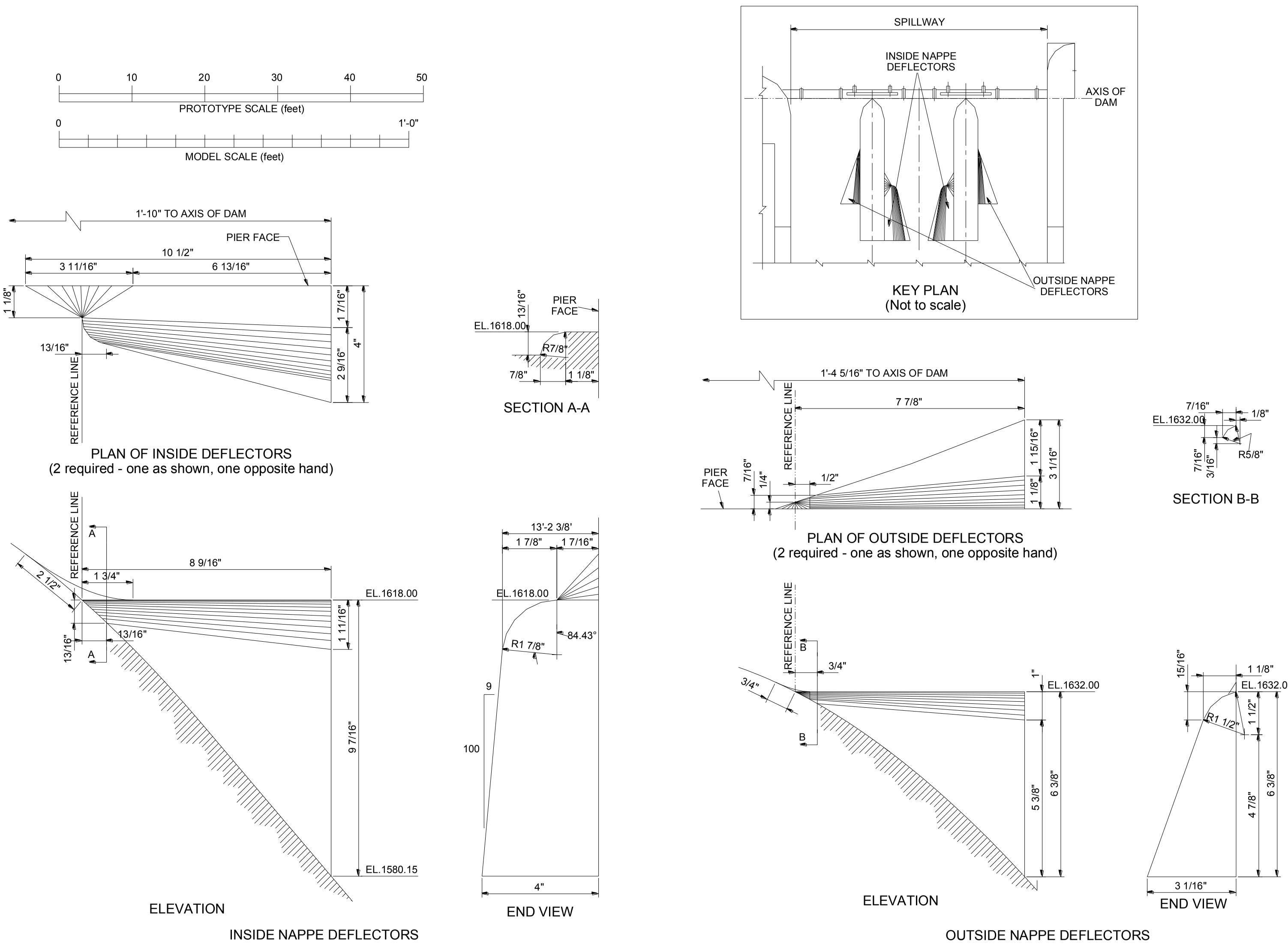


Figure A-8 Plan, Elevation, and Section of Nappe Deflectors for 1:48 Sectional Model

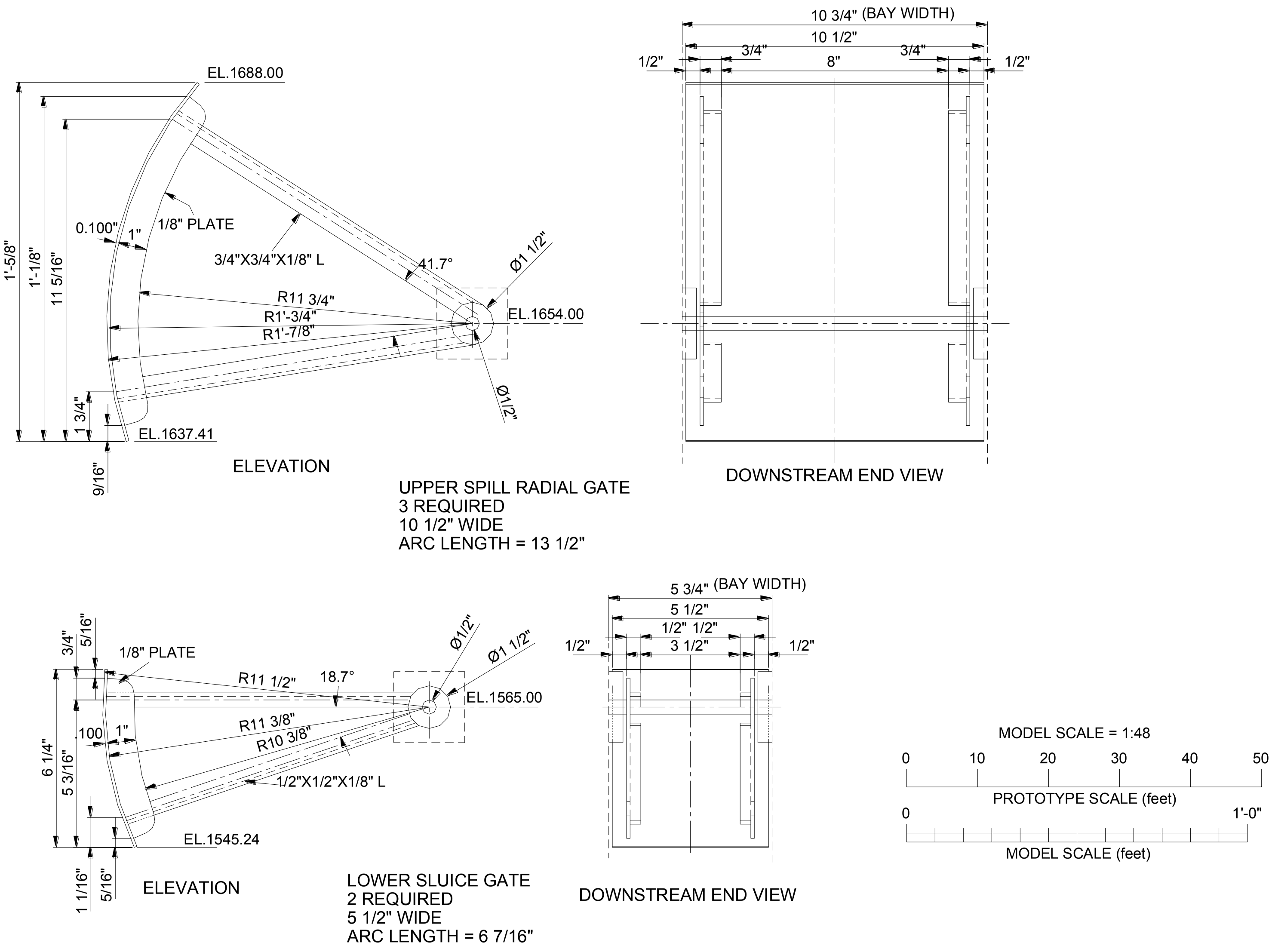


Figure A-9 Details of Spillway and Sluiceway Gates for 1:48 Sectional Model

APPENDIX B

1:48 MODEL GATE POSITIONING RELATIONSHIPS

Hells Canyon Spillway Gate Positioning -- Gate 1

May 9, 2000

Blue indicates inputted information.

Model Information:

Gate Seal Elevation	1637.63	proto ft
Trunnion CL Elevation	1653.88	proto ft
Upper Collar CL Elevation	1794.42	proto ft
Seal to Trunnion Distance	4.06	model in
Trunnion Seal Declination	18.3	degrees

Black indicates calculated information.

Model Information:

RodPivot to Trunnion, B	31 7/8	model in
RodConnect to Trunnion, D	10 1/4	model in
Collar to Trunnion (Horizontal), F	14 25/32	model in
Closed RodLength, Linit	30 29/32	model in
Tainter Gate Radius, R	12 31/32	model in
Initial Rod Pivot to Trunnion Angle, λ	62.372	degrees

Definition of Terms:

Rod Extension, Rod ΔL
Total Rod Length, L
Rod Extension Angle, β
Gate Arm Inclination Angle, α
Subtended Angle, α–α'
Gate Lip Declination Angle, δ
Vertical Subtended Height, H
Initial Rod Pivot to Trunnion Angle, λ
RodPivot to Trunnion, B
Horiz. Collar to Trunnion, F

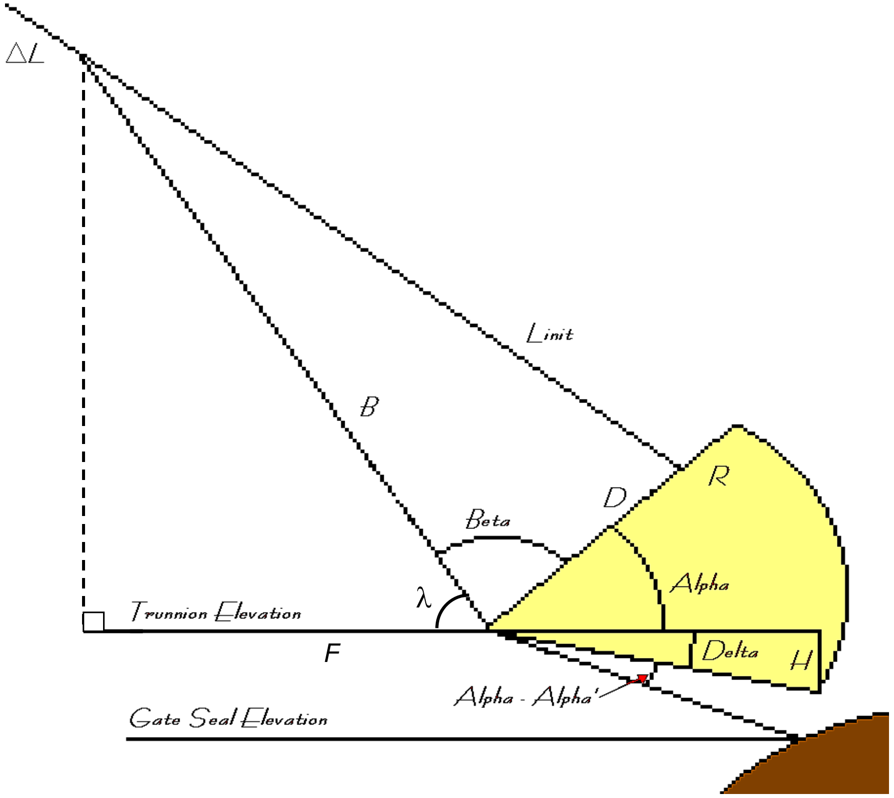


Figure B-1 Details of 1:48 Model Spillway—Gate 1

Hells Canyon Spillway Gate Positioning -- Gate 1

May 9, 2000

Gate Seal	Gate Opening	H	Sin(δ)	δ	δ	α – α'	α	β	β	Cos(β)	L = ΔL +Linit	Rod ΔL
feet proto	proto ft	model in		rad	deg	deg	deg	deg	rad		model in	model in
1637.63	0.0	4.06	0.31	0.32	18.3	0.00	42	75	1.31	0.25	30.9	0.000
1638.63	1.0	3.81	0.29	0.30	17.1	1.16	43	74	1.29	0.27	30.7	0.207
1639.63	2.0	3.56	0.27	0.28	15.9	2.31	45	73	1.27	0.29	30.5	0.413
1640.63	3.0	3.31	0.26	0.26	14.8	3.46	46	72	1.25	0.31	30.3	0.618
1641.63	4.0	3.06	0.24	0.24	13.7	4.60	47	71	1.23	0.33	30.1	0.822
1642.63	5.0	2.81	0.22	0.22	12.5	5.73	48	70	1.21	0.35	29.9	1.024
1643.63	6.0	2.56	0.20	0.20	11.4	6.86	49	68	1.19	0.37	29.7	1.226
1644.63	7.0	2.31	0.18	0.18	10.3	7.98	50	67	1.17	0.39	29.5	1.427
1645.63	8.0	2.06	0.16	0.16	9.2	9.10	51	66	1.16	0.40	29.3	1.627
1646.63	9.0	1.81	0.14	0.14	8.0	10.22	53	65	1.14	0.42	29.1	1.826
1647.63	10.0	1.56	0.12	0.12	6.9	11.34	54	64	1.12	0.44	28.9	2.024
1648.63	11.0	1.31	0.10	0.10	5.8	12.45	55	63	1.10	0.46	28.7	2.221
1649.63	12.0	1.06	0.08	0.08	4.7	13.56	56	62	1.08	0.47	28.5	2.416
1650.63	13.0	0.81	0.06	0.06	3.6	14.66	57	61	1.06	0.49	28.3	2.611
1651.63	14.0	0.56	0.04	0.04	2.5	15.77	58	60	1.04	0.51	28.1	2.805
1652.63	15.0	0.31	0.02	0.02	1.4	16.87	59	58	1.02	0.52	27.9	2.998
1653.63	16.0	0.06	0.00	0.00	0.3	17.98	60	57	1.00	0.54	27.7	3.190
1654.63	17.0	-0.19	-0.01	-0.01	-0.8	19.08	61	56	0.98	0.56	27.5	3.380
1655.63	18.0	-0.44	-0.03	-0.03	-1.9	20.19	63	55	0.96	0.57	27.3	3.570
1656.63	19.0	-0.69	-0.05	-0.05	-3.0	21.29	64	54	0.94	0.59	27.1	3.759
1657.63	20.0	-0.94	-0.07	-0.07	-4.1	22.40	65	53	0.92	0.60	27.0	3.946
1659.63	22.0	-1.44	-0.11	-0.11	-6.4	24.62	67	51	0.88	0.63	26.6	4.317
1661.63	24.0	-1.94	-0.15	-0.15	-8.6	26.85	69	48	0.85	0.66	26.2	4.683
1663.63	26.0	-2.44	-0.19	-0.19	-10.8	29.09	71	46	0.81	0.69	25.9	5.044
1665.63	28.0	-2.94	-0.23	-0.23	-13.1	31.35	74	44	0.77	0.72	25.5	5.399
1667.63	30.0	-3.44	-0.27	-0.27	-15.4	33.63	76	42	0.73	0.75	25.2	5.748
1669.63	32.0	-3.94	-0.30	-0.31	-17.7	35.93	78	39	0.69	0.77	24.8	6.089
1671.63	34.0	-4.44	-0.34	-0.35	-20.0	38.26	81	37	0.65	0.80	24.5	6.423
1673.63	36.0	-4.94	-0.38	-0.39	-22.4	40.63	83	35	0.60	0.82	24.2	6.748
1675.63	38.0	-5.44	-0.42	-0.43	-24.8	43.04	85	32	0.56	0.85	23.8	7.064
1677.63	40.0	-5.94	-0.46	-0.48	-27.2	45.50	88	30	0.52	0.87	23.5	7.369
1679.63	42.0	-6.44	-0.50	-0.52	-29.8	48.02	90	27	0.48	0.89	23.2	7.662
1681.63	44.0	-6.94	-0.53	-0.56	-32.3	50.60	93	25	0.43	0.91	23.0	7.941
1683.63	46.0	-7.44	-0.57	-0.61	-35.0	53.25	96	22	0.38	0.93	22.7	8.204
1685.63	48.0	-7.94	-0.61	-0.66	-37.7	55.99	98	19	0.34	0.94	22.5	8.448
1687.63	50.0	-8.44	-0.65	-0.71	-40.6	58.84	101	16	0.29	0.96	22.2	8.671
1689.63	52.0	-8.94	-0.69	-0.76	-43.6	61.82	104	13	0.24	0.97	22.0	8.869
1691.63	54.0	-9.44	-0.73	-0.81	-46.7	64.95	107	10	0.18	0.98	21.9	9.037
1693.63	56.0	-9.94	-0.77	-0.87	-50.0	68.28	111	7	0.12	0.99	21.7	9.168

Figure B-2 Spillway Gate Positioning Relationships—Gate 1

Hells Canyon Spillway Gate Positioning -- Gate 2

May 9, 2000

Blue indicates inputted information.

Model Information:

Gate Seal Elevation	1637.50	proto ft
Trunnion CL Elevation	1653.50	proto ft
Upper Collar CL Elevation	1795.42	proto ft
Seal to Trunnion Distance	4.00	model in
Trunnion Seal Declination	18.1	degrees

Black indicates calculated information.

Model Information:

RodPivot to Trunnion, B	32 1/8	model in
RodConnect to Trunnion, D	10 1/4	model in
Horiz. Collar to Trunnion, F	15 1/16	model in
Closed RodLength, Linit	30 29/32	model in
Tainter Gate Radius, R	12 27/32	model in
Initial Rod Pivot to Trunnion Angle, λ	62.039	degrees

Definition of Terms:

Rod Extension, Rod ΔL
Total Rod Length, L
Rod Extension Angle, β
Gate Arm Inclination Angle, α
Subtended Angle, α–α'
Gate Lip Declination Angle, δ
Vertical Subtended Height, H
Initial Rod Pivot to Trunnion Angle, λ
RodPivot to Trunnion, B
Horiz. Collar to Trunnion, F

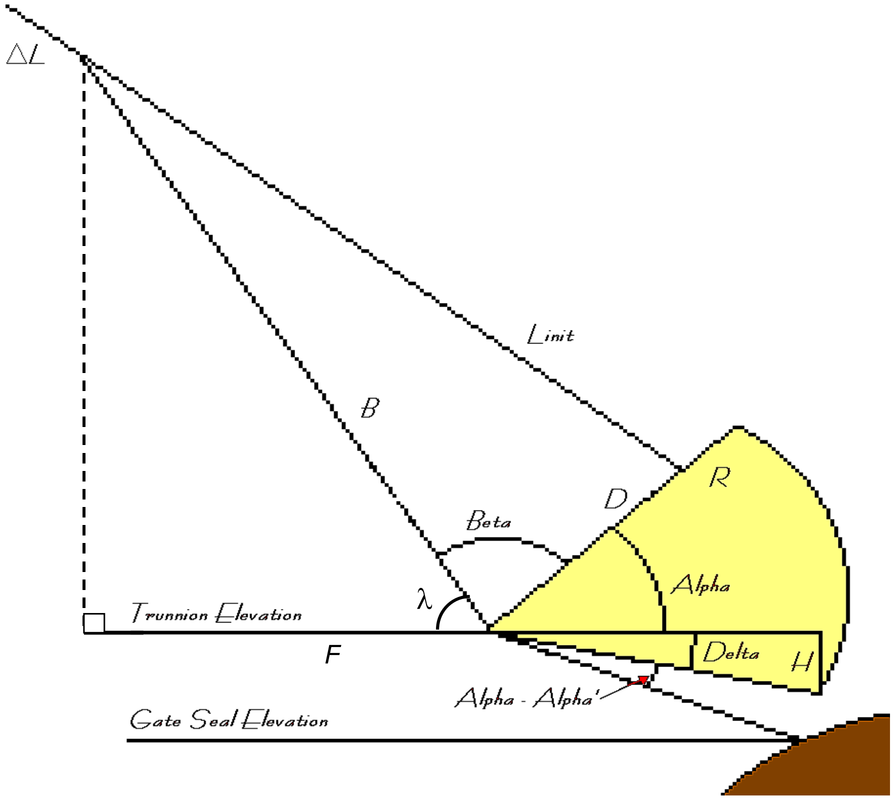


Figure B-3 Details of 1:48 Model Spillway—Gate 2

Hells Canyon Spillway Gate Positioning -- Gate 2 **May 9, 2000**

Gate Seal	Gate Opening	H	Sin(δ)	δ	δ	α – α'	α	β	β	Cos(β)	L = ΔL +Linit	Rod ΔL
feet proto	proto ft	model in		rad	deg	deg	deg	deg	rad		model in	model in
1637.50	0.0	4.00	0.31	0.32	18.1	0.00	44	74	1.29	0.28	30.9	0.000
1638.50	1.0	3.75	0.29	0.30	17.0	1.17	45	73	1.27	0.30	30.7	0.209
1639.50	2.0	3.50	0.27	0.28	15.8	2.33	46	72	1.25	0.32	30.5	0.417
1640.50	3.0	3.25	0.25	0.26	14.7	3.49	47	70	1.23	0.33	30.3	0.624
1641.50	4.0	3.00	0.23	0.24	13.5	4.64	49	69	1.21	0.35	30.1	0.829
1642.50	5.0	2.75	0.21	0.22	12.4	5.78	50	68	1.19	0.37	29.9	1.034
1643.50	6.0	2.50	0.19	0.20	11.2	6.92	51	67	1.17	0.39	29.7	1.237
1644.50	7.0	2.25	0.18	0.18	10.1	8.06	52	66	1.15	0.41	29.5	1.440
1645.50	8.0	2.00	0.16	0.16	9.0	9.19	53	65	1.13	0.43	29.3	1.641
1646.50	9.0	1.75	0.14	0.14	7.8	10.31	54	64	1.11	0.44	29.1	1.841
1647.50	10.0	1.50	0.12	0.12	6.7	11.44	55	63	1.09	0.46	28.9	2.040
1648.50	11.0	1.25	0.10	0.10	5.6	12.56	57	61	1.07	0.48	28.7	2.237
1649.50	12.0	1.00	0.08	0.08	4.5	13.68	58	60	1.05	0.50	28.5	2.434
1650.50	13.0	0.75	0.06	0.06	3.3	14.80	59	59	1.03	0.51	28.3	2.630
1651.50	14.0	0.50	0.04	0.04	2.2	15.91	60	58	1.01	0.53	28.1	2.824
1652.50	15.0	0.25	0.02	0.02	1.1	17.03	61	57	0.99	0.55	27.9	3.017
1653.50	16.0	0.00	0.00	0.00	0.0	18.15	62	56	0.97	0.56	27.7	3.209
1654.50	17.0	-0.25	-0.02	-0.02	-1.1	19.26	63	55	0.95	0.58	27.5	3.400
1655.50	18.0	-0.50	-0.04	-0.04	-2.2	20.38	64	54	0.94	0.59	27.3	3.590
1656.50	19.0	-0.75	-0.06	-0.06	-3.3	21.49	65	52	0.92	0.61	27.1	3.778
1657.50	20.0	-1.00	-0.08	-0.08	-4.5	22.61	67	51	0.90	0.62	26.9	3.965
1659.50	22.0	-1.50	-0.12	-0.12	-6.7	24.85	69	49	0.86	0.65	26.6	4.335
1661.50	24.0	-2.00	-0.16	-0.16	-9.0	27.10	71	47	0.82	0.68	26.2	4.700
1663.50	26.0	-2.50	-0.19	-0.20	-11.2	29.37	73	45	0.78	0.71	25.8	5.058
1665.50	28.0	-3.00	-0.23	-0.24	-13.5	31.65	76	42	0.74	0.74	25.5	5.409
1667.50	30.0	-3.50	-0.27	-0.28	-15.8	33.96	78	40	0.70	0.77	25.2	5.754
1669.50	32.0	-4.00	-0.31	-0.32	-18.1	36.29	80	38	0.66	0.79	24.8	6.090
1671.50	34.0	-4.50	-0.35	-0.36	-20.5	38.66	83	35	0.62	0.82	24.5	6.418
1673.50	36.0	-5.00	-0.39	-0.40	-22.9	41.06	85	33	0.57	0.84	24.2	6.736
1675.50	38.0	-5.50	-0.43	-0.44	-25.4	43.50	87	30	0.53	0.86	23.9	7.043
1677.50	40.0	-6.00	-0.47	-0.49	-27.8	46.00	90	28	0.49	0.88	23.6	7.338
1679.50	42.0	-6.50	-0.51	-0.53	-30.4	48.55	93	25	0.44	0.90	23.3	7.620
1681.50	44.0	-7.00	-0.55	-0.58	-33.0	51.17	95	23	0.40	0.92	23.0	7.885
1683.50	46.0	-7.50	-0.58	-0.62	-35.7	53.87	98	20	0.35	0.94	22.8	8.133
1685.50	48.0	-8.00	-0.62	-0.67	-38.5	56.67	101	17	0.30	0.95	22.5	8.361
1687.50	50.0	-8.50	-0.66	-0.72	-41.4	59.58	104	14	0.25	0.97	22.3	8.564
1689.50	52.0	-9.00	-0.70	-0.78	-44.5	62.63	107	11	0.20	0.98	22.2	8.740
1691.50	54.0	-9.50	-0.74	-0.83	-47.7	65.85	110	8	0.14	0.99	22.0	8.881
1693.50	56.0	-10.00	-0.78	-0.89	-51.1	69.28	113	5	0.08	1.00	21.9	8.981

Figure B-4 Spillway Gate Positioning Relationships—Gate 2

Hells Canyon Spillway Gate Positioning -- Gate 3

May 9, 2000

Blue indicates inputted information.

Model Information:

Gate Seal Elevation	1637.63	proto ft
Trunnion CL Elevation	1653.63	proto ft
Upper Collar CL Elevation	1795.82	proto ft
Seal to Trunnion Distance	4.00	model in
Trunnion Seal Declination	18.2	degrees

Black indicates calculated information.

Model Information:

RodPivot to Trunnion, B	32 1/8	model in
RodConnect to Trunnion, D	10 1/8	model in
Horiz. Collar to Trunnion, F	15 7/32	model in
Closed RodLength, Linit	31 3/32	model in
Tainter Gate Radius, R	12 13/16	model in
Initial Rod Pivot to Trunnion Angle, λ	61.723	degrees

Definition of Terms:

Rod Extension, Rod ΔL
Total Rod Length, L
Rod Extension Angle, β
Gate Arm Inclination Angle, α
Subtended Angle, α–α'
Gate Lip Declination Angle, δ
Vertical Subtended Height, H
Initial Rod Pivot to Trunnion Angle, λ
RodPivot to Trunnion, B
Horiz. Collar to Trunnion, F

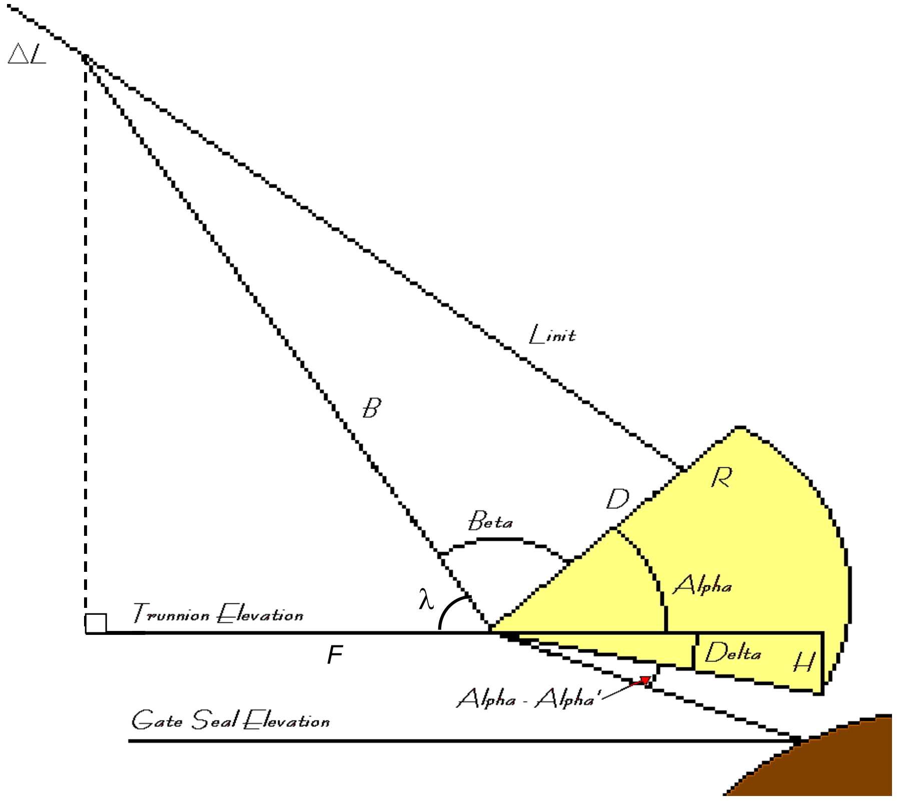


Figure B-5 Details of 1:48 Model Spillway—Gate 3

Hells Canyon Spillway Gate Positioning -- Gate 3

May 9, 2000

Gate Seal	Gate Opening	H	Sin(δ)	δ	δ	α – α'	α	β	β	Cos(β)	L = ΔL +Linit	Rod ΔL
feet proto	proto ft	model in		rad	deg	deg	deg	deg	rad		model in	model in
1637.63	0.0	4.00	0.31	0.32	18.2	0.00	43	75	1.31	0.26	31.1	0.000
1638.63	1.0	3.75	0.29	0.30	17.0	1.17	44	74	1.29	0.28	30.9	0.207
1639.63	2.0	3.50	0.27	0.28	15.9	2.34	46	73	1.27	0.30	30.7	0.413
1640.63	3.0	3.25	0.25	0.26	14.7	3.50	47	72	1.25	0.32	30.5	0.618
1641.63	4.0	3.00	0.23	0.24	13.5	4.65	48	70	1.23	0.34	30.3	0.821
1642.63	5.0	2.75	0.21	0.22	12.4	5.80	49	69	1.21	0.35	30.1	1.024
1643.63	6.0	2.50	0.20	0.20	11.3	6.94	50	68	1.19	0.37	29.9	1.226
1644.63	7.0	2.25	0.18	0.18	10.1	8.08	51	67	1.17	0.39	29.7	1.426
1645.63	8.0	2.00	0.16	0.16	9.0	9.21	52	66	1.15	0.41	29.5	1.626
1646.63	9.0	1.75	0.14	0.14	7.9	10.34	54	65	1.13	0.43	29.3	1.824
1647.63	10.0	1.50	0.12	0.12	6.7	11.47	55	64	1.11	0.44	29.1	2.021
1648.63	11.0	1.25	0.10	0.10	5.6	12.59	56	62	1.09	0.46	28.9	2.218
1649.63	12.0	1.00	0.08	0.08	4.5	13.72	57	61	1.07	0.48	28.7	2.413
1650.63	13.0	0.75	0.06	0.06	3.4	14.84	58	60	1.05	0.50	28.5	2.607
1651.63	14.0	0.50	0.04	0.04	2.2	15.96	59	59	1.03	0.51	28.3	2.801
1652.63	15.0	0.25	0.02	0.02	1.1	17.07	60	58	1.01	0.53	28.1	2.993
1653.63	16.0	0.00	0.00	0.00	0.0	18.19	61	57	0.99	0.55	27.9	3.184
1654.63	17.0	-0.25	-0.02	-0.02	-1.1	19.31	63	56	0.97	0.56	27.7	3.373
1655.63	18.0	-0.50	-0.04	-0.04	-2.2	20.43	64	55	0.95	0.58	27.5	3.562
1656.63	19.0	-0.75	-0.06	-0.06	-3.4	21.55	65	54	0.93	0.59	27.3	3.750
1657.63	20.0	-1.00	-0.08	-0.08	-4.5	22.67	66	52	0.91	0.61	27.2	3.936
1659.63	22.0	-1.50	-0.12	-0.12	-6.7	24.91	68	50	0.88	0.64	26.8	4.305
1661.63	24.0	-2.00	-0.16	-0.16	-9.0	27.17	70	48	0.84	0.67	26.4	4.668
1663.63	26.0	-2.50	-0.20	-0.20	-11.3	29.44	73	46	0.80	0.70	26.1	5.026
1665.63	28.0	-3.00	-0.23	-0.24	-13.5	31.73	75	43	0.76	0.73	25.7	5.378
1667.63	30.0	-3.50	-0.27	-0.28	-15.9	34.04	77	41	0.72	0.75	25.4	5.723
1669.63	32.0	-4.00	-0.31	-0.32	-18.2	36.38	80	39	0.68	0.78	25.0	6.060
1671.63	34.0	-4.50	-0.35	-0.36	-20.6	38.75	82	36	0.63	0.81	24.7	6.390
1673.63	36.0	-5.00	-0.39	-0.40	-23.0	41.16	84	34	0.59	0.83	24.4	6.710
1675.63	38.0	-5.50	-0.43	-0.44	-25.4	43.61	87	31	0.55	0.85	24.1	7.020
1677.63	40.0	-6.00	-0.47	-0.49	-27.9	46.12	89	29	0.51	0.88	23.8	7.319
1679.63	42.0	-6.50	-0.51	-0.53	-30.5	48.68	92	26	0.46	0.90	23.5	7.604
1681.63	44.0	-7.00	-0.55	-0.58	-33.1	51.31	95	24	0.41	0.92	23.2	7.875
1683.63	46.0	-7.50	-0.59	-0.63	-35.8	54.02	97	21	0.37	0.93	23.0	8.129
1685.63	48.0	-8.00	-0.62	-0.67	-38.6	56.83	100	18	0.32	0.95	22.7	8.364
1687.63	50.0	-8.50	-0.66	-0.73	-41.6	59.75	103	15	0.27	0.96	22.5	8.575
1689.63	52.0	-9.00	-0.70	-0.78	-44.6	62.81	106	12	0.21	0.98	22.3	8.760
1691.63	54.0	-9.50	-0.74	-0.84	-47.9	66.05	109	9	0.16	0.99	22.2	8.912
1693.63	56.0	-10.00	-0.78	-0.90	-51.3	69.50	113	6	0.10	1.00	22.1	9.024

Figure B-6 Spillway Gate Positioning Relationships—Gate 3

Hells Canyon Sluiceway Gate Positioning -- Gate 1

May 9, 2000

Blue indicates inputted information.

Model Information:

Gate Seal Elevation	1544.94	proto ft
Trunnion CL Elevation	1564.50	proto ft
Upper Collar CL Elevation	1662.19	proto ft
Seal to Trunnion Distance	4.89	model in
Trunnion Seal Declination	25.2	degrees

Black indicates calculated information.

Model Information:

RodPivot to Trunnion, B	24.504	model in
RodConnect to Trunnion, D	9 7/16	model in
Horiz. Collar to Trunnion, F	2	model in
Closed RodLength, Linit	25 29/32	model in
Tainter Gate Radius, R	11 1/2	model in
Initial Rod Pivot to Trunnion Angle, λ	85.318	degrees

Definition of Terms:

Rod Extension, Rod ΔL
Total Rod Length, L
Rod Extension Angle, β
Gate Arm Inclination Angle, α
Subtended Angle, α–α'
Gate Lip Declination Angle, δ
Vertical Subtended Height, H
Initial Rod Pivot to Trunnion Angle, λ
RodPivot to Trunnion, B
Horiz. Collar to Trunnion, F

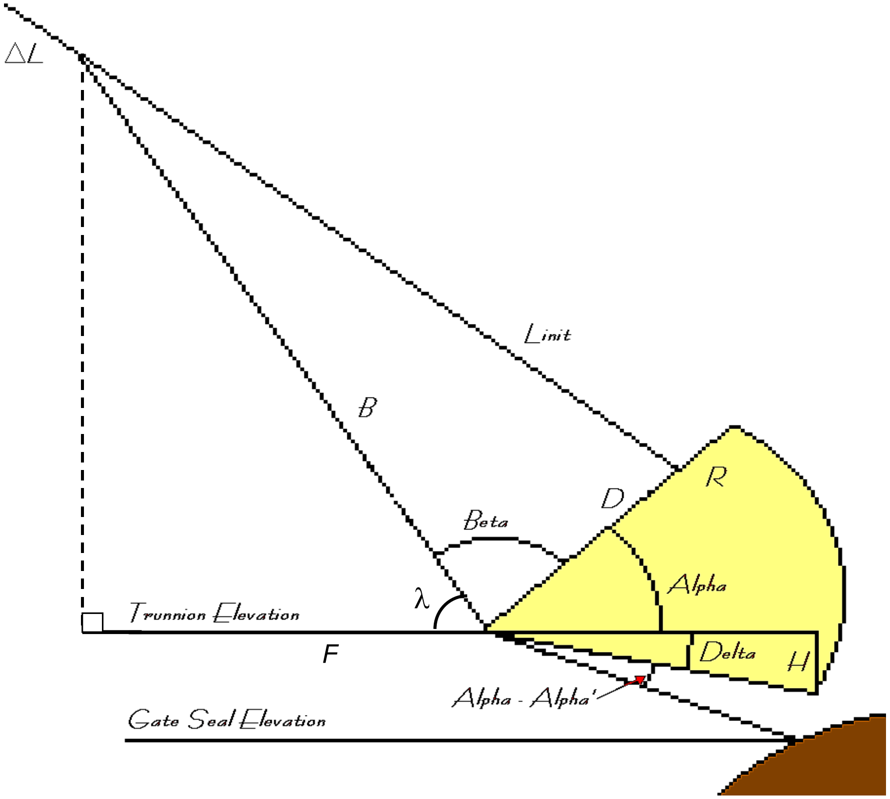


Figure B-7 Details of 1:48 Model Sluiceway—Gate 1

Hells Canyon Sluiceway Gate Positioning -- Gate 1 **May 9, 2000**

Gate Seal	Gate Opening	H	Sin(δ)	δ	δ	α – α'	α	β	β	Cos(β)	L = ΔL +Linit	Rod ΔL
feet proto	proto ft	model in		rad	deg	deg	deg	deg	rad		model in	model in
1544.94	0.0	4.89	0.43	0.44	25.2	0.00	7	88	1.53	0.04	25.9	0.000
1545.94	1.0	4.64	0.40	0.42	23.8	1.37	8	86	1.51	0.06	25.7	0.214
1546.94	2.0	4.39	0.38	0.39	22.4	2.72	10	85	1.48	0.09	25.5	0.427
1547.94	3.0	4.14	0.36	0.37	21.1	4.06	11	84	1.46	0.11	25.3	0.639
1548.94	4.0	3.89	0.34	0.35	19.8	5.39	12	82	1.44	0.13	25.1	0.851
1549.94	5.0	3.64	0.32	0.32	18.5	6.71	14	81	1.41	0.16	24.8	1.062
1550.94	6.0	3.39	0.29	0.30	17.1	8.02	15	80	1.39	0.18	24.6	1.272
1551.94	7.0	3.14	0.27	0.28	15.8	9.32	16	78	1.37	0.20	24.4	1.482
1552.94	8.0	2.89	0.25	0.25	14.6	10.61	18	77	1.35	0.22	24.2	1.691
1553.94	9.0	2.64	0.23	0.23	13.3	11.89	19	76	1.32	0.24	24.0	1.900
1554.94	10.0	2.39	0.21	0.21	12.0	13.17	20	75	1.30	0.27	23.8	2.109
1555.94	11.0	2.14	0.19	0.19	10.7	14.44	21	73	1.28	0.29	23.6	2.317
1556.94	12.0	1.89	0.16	0.17	9.5	15.71	23	72	1.26	0.31	23.4	2.524
1557.94	13.0	1.64	0.14	0.14	8.2	16.97	24	71	1.23	0.33	23.2	2.731
1558.94	14.0	1.39	0.12	0.12	6.9	18.22	25	70	1.21	0.35	23.0	2.938
1559.94	15.0	1.14	0.10	0.10	5.7	19.48	26	68	1.19	0.37	22.8	3.144
1560.94	16.0	0.89	0.08	0.08	4.4	20.73	28	67	1.17	0.39	22.6	3.350
1561.94	17.0	0.64	0.06	0.06	3.2	21.97	29	66	1.15	0.41	22.4	3.556
1562.94	18.0	0.39	0.03	0.03	1.9	23.22	30	65	1.13	0.43	22.1	3.761
1563.94	19.0	0.14	0.01	0.01	0.7	24.47	31	63	1.10	0.45	21.9	3.966
1564.94	20.0	-0.11	-0.01	-0.01	-0.5	25.71	33	62	1.08	0.47	21.7	4.170
1565.94	21.0	-0.36	-0.03	-0.03	-1.8	26.96	34	61	1.06	0.49	21.5	4.374
1566.94	22.0	-0.61	-0.05	-0.05	-3.0	28.21	35	60	1.04	0.51	21.3	4.578
1567.94	23.0	-0.86	-0.07	-0.07	-4.3	29.45	36	58	1.02	0.53	21.1	4.781
1568.94	24.0	-1.11	-0.10	-0.10	-5.5	30.70	38	57	1.00	0.54	20.9	4.984
1569.94	25.0	-1.36	-0.12	-0.12	-6.8	31.96	39	56	0.97	0.56	20.7	5.186
1570.94	26.0	-1.61	-0.14	-0.14	-8.0	33.21	40	55	0.95	0.58	20.5	5.388
1571.94	27.0	-1.86	-0.16	-0.16	-9.3	34.47	41	53	0.93	0.60	20.3	5.589
1572.94	28.0	-2.11	-0.18	-0.18	-10.6	35.74	43	52	0.91	0.62	20.1	5.790
1573.94	29.0	-2.36	-0.21	-0.21	-11.8	37.01	44	51	0.89	0.63	19.9	5.990
1574.94	30.0	-2.61	-0.23	-0.23	-13.1	38.28	45	49	0.86	0.65	19.7	6.189
1575.94	31.0	-2.86	-0.25	-0.25	-14.4	39.56	47	48	0.84	0.67	19.5	6.388
1576.94	32.0	-3.11	-0.27	-0.27	-15.7	40.85	48	47	0.82	0.68	19.3	6.585
1577.94	33.0	-3.36	-0.29	-0.30	-17.0	42.15	49	46	0.80	0.70	19.1	6.782
1578.94	34.0	-3.61	-0.31	-0.32	-18.3	43.46	50	44	0.77	0.72	18.9	6.978
1579.94	35.0	-3.86	-0.34	-0.34	-19.6	44.78	52	43	0.75	0.73	18.7	7.173
1580.94	36.0	-4.11	-0.36	-0.37	-20.9	46.10	53	42	0.73	0.75	18.5	7.366

Figure B-8 Sluiceway Gate Positioning Relationships—Gate 1

Hells Canyon Sluiceway Gate Positioning -- Gate 2

May 9, 2000

Blue indicates inputted information.

Model Information:

Gate Seal Elevation	1544.81	proto ft
Trunnion CL Elevation	1564.75	proto ft
Upper Collar CL Elevation	1662.19	proto ft
Seal to Trunnion Distance	4.98	model in
Trunnion Seal Declination	25.8	degrees

Black indicates calculated information.

Model Information:

RodPivot to Trunnion, B	24.441	model in
RodConnect to Trunnion, D	9 7/16	model in
Horiz. Collar to Trunnion, F	2	model in
Closed RodLength, Linit	25 7/8	model in
Tainter Gate Radius, R	11 15/32	model in
Initial Rod Pivot to Trunnion Angle, λ	85.306	degrees

Definition of Terms:

Rod Extension, Rod ΔL
Total Rod Length, L
Rod Extension Angle, β
Gate Arm Inclination Angle, α
Subtended Angle, α–α'
Gate Lip Declination Angle, δ
Vertical Subtended Height, H
Initial Rod Pivot to Trunnion Angle, λ
RodPivot to Trunnion, B
Horiz. Collar to Trunnion, F

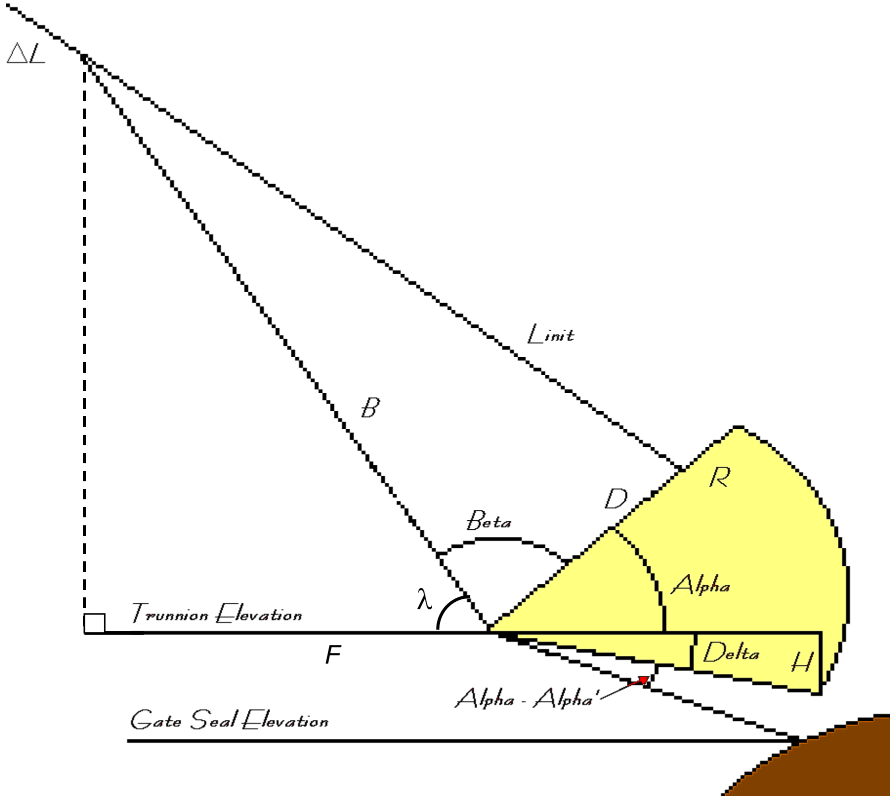


Figure B-9 Details of 1:48 Model Sluiceway—Gate 2

Hells Canyon Sluiceway Gate Positioning -- Gate 2

May 9, 2000

Gate Seal	Gate Opening	H	Sin(δ)	δ	δ	α – α'	α	β	β	Cos(β)	L = ΔL +Linit	Rod ΔL
feet proto	proto ft	model in		rad	deg	deg	deg	deg	rad		model in	model in
1544.81	0.0	4.98	0.43	0.45	25.8	0.00	7	88	1.53	0.04	25.9	0.000
1545.81	1.0	4.73	0.41	0.43	24.4	1.38	8	87	1.51	0.06	25.7	0.215
1546.81	2.0	4.48	0.39	0.40	23.0	2.74	10	85	1.49	0.08	25.4	0.430
1547.81	3.0	4.23	0.37	0.38	21.7	4.09	11	84	1.46	0.11	25.2	0.643
1548.81	4.0	3.98	0.35	0.35	20.3	5.43	12	82	1.44	0.13	25.0	0.856
1549.81	5.0	3.73	0.33	0.33	19.0	6.76	14	81	1.42	0.15	24.8	1.068
1550.81	6.0	3.48	0.30	0.31	17.7	8.07	15	80	1.39	0.18	24.6	1.280
1551.81	7.0	3.23	0.28	0.29	16.4	9.38	16	79	1.37	0.20	24.4	1.490
1552.81	8.0	2.98	0.26	0.26	15.1	10.68	17	77	1.35	0.22	24.2	1.701
1553.81	9.0	2.73	0.24	0.24	13.8	11.97	19	76	1.33	0.24	24.0	1.911
1554.81	10.0	2.48	0.22	0.22	12.5	13.25	20	75	1.30	0.26	23.8	2.120
1555.81	11.0	2.23	0.19	0.20	11.2	14.53	21	73	1.28	0.29	23.5	2.329
1556.81	12.0	1.98	0.17	0.17	10.0	15.80	23	72	1.26	0.31	23.3	2.537
1557.81	13.0	1.73	0.15	0.15	8.7	17.06	24	71	1.24	0.33	23.1	2.745
1558.81	14.0	1.48	0.13	0.13	7.4	18.32	25	70	1.21	0.35	22.9	2.953
1559.81	15.0	1.23	0.11	0.11	6.2	19.58	26	68	1.19	0.37	22.7	3.160
1560.81	16.0	0.98	0.09	0.09	4.9	20.84	28	67	1.17	0.39	22.5	3.366
1561.81	17.0	0.73	0.06	0.06	3.7	22.09	29	66	1.15	0.41	22.3	3.573
1562.81	18.0	0.48	0.04	0.04	2.4	23.34	30	65	1.13	0.43	22.1	3.779
1563.81	19.0	0.23	0.02	0.02	1.2	24.59	31	63	1.10	0.45	21.9	3.984
1564.81	20.0	-0.02	0.00	0.00	-0.1	25.84	33	62	1.08	0.47	21.7	4.189
1565.81	21.0	-0.27	-0.02	-0.02	-1.3	27.09	34	61	1.06	0.49	21.5	4.394
1566.81	22.0	-0.52	-0.04	-0.04	-2.6	28.34	35	60	1.04	0.51	21.3	4.598
1567.81	23.0	-0.77	-0.07	-0.07	-3.8	29.59	36	58	1.02	0.53	21.1	4.802
1568.81	24.0	-1.02	-0.09	-0.09	-5.1	30.84	38	57	1.00	0.54	20.9	5.005
1569.81	25.0	-1.27	-0.11	-0.11	-6.3	32.10	39	56	0.97	0.56	20.7	5.207
1570.81	26.0	-1.52	-0.13	-0.13	-7.6	33.35	40	55	0.95	0.58	20.5	5.410
1571.81	27.0	-1.77	-0.15	-0.15	-8.9	34.62	41	53	0.93	0.60	20.3	5.611
1572.81	28.0	-2.02	-0.18	-0.18	-10.1	35.88	43	52	0.91	0.62	20.1	5.812
1573.81	29.0	-2.27	-0.20	-0.20	-11.4	37.15	44	51	0.89	0.63	19.9	6.013
1574.81	30.0	-2.52	-0.22	-0.22	-12.7	38.43	45	49	0.86	0.65	19.7	6.212
1575.81	31.0	-2.77	-0.24	-0.24	-14.0	39.71	47	48	0.84	0.67	19.5	6.411
1576.81	32.0	-3.02	-0.26	-0.27	-15.2	41.00	48	47	0.82	0.68	19.3	6.609
1577.81	33.0	-3.27	-0.28	-0.29	-16.5	42.30	49	46	0.80	0.70	19.1	6.806
1578.81	34.0	-3.52	-0.31	-0.31	-17.9	43.61	50	44	0.77	0.72	18.9	7.002
1579.81	35.0	-3.77	-0.33	-0.33	-19.2	44.93	52	43	0.75	0.73	18.7	7.197
1580.81	36.0	-4.02	-0.35	-0.36	-20.5	46.26	53	42	0.73	0.75	18.5	7.390

Figure B-10 Sluiceway Gate Positioning Relationships—Gate 2

Spillway Rod Marking Tables

Spillway Gate 1

Gate Opening proto ft	Rod ΔL model in
0	0.000
1	0.207
2	0.413
3	0.618
4	0.822
5	1.024
6	1.226
7	1.427
8	1.627
9	1.826
10	2.024
11	2.221
12	2.416
13	2.611
14	2.805
15	2.998
16	3.190
17	3.380
18	3.570
19	3.759
20	3.946
22	4.317
24	4.683
26	5.044
28	5.399
30	5.748
32	6.089
34	6.423
36	6.748
38	7.064
40	7.369
42	7.662
44	7.941
46	8.204
48	8.448
50	8.671
52	8.869
54	9.037
56	9.168

Spillway Gate 2

Gate Opening proto ft	Rod ΔL model in
0	0.000
1	0.209
2	0.417
3	0.624
4	0.829
5	1.034
6	1.237
7	1.440
8	1.641
9	1.841
10	2.040
11	2.237
12	2.434
13	2.630
14	2.824
15	3.017
16	3.209
17	3.400
18	3.590
19	3.778
20	3.965
22	4.335
24	4.700
26	5.058
28	5.409
30	5.754
32	6.090
34	6.418
36	6.736
38	7.043
40	7.338
42	7.620
44	7.885
46	8.133
48	8.361
50	8.564
52	8.740
54	8.881
56	8.981

Spillway Gate 3

Gate Opening proto ft	Rod ΔL model in
0	0.000
1	0.207
2	0.413
3	0.618
4	0.821
5	1.024
6	1.226
7	1.426
8	1.626
9	1.824
10	2.021
11	2.218
12	2.413
13	2.607
14	2.801
15	2.993
16	3.184
17	3.373
18	3.562
19	3.750
20	3.936
22	4.305
24	4.668
26	5.026
28	5.378
30	5.723
32	6.060
34	6.390
36	6.710
38	7.020
40	7.319
42	7.604
44	7.875
46	8.129
48	8.364
50	8.575
52	8.760
54	8.912
56	9.024

Sluiceway Rod Marking Tables

Sluiceway Gate 1

Gate Opening proto ft	Rod ΔL model in
0	0.000
1	0.214
2	0.427
3	0.639
4	0.851
5	1.062
6	1.272
7	1.482
8	1.691
9	1.900
10	2.109
11	2.317
12	2.524
13	2.731
14	2.938
15	3.144
16	3.350
17	3.556
18	3.761
19	3.966
20	4.170
21	4.374
22	4.578
23	4.781
24	4.984
25	5.186

Sluiceway Gate 2

Gate Opening proto ft	Rod ΔL model in
0	0.000
1	0.215
2	0.430
3	0.643
4	0.856
5	1.068
6	1.280
7	1.490
8	1.701
9	1.911
10	2.120
11	2.329
12	2.537
13	2.745
14	2.953
15	3.160
16	3.366
17	3.573
18	3.779
19	3.984
20	4.189
21	4.394
22	4.598
23	4.802
24	5.005
25	5.207

Figure B-11 Rod Lengths for 1:48 Model Spillway and Sluiceway Gates

APPENDIX C

1:48 MODEL NORMAL HEADWATER CONDITION

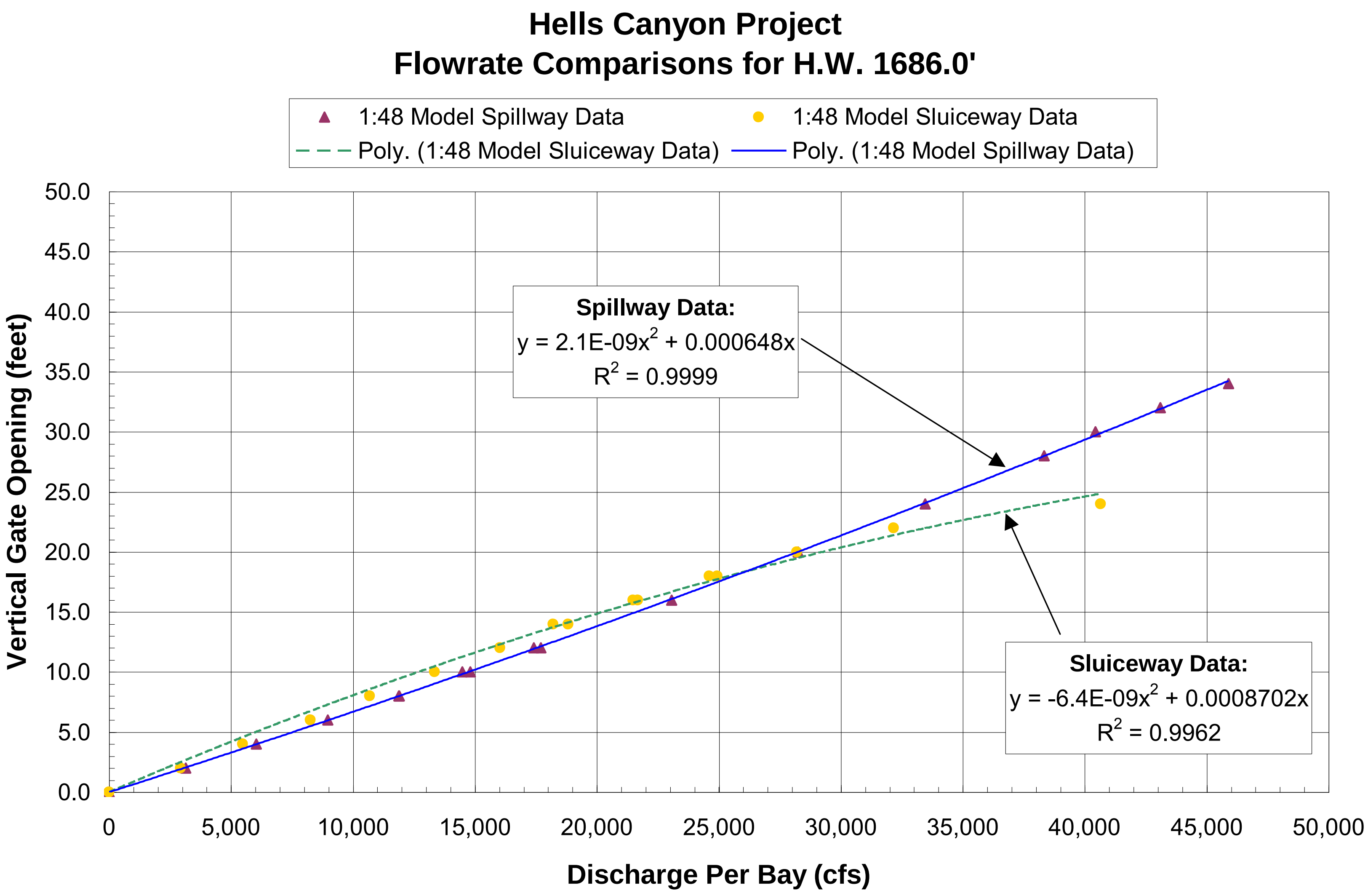


Figure C-1 Normal Headwater Rating Curve for 1:48 Model Spillway and Sluiceway

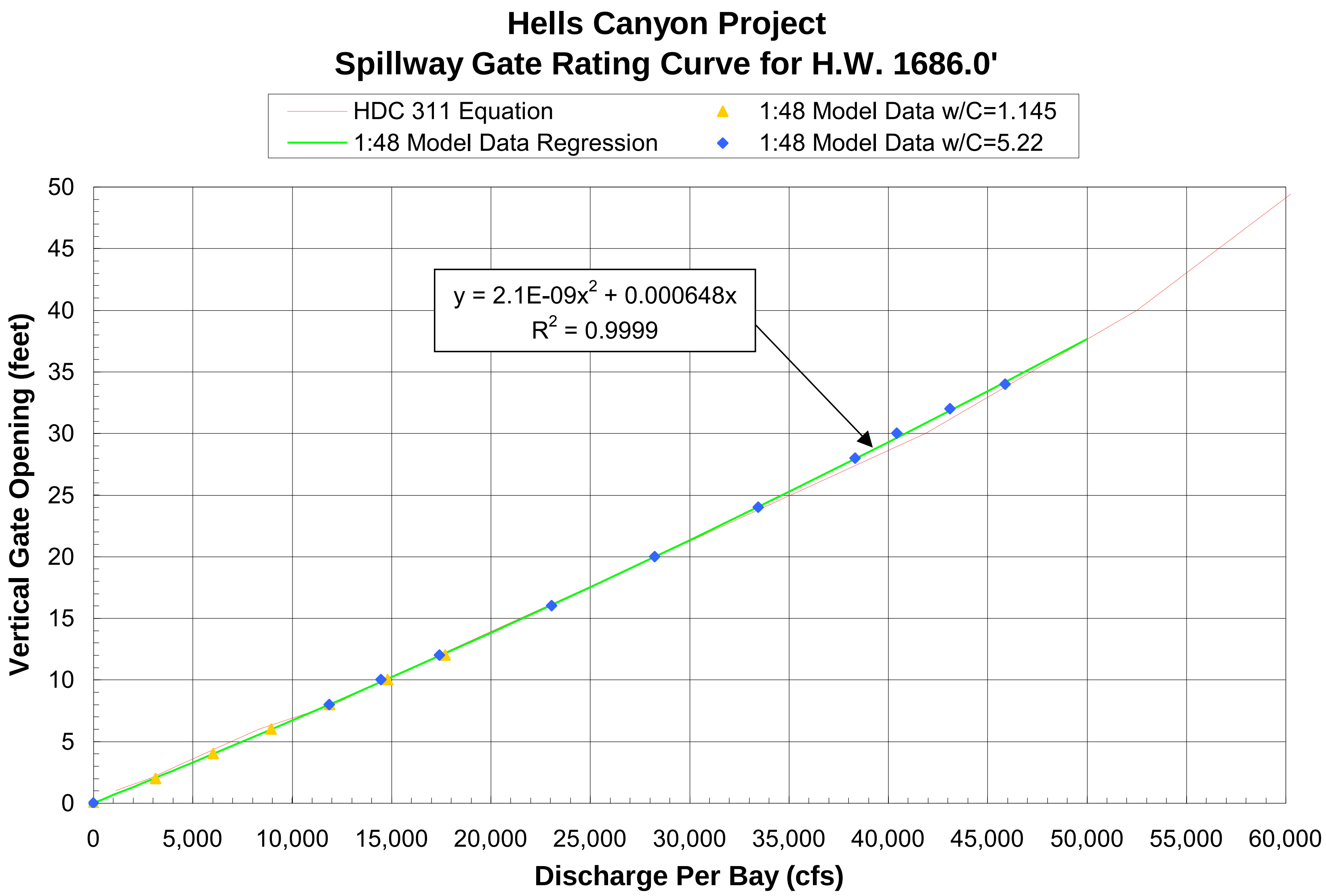


Figure C-2 Normal Headwater Rating Curve for 1:48 Model Spillway

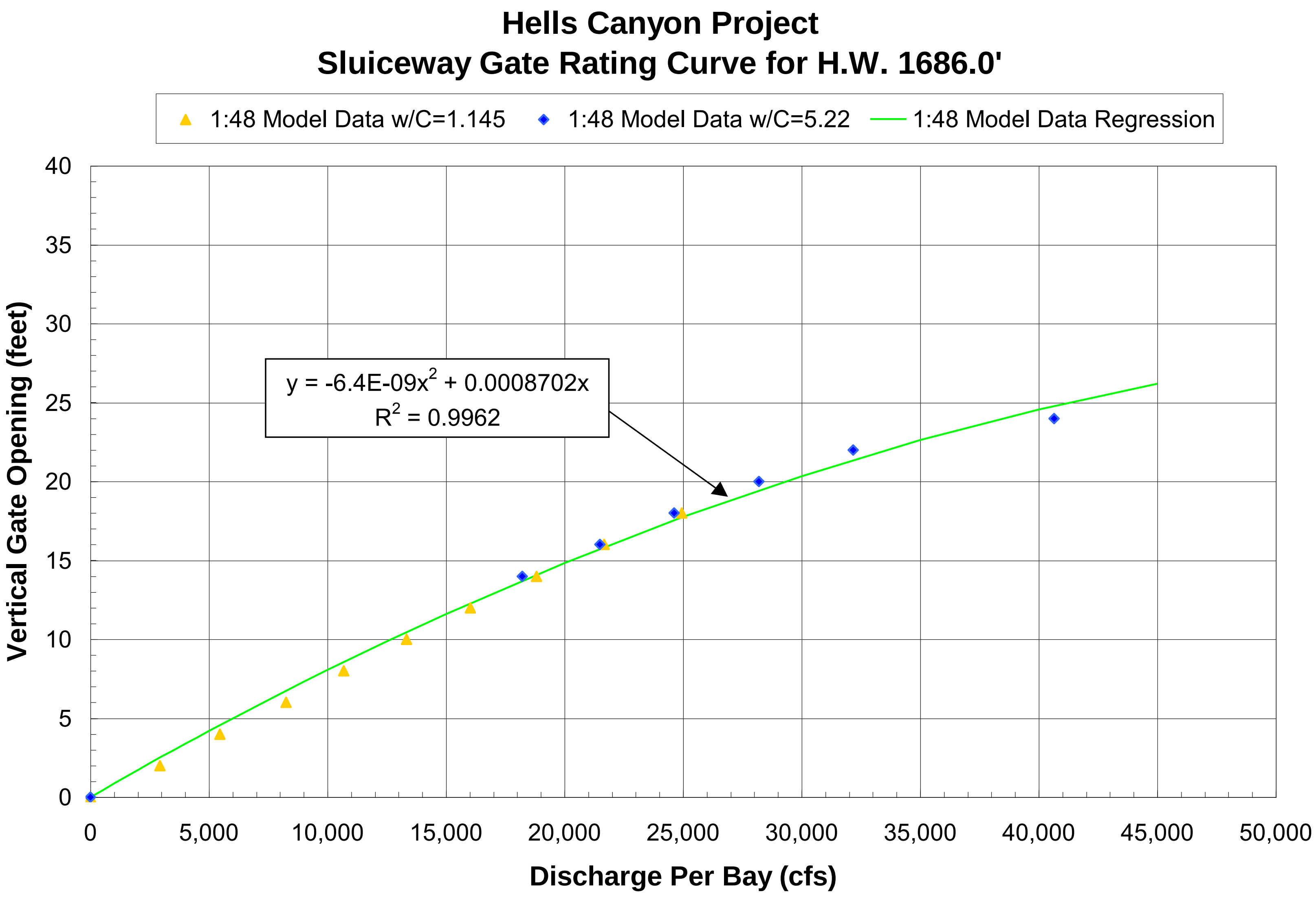


Figure C-3 Normal Headwater Rating Curve for 1:48 Model Sluiceway

Hells Canyon Flowrate Comparison 6/8/00

Following measurements of 6" and 12" orifices were conducted using 90° V-notch weir

Weir Flow: $Q=2.49 * H^{2.48}$

-A reading was taken for zeroed height of V-notch weir= 0.189

Scale: 48

6" orifice with C=1.145 (60hp pump)

C = 1.145

Standpipe Gage (model ft.)	Ht above weir (model ft.)	Proto weir Flow (proto cfs)	Manometer Δh (model ft.)	Proto Manometer Flow (proto cfs)	% error
0.869	0.680	**15,273**	0.679	**15,061**	**1.41%**
1.083	0.894	**30,104**	2.689	**29,971**	**0.44%**

Note: Closest obstruction is change in diameter of pipe from 8" I.D. to 14" I.D. at 42.5" d/s of orifice (7D d/s of orifice); the next closest obstruction to the orifice is a 45° bend in the pipe at 78" d/s of orifice (13D d/s of orifice)

12" orifice with C=5.22 (75 hp pump)

C = 5.22

Standpipe Gage (model ft.)	Ht above weir (model ft.)	Proto weir Flow (proto cfs)	Manometer Δh (model ft.)	Proto Manometer Flow (proto cfs)	% error
0.872	0.683	**15,441**	0.035	**15,589**	**0.95%**
1.093	0.904	**30,946**	0.135	**30,615**	**1.08%**
1.372	1.183	**60,298**	0.52	**60,086**	**0.35%**

Note: Closest obstruction is the placement of honeycomb in pipe at 90" u/s of orifice (7.5D u/s of orifice); the next closest obstruction is the location of a tee section at 94" d/s of orifice (about 8D d/s of orifice)

Figure C-4 Weir and Orifice Discharge Comparisons for 1:48 Model

Orifice Calibration Worksheet

Date:	**4/27/00**	**Name:**	**Pete Haug**		
Pipe Size:	**8 inch circular**	**Project Description:** Billable to Project IPC1		**$Q = C_d * \text{sqrt}(\Delta H)$**	**1 cubic ft H_2O = 62.43 lbs**
Orifice Size:	**6 inch annular**	**Hells Canyon 1:48 Physical Model Iowa Institute of Hydraulic Research**		**$C_d = Q / \text{sqrt}(\Delta H)$**	**C_d = 1.145**

End Scale Reading	Start Scale Reading	Net H_2O Weight (lbs)	Volume H_2O (ft^3)	ΔH (feet)	Time 1 (sec)	Time 2 (sec)	Time 3 (sec)	Average Time (sec)	Flowrate Q (cfs)	C_d
2000	1000	1000	16.0	0.2465	28.41	28.06	28.47	28.31	0.566	1.1395
2500	1000	1500	24.0	0.4770	30.81	30.41	30.60	30.61	0.785	1.1366
3000	1000	2000	32.0	0.6805	33.63	34.12	34.00	33.92	0.945	1.1450
3500	1000	2500	40.0	1.4120	29.41	29.44	29.53	29.46	1.359	1.1439
5000	1000	4000	64.1	2.6700	34.32	34.06	34.06	34.15	1.876	1.1483
7000	1000	6000	96.1	3.9200	42.04	42.28	42.40	42.24	2.275	1.1492
11000	1000	10000	160.2	6.3280	56.59	56.31	55.62	56.17	2.852	1.1336

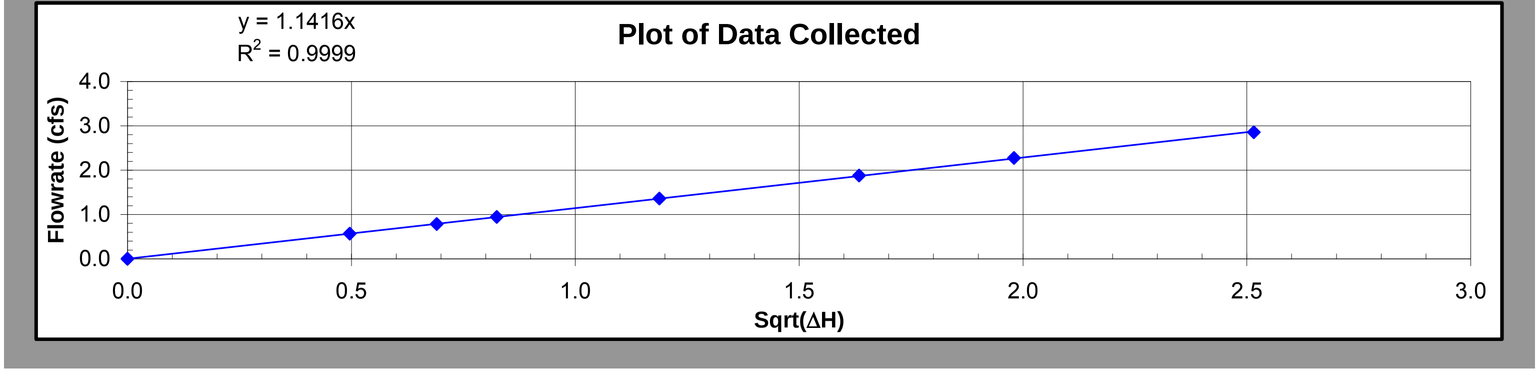


Figure C-5 Calibration of 6-inch Orifice for 1:48 Sectional Model

Empirical HDC 311 Equation from USACE

Normal Pool	Elevation	1686.0	Feet
Spill Crest	Elevation	1638.0	Feet
Gate Width	B	43.0	Feet
Gravity	g	32.2	Feet / Sec / Sec
Design Head	Hd	24.0	Feet
HDC 311-2	X	5.6	Feet
HDC 311-2	X/Hd	0.24	Within 0.1 to 0.3 range

Gate Opening Given Feet	Measured Angle β Degrees	HDC 311-1 Discharge C Coefficient	Measured Effective Opening Copy Inch	Effective Opening Go Feet	Effective Head H Feet	Estimated Flowrate Q=C*Go*B*sqrt(2*g*H) Feet^3 / Sec
1	64.5	0.675	1/16	0.7	47.6	1134
2	67	0.675	5/32	1.8	47.1	2819
4	68.5	0.675	5/16	3.5	46.2	5585
6	70.5	0.68	15/32	5.3	45.4	8359
8	73.5	0.68	11/16	7.8	44.1	12092
10	75	0.68	27/32	9.5	43.2	14691
15	80	0.69	1 1/4	14.1	40.9	21491
20	85.5	0.695	1 11/16	19.1	38.5	28328
30	98.5	0.725	2 9/16	28.9	33.5	41894
40	110.5	0.725	3 1/2	39.5	28.2	52512
50	127	0.725	4 9/16	51.5	22.2	60751

Figure C-6 Empirical Spillway Discharges for Hells Canyon Dam from USACE 311 Relation

APPENDIX D

1:48 MODEL NO GATE CONTROL CONDITION

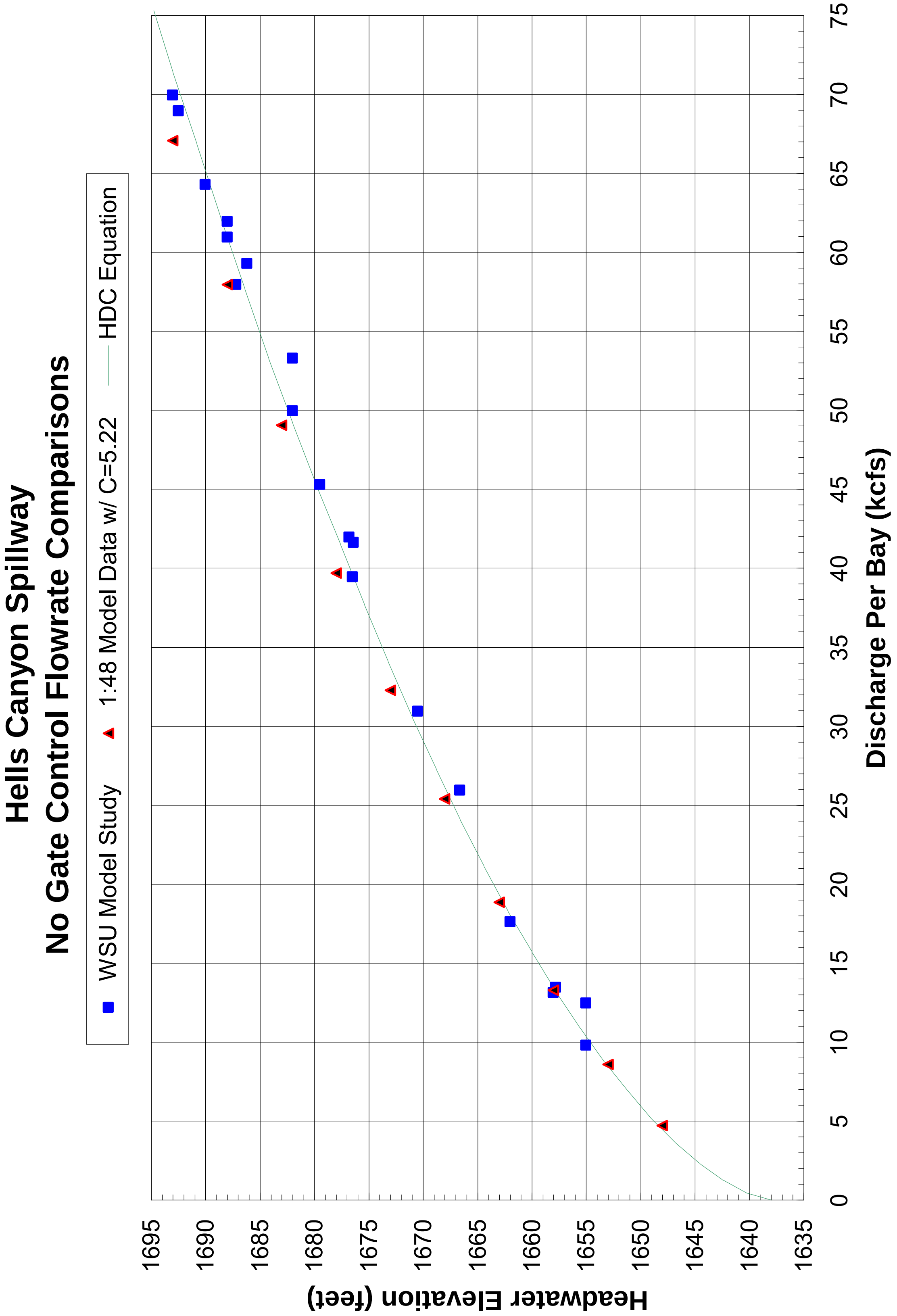


Figure D-1 Rating Curves for 1:48 Model Full Open Spillway Condition

Hells Canyon Project--Empirical HDC Spillway Discharge

June 06, 2000

Rev No:	2
Rev By:	PBD

Assuming no tailwater affects

Maximum Pool	Em	1693.00
Normal Pool	En	1688.00
Trunnion Elevation	Et	1658.00
Crest Elevation	Ec	1638.00
Stilling Basin	Eb	1400.00

Crest Information:

			HDC 111-6 Suggestion
Hd	44.00		
L	129.00		
R1	8.83	= 0.2 Hd	8.80
R2	22.00	= 0.5 Hd	22.00
Sc	49.88	= K Hd^0.85	49.88
K	2.00	= Sc / Hd^0.85	2.00

Pier Information:

Number of Piers	2		
Type	3		HDC 111-5
Kp	varies	depends on He/Hd	

Abutment Information:

left rad, R_1 (ft)	17		
right rad, R_2 (ft)	25		
Ka	varies	depends on He/R	HDC 111-3/1

Head Information:

He	55.00	= Em - Ec
He / Hd	1.25	
P	238	= Ec - Eb
P / Hd	5.41	

Discharge: $Q=CL_eH_e^{1.5}$ where $L_e=L-2(nK_p+K_a)H_e$

Note: since left and right abutments are different, assume $2Ka=Ka_1+Ka_2$

Empirical HDC Equation Spillway Discharge

June 06, 2000

Water Surface Elevation (feet)	Dimension Head He/Hd (feet)	HDC 111-5 Given He/Hd Pier Contraction Coeff. Kp	Dimension Parameter He/R_1 (feet)	HDC 111-3/1 Given He/R_1 Abut. Contract Coeff. Ka_1	Dimensionless Parameter He/R_2 (feet)	HDC 111-3/1 Given He/R_2 Abut. Contract Coeff. Ka_2	From HDC 111-21 Given P/Hd = 5.4 Discharge C	Empirical Flowrate $=CL_eH_e$^1.5 (total cfs)	Single Bay Spillway Discharge kcfs
1638.0	0.00	0.123	0.000	0.000	0.000	0.000	3.08	0	0.0
1640.2	0.05	0.112	0.129	0.002	0.088	0.001	3.14	1312	0.4
1642.4	0.10	0.105	0.259	0.004	0.176	0.003	3.21	3769	1.3
1644.6	0.15	0.092	0.388	0.006	0.264	0.004	3.26	6993	2.3
1646.8	0.20	0.081	0.518	0.008	0.352	0.006	3.32	10923	3.6
1649.0	0.25	0.072	0.647	0.010	0.440	0.007	3.38	15472	5.2
1651.2	0.30	0.063	0.776	0.012	0.528	0.008	3.44	20697	6.9
1653.4	0.35	0.054	0.906	0.014	0.616	0.009	3.49	26395	8.8
1655.6	0.40	0.046	1.035	0.016	0.704	0.011	3.54	32749	10.9
1657.8	0.45	0.039	1.165	0.020	0.792	0.012	3.59	39598	13.2
1660.0	0.50	0.033	1.294	0.023	0.880	0.013	3.64	47125	15.7
1662.2	0.55	0.028	1.424	0.026	0.968	0.015	3.68	54931	18.3
1664.4	0.60	0.023	1.553	0.028	1.056	0.017	3.73	63440	21.1
1666.6	0.65	0.019	1.682	0.032	1.144	0.019	3.77	72339	24.1
1668.8	0.70	0.015	1.812	0.035	1.232	0.021	3.82	81976	27.3
1671.0	0.75	0.011	1.941	0.038	1.320	0.023	3.86	91802	30.6
1673.2	0.80	0.008	2.071	0.040	1.408	0.025	3.90	102288	34.1
1675.4	0.85	0.005	2.200	0.043	1.496	0.027	3.94	113075	37.7
1677.6	0.90	0.003	2.329	0.045	1.584	0.029	3.98	124473	41.5
1679.8	0.95	0.002	2.459	0.048	1.672	0.032	4.01	135644	45.2
1682.0	1.00	0.001	2.588	0.050	1.760	0.034	4.04	147542	49.2
1684.2	1.05	-0.002	2.718	0.054	1.848	0.036	4.07	159834	53.3
1686.4	1.10	-0.006	2.847	0.057	1.936	0.038	4.10	173135	57.7
1688.6	1.15	-0.010	2.976	0.060	2.024	0.040	4.12	186570	62.2
1690.8	1.20	-0.013	3.106	0.062	2.112	0.041	4.14	200622	66.9
1693.0	1.25	-0.013	3.235	0.063	2.200	0.043	4.17	214237	71.4
1695.2	1.30	-0.014	3.365	0.064	2.288	0.044	4.20	229010	76.3
1697.4	1.35	-0.014	3.494	0.065	2.376	0.046	4.22	243052	81.0
1699.6	1.40	-0.014	3.624	0.066	2.464	0.048	4.25	257722	85.9

Figure D-2 Empirical Ungated Spillway Discharges for Hells Canyon Dam

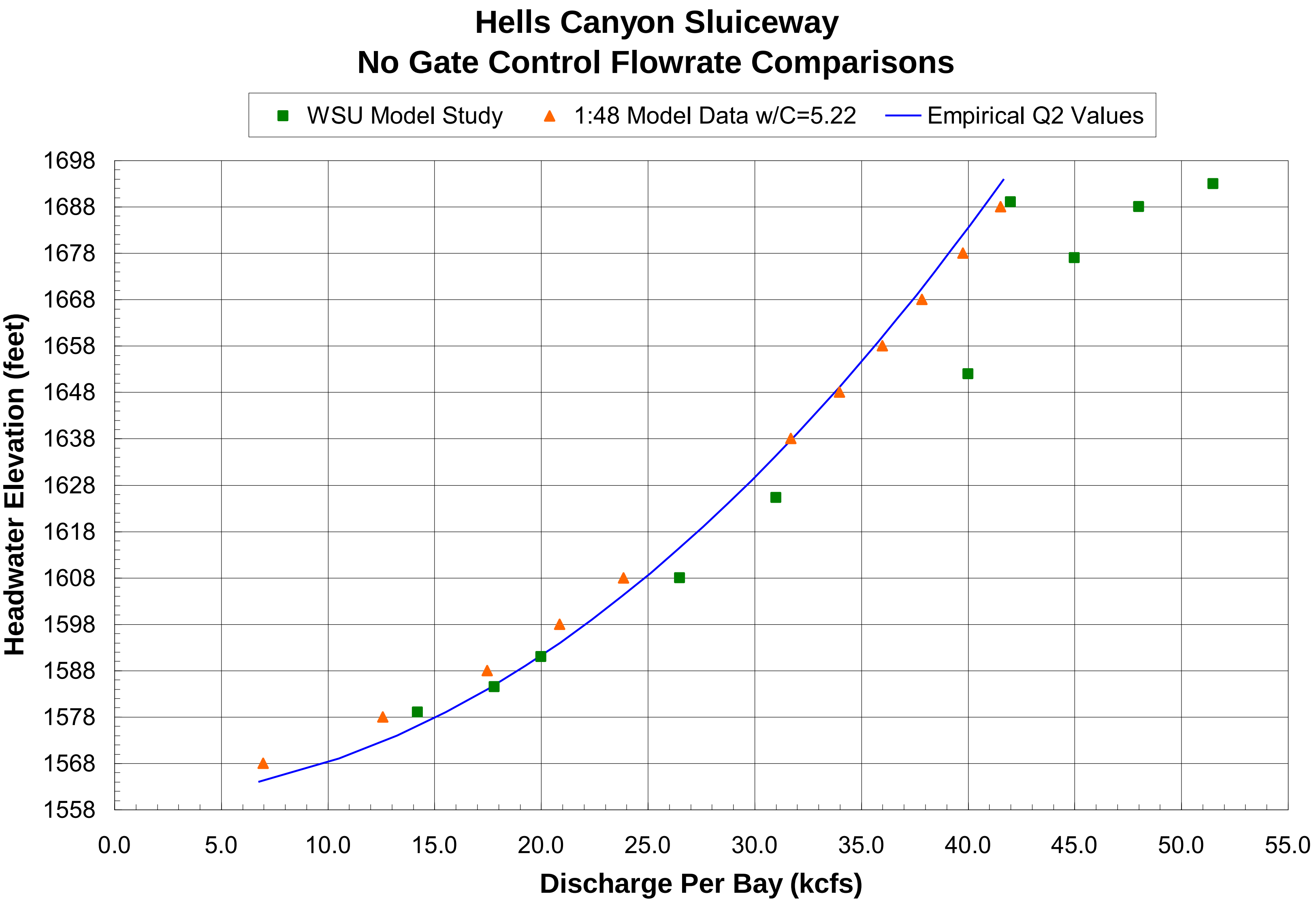


Figure D-3 Rating Curves for 1:48 Model Full Open Sluiceway Condition

Hells Canyon Project--Empirical Sluiceway Discharge

June 06, 2000

Rev No:	2
Rev By:	PBD

Head Information:

H_{max}	1693.00	Maximum Pool
H_{norm}	1688.00	Normal Pool
H_{ot}	1584.90	Top of Orifice Transition Elev.
H_{cr}	1549.00	Crest Elevation

Outlet Information:

H_t (ft)	37.96	Height of outlet including transitions	
W_t (ft)	31.50	Width of outlet including transitions	
H (ft)	23.00	Nominal height of outlet	
W (ft)	23.00	Nominal width of outlet	
L (ft)	23	Width of orifice (assumed)	Fig. 21 Davis' Handbook of Hydraulics
C	0.85	Orifice coefficient (assumed)	Fig. 20 Davis' Handbook of Hydraulics

Discharge Information:

$Q_1=2/3C(2g)^{0.5}L(H_2^{1.5}-H_1^{1.5})$	when size of orifice is large compared to head
$Q_2=CA(2gH_3)^{0.5}$	when head is relatively large compared to orifice size

g (ft/s^2) 32.20

Note: The values for Q_2 were used to plot since Q_1 and Q_2 are very similar and higher heads are of more concern.

Empirical Sluiceway Discharges

June 6, 2000

Water Surface Elevation (feet)	Total Head Above CL of Orifice, H_3 (feet)	Total Head Above Crest H_2 (feet)	Head Above Top of Orifice Transition, H_1 (feet)	Empirical Flowrate Q_1 (Total cfs)	Empirical Flowrate Q_2 (Total cfs)	Single Bay Sluiceway Discharge Q_1 kcfs	Single Bay Sluiceway Discharge Q_2 kcfs
1549.0	na	0.00	na	-	-	-	-
1554.0	na	5.00	na	-	-	-	-
1559.0	na	10.00	na	-	-	-	-
1564.0	3.5	15.00	na	-	6,751	-	6.8
1569.0	8.5	20.00	na	-	10,520	-	10.5
1574.0	13.5	25.00	2.00	12,778	13,258	12.8	13.3
1579.0	18.5	30.00	7.00	15,249	15,520	15.2	15.5
1584.0	23.5	35.00	12.00	17,309	17,492	17.3	17.5
1589.0	28.5	40.00	17.00	19,129	19,264	19.1	19.3
1594.0	33.5	45.00	22.00	20,780	20,885	20.8	20.9
1599.0	38.5	50.00	27.00	22,305	22,390	22.3	22.4
1604.0	43.5	55.00	32.00	23,729	23,799	23.7	23.8
1609.0	48.5	60.00	37.00	25,070	25,130	25.1	25.1
1614.0	53.5	65.00	42.00	26,342	26,393	26.3	26.4
1619.0	58.5	70.00	47.00	27,554	27,599	27.6	27.6
1624.0	63.5	75.00	52.00	28,715	28,754	28.7	28.8
1629.0	68.5	80.00	57.00	29,830	29,865	29.8	29.9
1634.0	73.5	85.00	62.00	30,904	30,936	30.9	30.9
1639.0	78.5	90.00	67.00	31,942	31,971	31.9	32.0
1644.0	83.5	95.00	72.00	32,947	32,973	32.9	33.0
1649.0	88.5	100.00	77.00	33,922	33,946	33.9	33.9
1654.0	93.5	105.00	82.00	34,870	34,892	34.9	34.9
1659.0	98.5	110.00	87.00	35,792	35,813	35.8	35.8
1664.0	103.5	115.00	92.00	36,691	36,710	36.7	36.7
1669.0	108.5	120.00	97.00	37,569	37,587	37.6	37.6
1674.0	113.5	125.00	102.00	38,426	38,443	38.4	38.4
1679.0	118.5	130.00	107.00	39,265	39,280	39.3	39.3
1684.0	123.5	135.00	112.00	40,086	40,101	40.1	40.1
1689.0	128.5	140.00	117.00	40,891	40,904	40.9	40.9
1694.0	133.5	145.00	122.00	41,680	41,693	41.7	41.7

Figure D-4 Empirical Ungated Sluiceway Discharges for Hells Canyon Dam

APPENDIX E

1:48 MODEL COMPREHENSIVE RATING CURVES

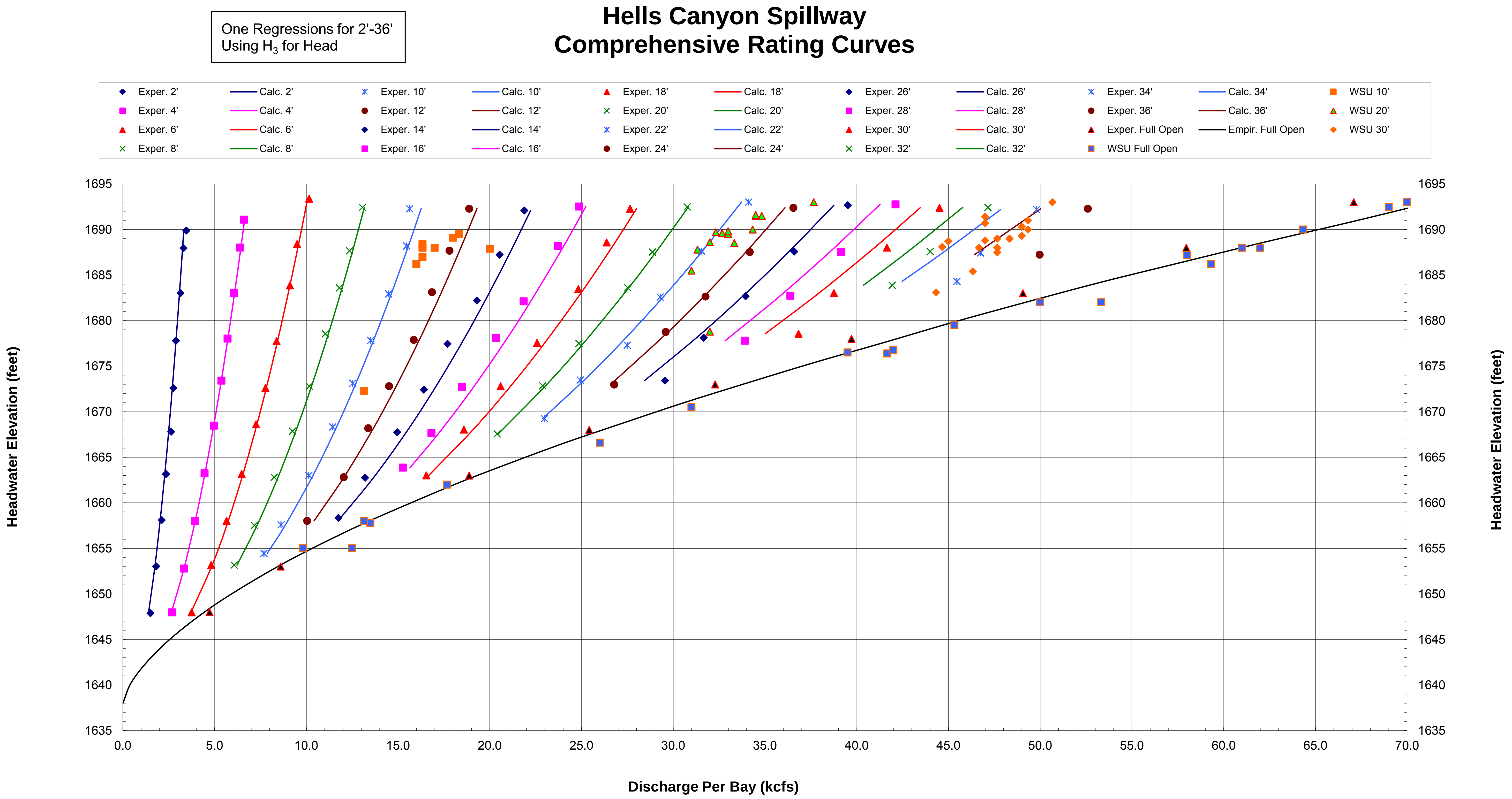


Figure E-1 Spillway Rating Curves from Comprehensive Regression Analysis

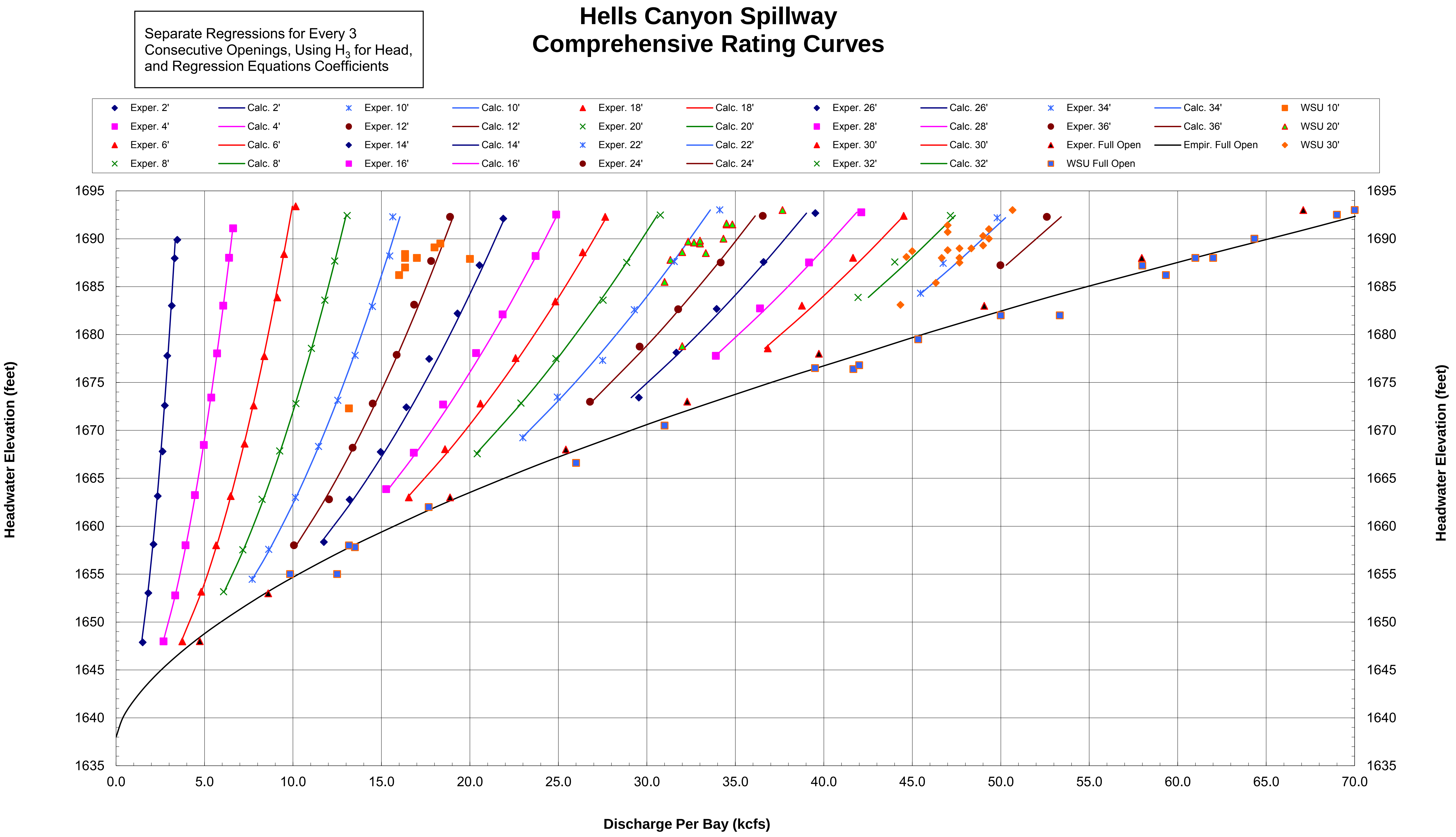


Figure E-2 Spillway Rating Curves from Consecutive Regression Analysis

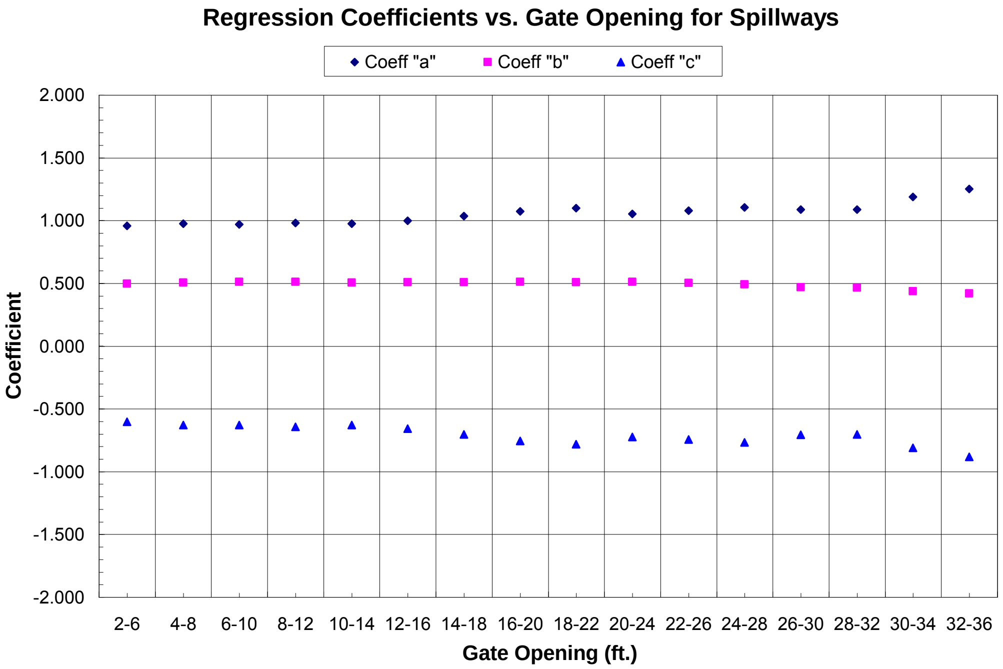


Figure E-3 Regression Coefficients for Every Three Consecutive Spillway Gate Openings

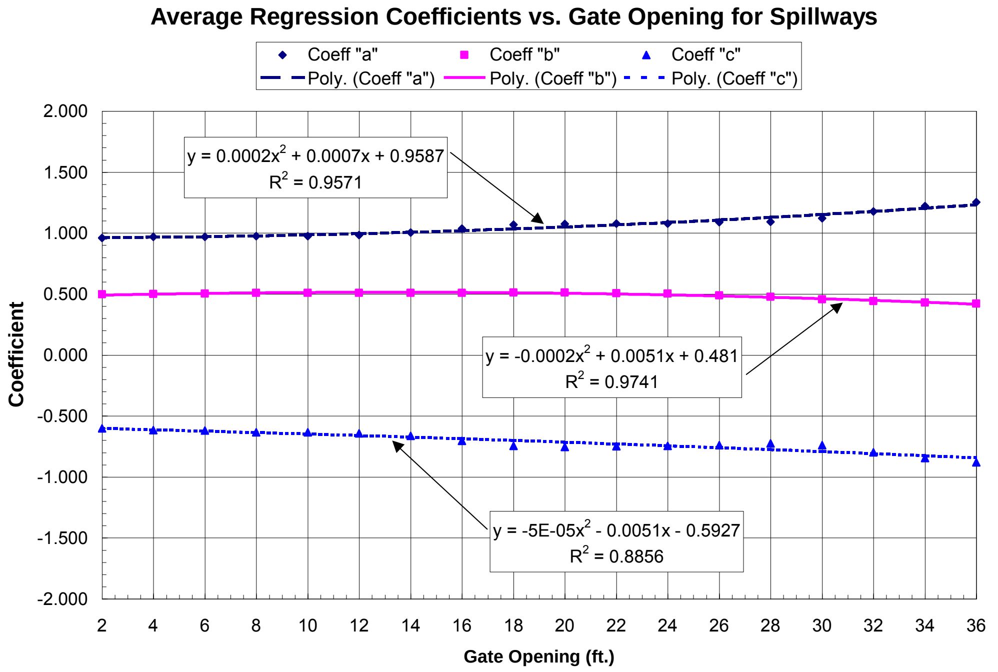


Figure E-4 Average Regression Coefficients for Consecutive Spillway Gate Openings

Hells Canyon Model **April 3, 2001**

Results from Consecutive Regression of Spillway Rating Curves Using Alternative Head

Theorectical Equation:

$\boxed{Q = G^a*H^b*10^c}$

Spillway Crest Elev: 1638.0
Spill Gate Seal Elev: 1637.625
Model Scale: 48

G = vertical gate opening (proto. ft.)
H = head to center of opening (proto. ft.)

Note: Head used for this data set is taken as H.W. Elev. Minus the Elev. At the center of the gate opening

Gate Openings (proto. ft.)	Coeff. "a"	Coeff. "b"	Coeff. "c"
2-6	0.959	0.495	-0.603
4-8	0.975	0.505	-0.630
6-10	0.968	0.510	-0.629
8-12	0.980	0.511	-0.642
10-14	0.974	0.506	-0.630
12-16	0.999	0.507	-0.659
14-18	1.035	0.509	-0.703
16-20	1.074	0.512	-0.756
18-22	1.097	0.508	-0.781
20-24	1.052	0.510	-0.724
22-26	1.077	0.502	-0.745
24-28	1.104	0.492	-0.768
26-30	1.086	0.469	-0.706
28-32	1.088	0.464	-0.703
30-34	1.188	0.437	-0.810
32-36	1.252	0.420	-0.882

Note: Coefficients "a", "b", and "c" taken from regression of 3 consecutive gate openings w/ G and H as variables

Gate Opening	Average Values			Trendline Equation Values		
(proto. ft.)	Coeff. "a"	Coeff. "b"	Coeff. "c"	Coeff. "a"	Coeff. "b"	Coeff. "c"
2	0.959	0.495	-0.603	0.961	0.490	-0.603
4	0.967	0.500	-0.616	0.965	0.498	-0.614
6	0.967	0.503	-0.621	0.970	0.504	-0.625
8	0.975	0.509	-0.634	0.977	0.509	-0.637
10	0.974	0.509	-0.634	0.986	0.512	-0.649
12	0.984	0.508	-0.644	0.996	0.513	-0.661
14	1.002	0.508	-0.664	1.008	0.513	-0.674
16	1.036	0.510	-0.706	1.021	0.511	-0.687
18	1.068	0.510	-0.747	1.036	0.508	-0.701
20	1.074	0.510	-0.753	1.053	0.503	-0.715
22	1.076	0.507	-0.750	1.071	0.496	-0.729
24	1.078	0.501	-0.746	1.091	0.488	-0.744
26	1.089	0.488	-0.740	1.112	0.478	-0.759
28	1.093	0.475	-0.726	1.135	0.467	-0.775
30	1.121	0.457	-0.740	1.160	0.454	-0.791
32	1.176	0.440	-0.798	1.186	0.439	-0.807
34	1.220	0.428	-0.846	1.214	0.423	-0.824
36	1.252	0.420	-0.882	1.243	0.405	-0.841

Figure E-5 Regression Coefficients from Consecutive Spillway Rating Curve Analysis

Hells Canyon Model **April 3, 2001**

Comparisons of Spillway Rating Curves

Theorectical Equation:

$\boxed{Q = G^a*H^b*10^c}$

Spillway Crest Elev: 1638.0
Spill Gate Seal Elev: 1637.625
Model Scale: 48

G = vertical gate opening (proto. ft.)
H = head to center of opening (proto. ft.)

Gate Openings	R^2 Values for Regression Analysis	
(proto. ft.)	Comprehensive	Consecutive w/ Trendline Equation Coeff.
2	0.977	0.991
4	1.000	1.000
6	0.999	0.999
8	0.995	1.000
10	0.991	0.997
12	0.981	0.996
14	0.979	0.995
16	0.981	0.996
18	0.989	0.998
20	0.998	0.999
22	0.995	0.993
24	0.994	0.994
26	0.966	0.990
28	0.931	0.995
30	0.834	0.978
32	0.576	0.934
34	-	0.925
36	-	0.778
Average R^2:	**0.949**	**0.975**

Note: R^2 values relate goodness of fit of the calculated discharge to the experimental discharge for each gate opening

Figure E-6 R^2 Values for Spillway Rating Curves

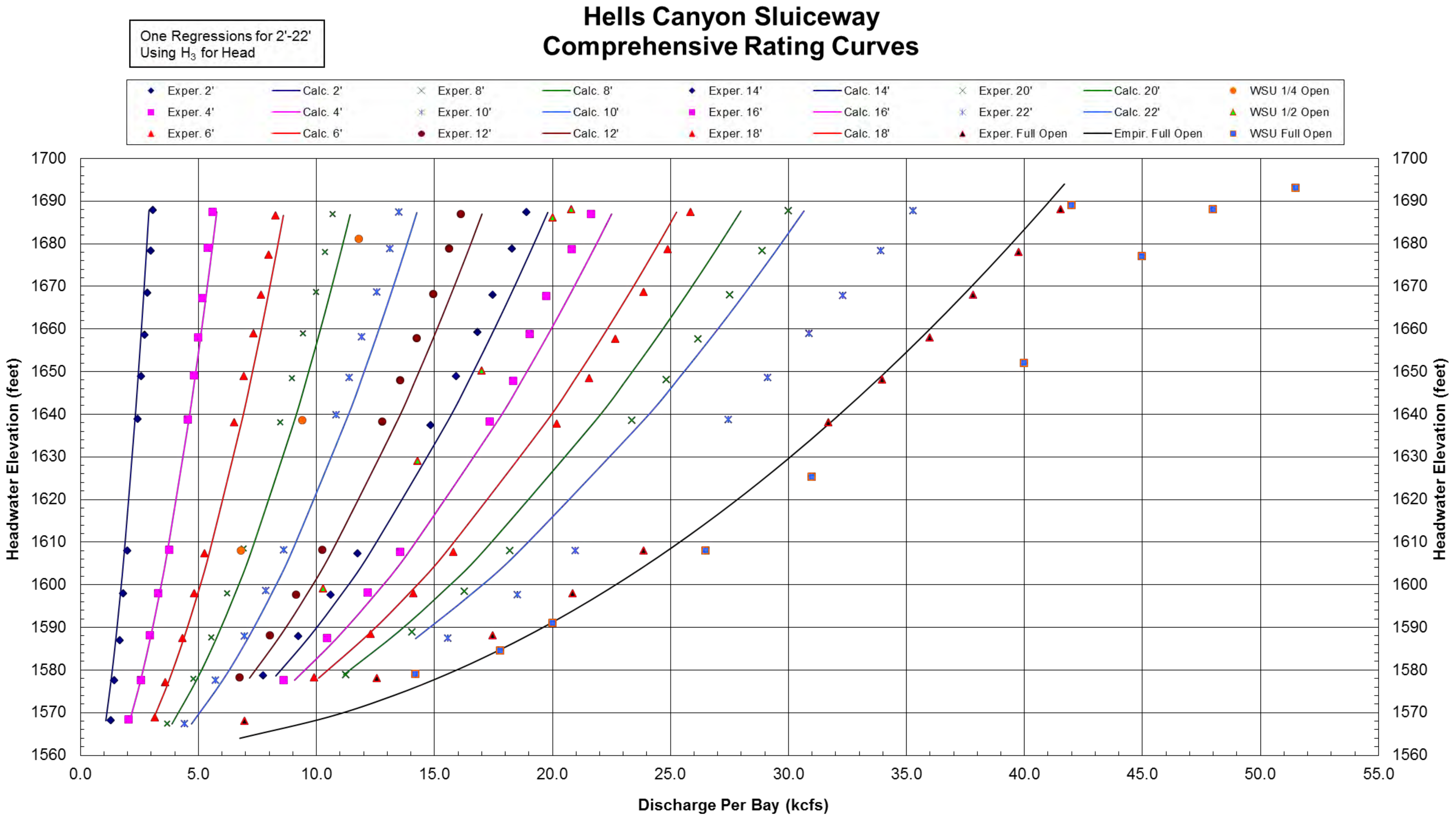


Figure E-7 Sluiceway Rating Curves from Comprehensive Regression Analysis

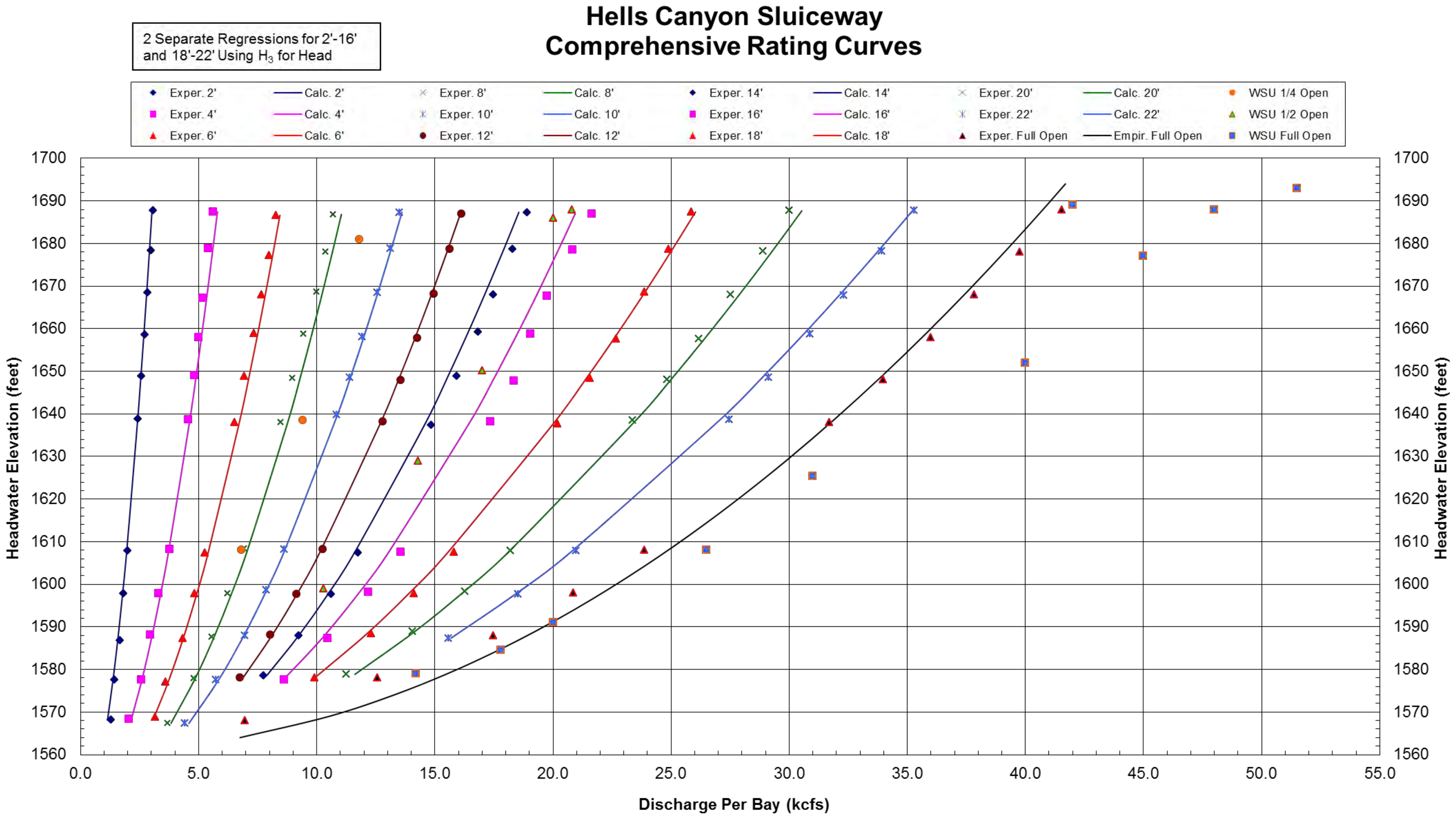


Figure E-8 Sluiceway Rating Curves from Two Separate Regression Analyses

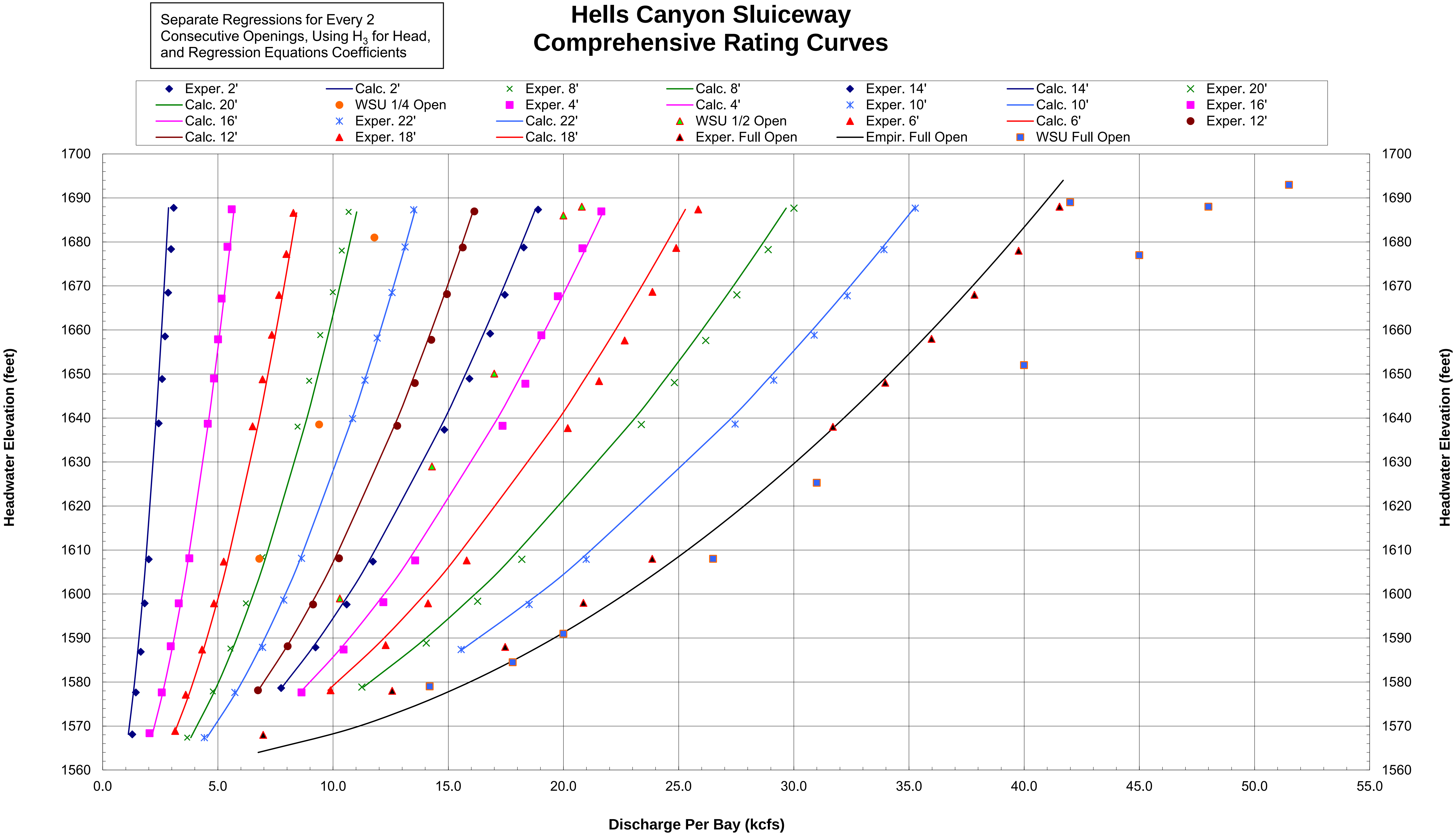


Figure E-9 Sluiceway Rating Curves from Consecutive Regression Analysis

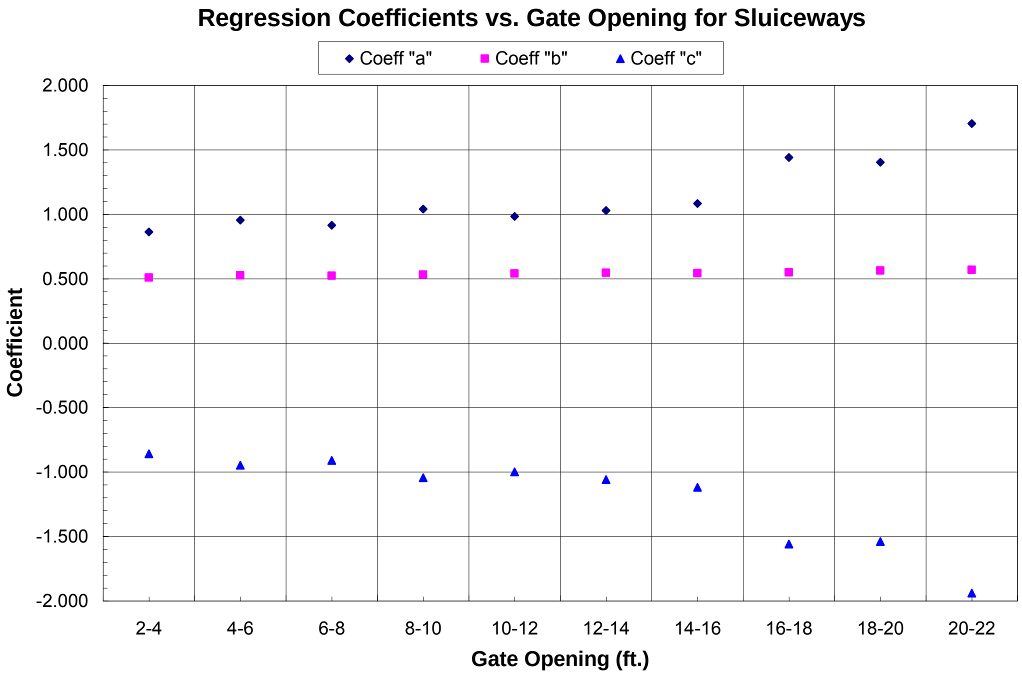


Figure E-10 Regression Coefficients for Consecutive Sluiceway Gate Openings

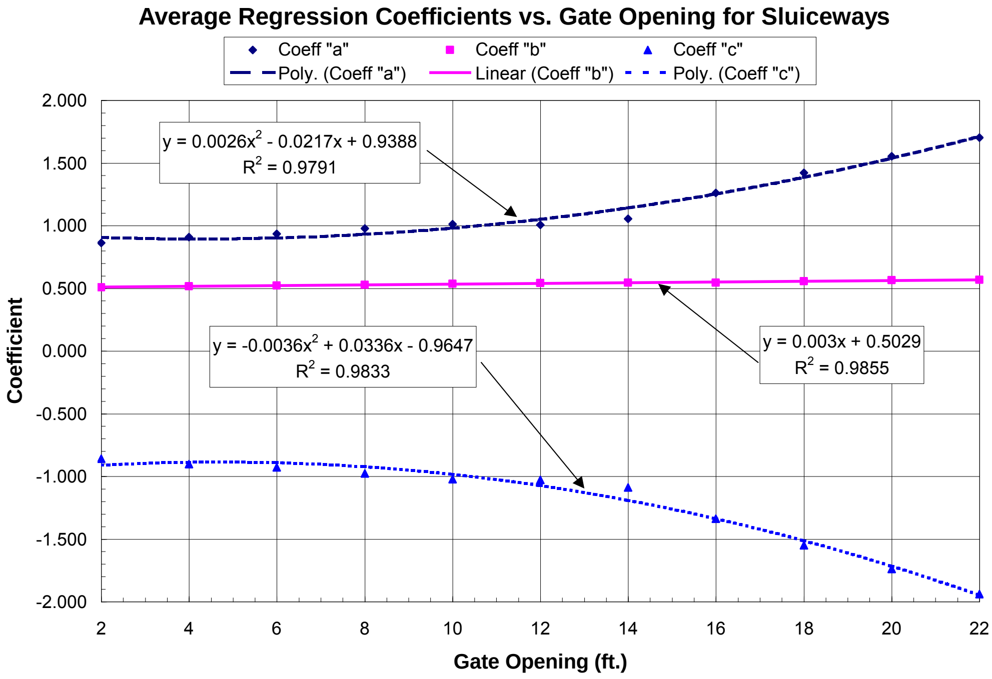
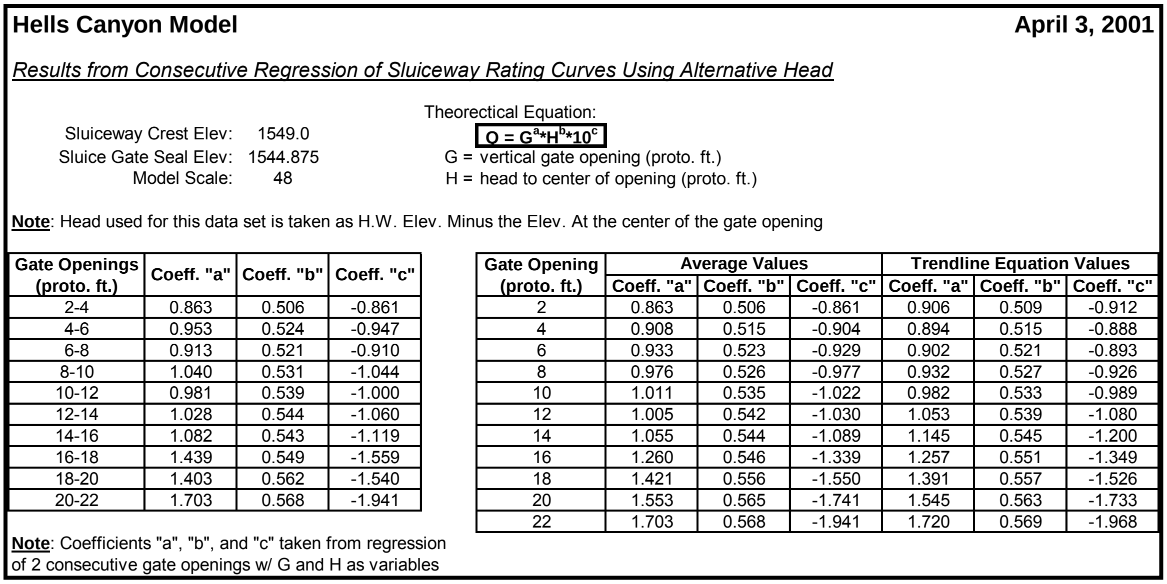


Figure E-11 Average Regression Coefficients for Consecutive Sluiceway Gate Openings



Hells Canyon Model **April 3, 2001**

Results from Consecutive Regression of Sluiceway Rating Curves Using Alternative Head

Sluiceway Crest Elev: 1549.0
Sluice Gate Seal Elev: 1544.875
Model Scale: 48

Theorectical Equation:

$\boxed{Q = G^{a} * H^{b} * 10^{c}}$

G = vertical gate opening (proto. ft.)
H = head to center of opening (proto. ft.)

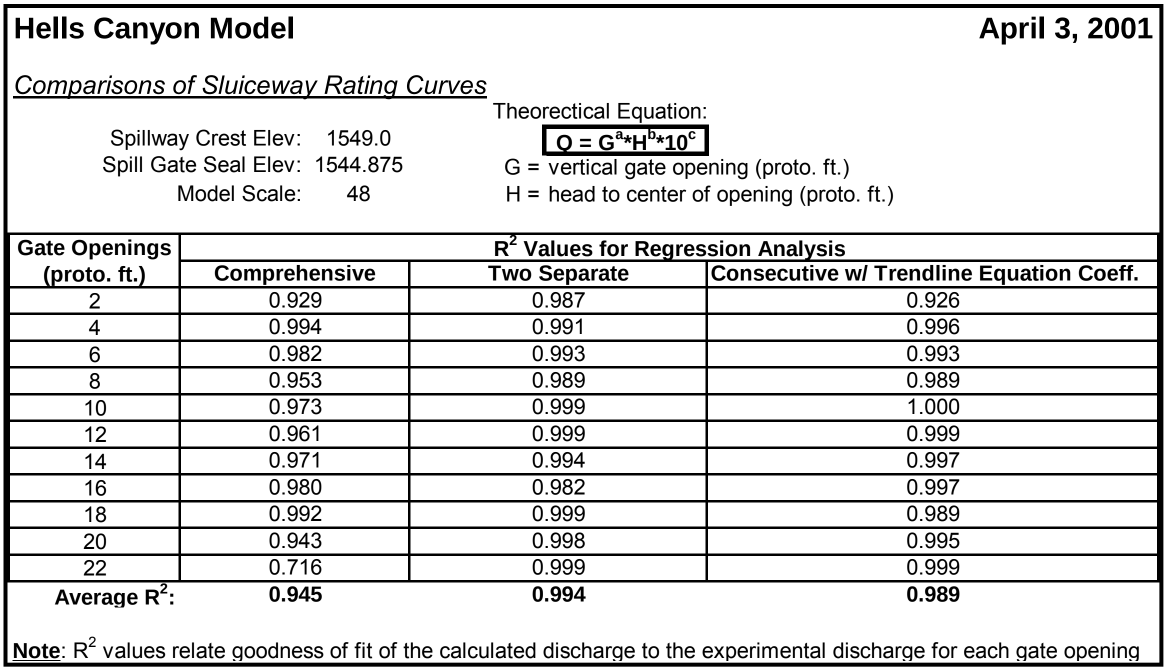
Note: Head used for this data set is taken as H.W. Elev. Minus the Elev. At the center of the gate opening

Gate Openings (proto. ft.)	Coeff. "a"	Coeff. "b"	Coeff. "c"
2-4	0.863	0.506	-0.861
4-6	0.953	0.524	-0.947
6-8	0.913	0.521	-0.910
8-10	1.040	0.531	-1.044
10-12	0.981	0.539	-1.000
12-14	1.028	0.544	-1.060
14-16	1.082	0.543	-1.119
16-18	1.439	0.549	-1.559
18-20	1.403	0.562	-1.540
20-22	1.703	0.568	-1.941

Note: Coefficients "a", "b", and "c" taken from regression of 2 consecutive gate openings w/ G and H as variables

Gate Opening (proto. ft.)	Average Values			Trendline Equation Values		
	Coeff. "a"	Coeff. "b"	Coeff. "c"	Coeff. "a"	Coeff. "b"	Coeff. "c"
2	0.863	0.506	-0.861	0.906	0.509	-0.912
4	0.908	0.515	-0.904	0.894	0.515	-0.888
6	0.933	0.523	-0.929	0.902	0.521	-0.893
8	0.976	0.526	-0.977	0.932	0.527	-0.926
10	1.011	0.535	-1.022	0.982	0.533	-0.989
12	1.005	0.542	-1.030	1.053	0.539	-1.080
14	1.055	0.544	-1.089	1.145	0.545	-1.200
16	1.260	0.546	-1.339	1.257	0.551	-1.349
18	1.421	0.556	-1.550	1.391	0.557	-1.526
20	1.553	0.565	-1.741	1.545	0.563	-1.733
22	1.703	0.568	-1.941	1.720	0.569	-1.968

Figure E-12 Regression Coefficients from Consecutive Sluiceway Rating Curve Analysis



Hells Canyon Model **April 3, 2001**

Comparisons of Sluiceway Rating Curves

Spillway Crest Elev: 1549.0
Spill Gate Seal Elev: 1544.875
Model Scale: 48

Theorectical Equation:

$\boxed{Q = G^{a} * H^{b} * 10^{c}}$

G = vertical gate opening (proto. ft.)
H = head to center of opening (proto. ft.)

Gate Openings (proto. ft.)	R^2 Values for Regression Analysis		
	Comprehensive	Two Separate	Consecutive w/ Trendline Equation Coeff.
2	0.929	0.987	0.926
4	0.994	0.991	0.996
6	0.982	0.993	0.993
8	0.953	0.989	0.989
10	0.973	0.999	1.000
12	0.961	0.999	0.999
14	0.971	0.994	0.997
16	0.980	0.982	0.997
18	0.992	0.999	0.989
20	0.943	0.998	0.995
22	0.716	0.999	0.999
Average R^2:	**0.945**	**0.994**	**0.989**

Note: R^2 values relate goodness of fit of the calculated discharge to the experimental discharge for each gate opening

Figure E-13 R^2 Values for Sluiceway Rating Curves

APPENDIX F

1:48 MODEL DEFLECTOR PERFORMANCE CURVES

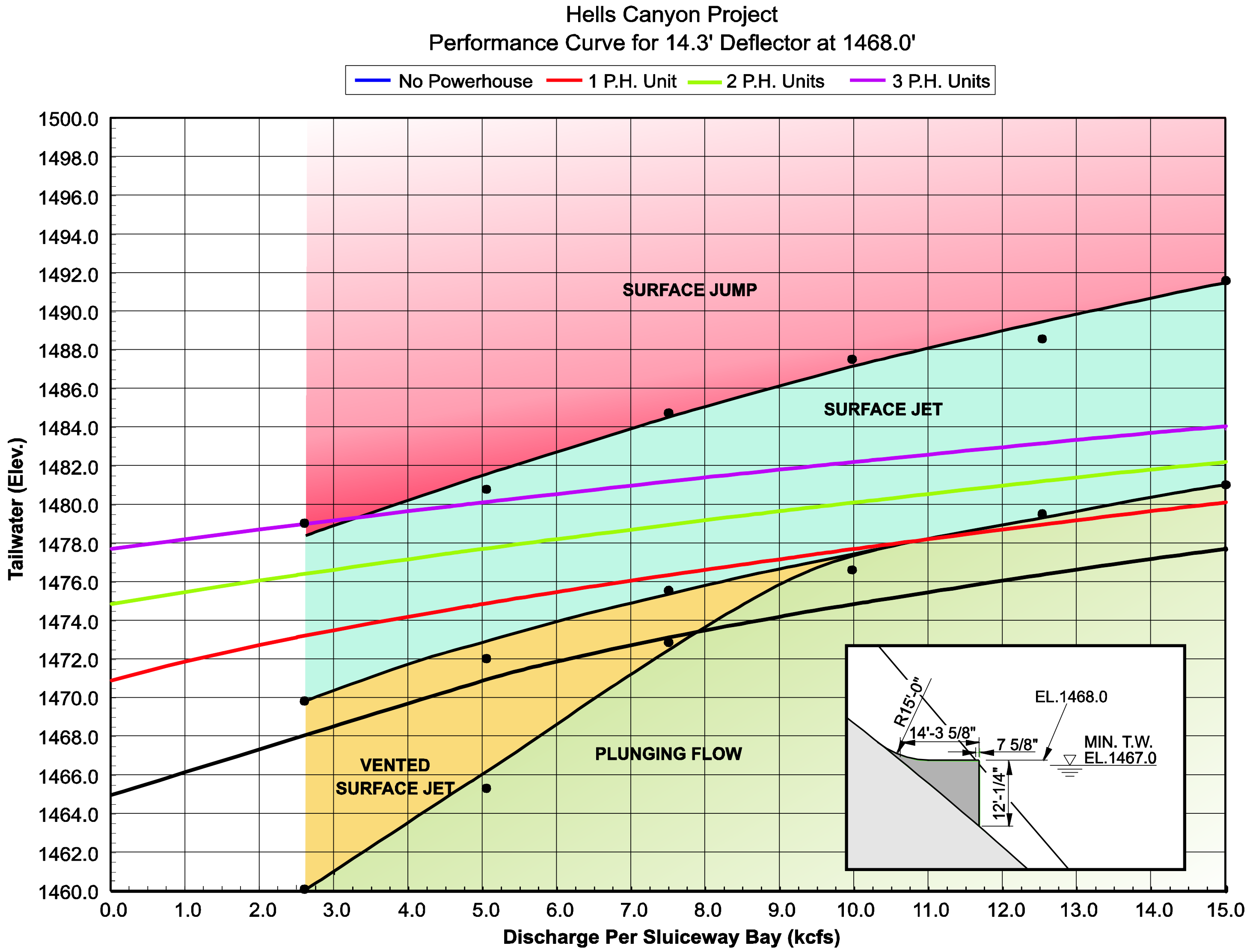


Figure F-1 Performance Curve for 14.3-Foot Deflector at Elevation 1468.0 Feet

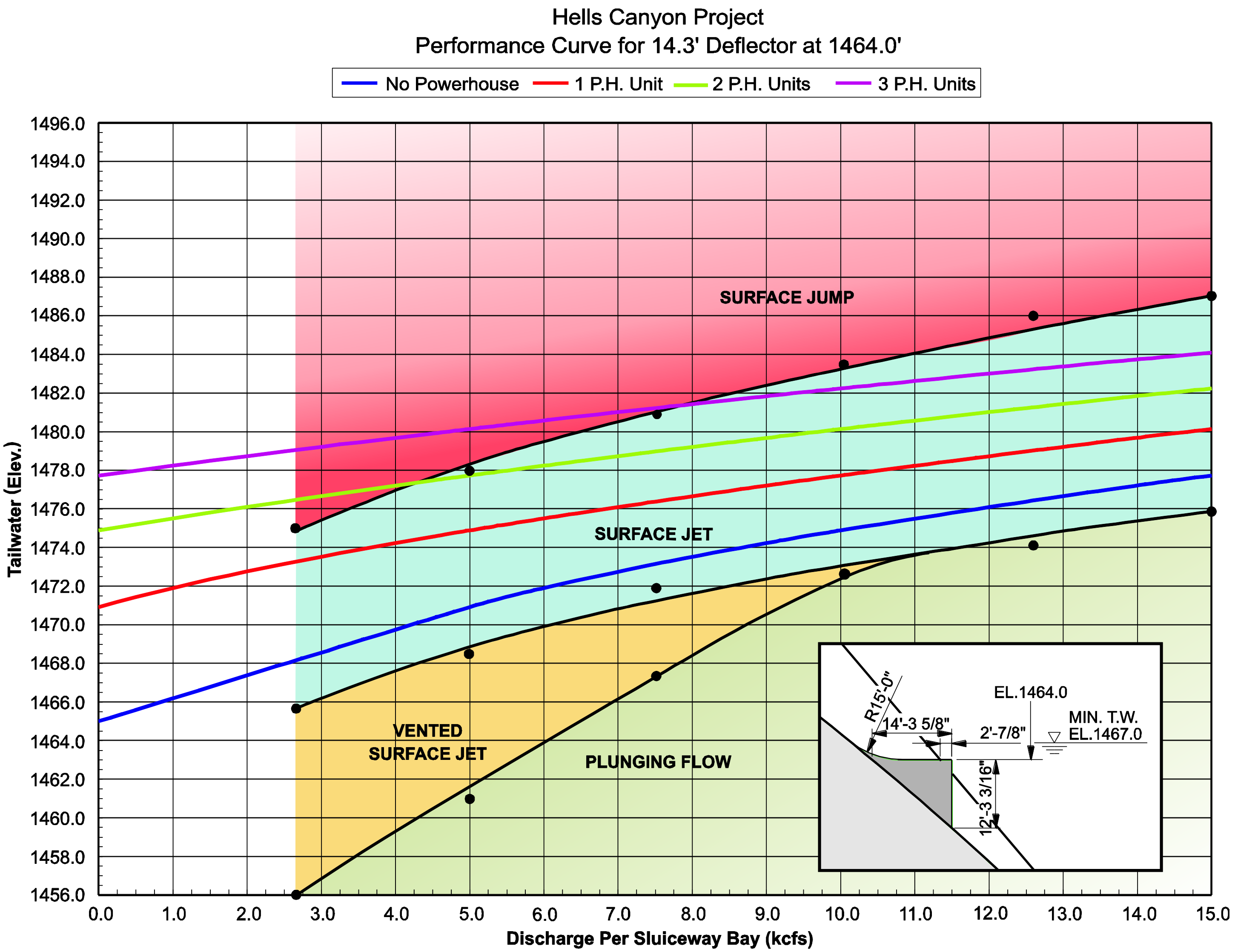


Figure F-2 Performance Curve for 14.3-Foot Deflector at Elevation 1464.0 Feet

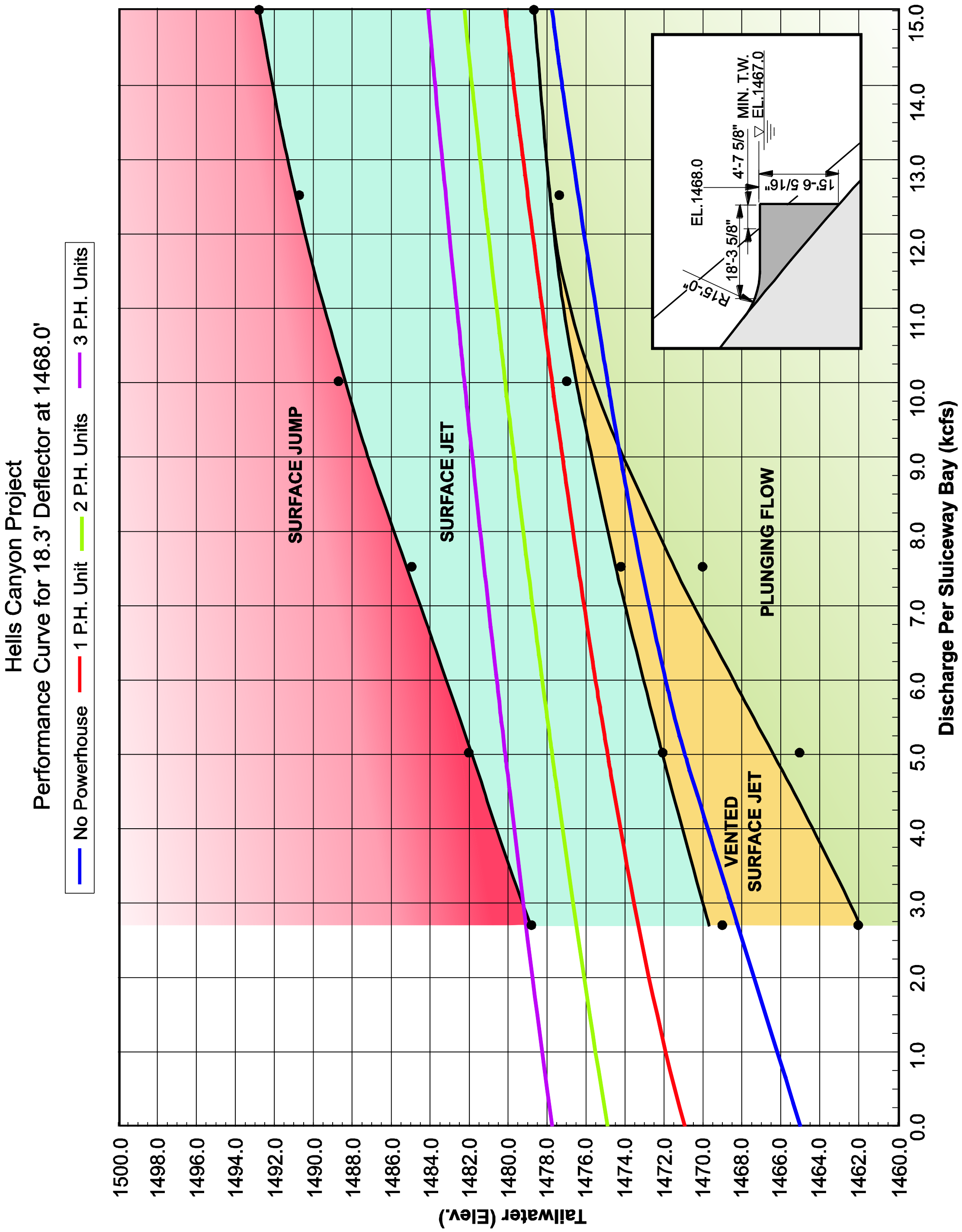


Figure F-3 Performance Curve for 18.3-Foot Deflector at Elevation 1468.0 Feet

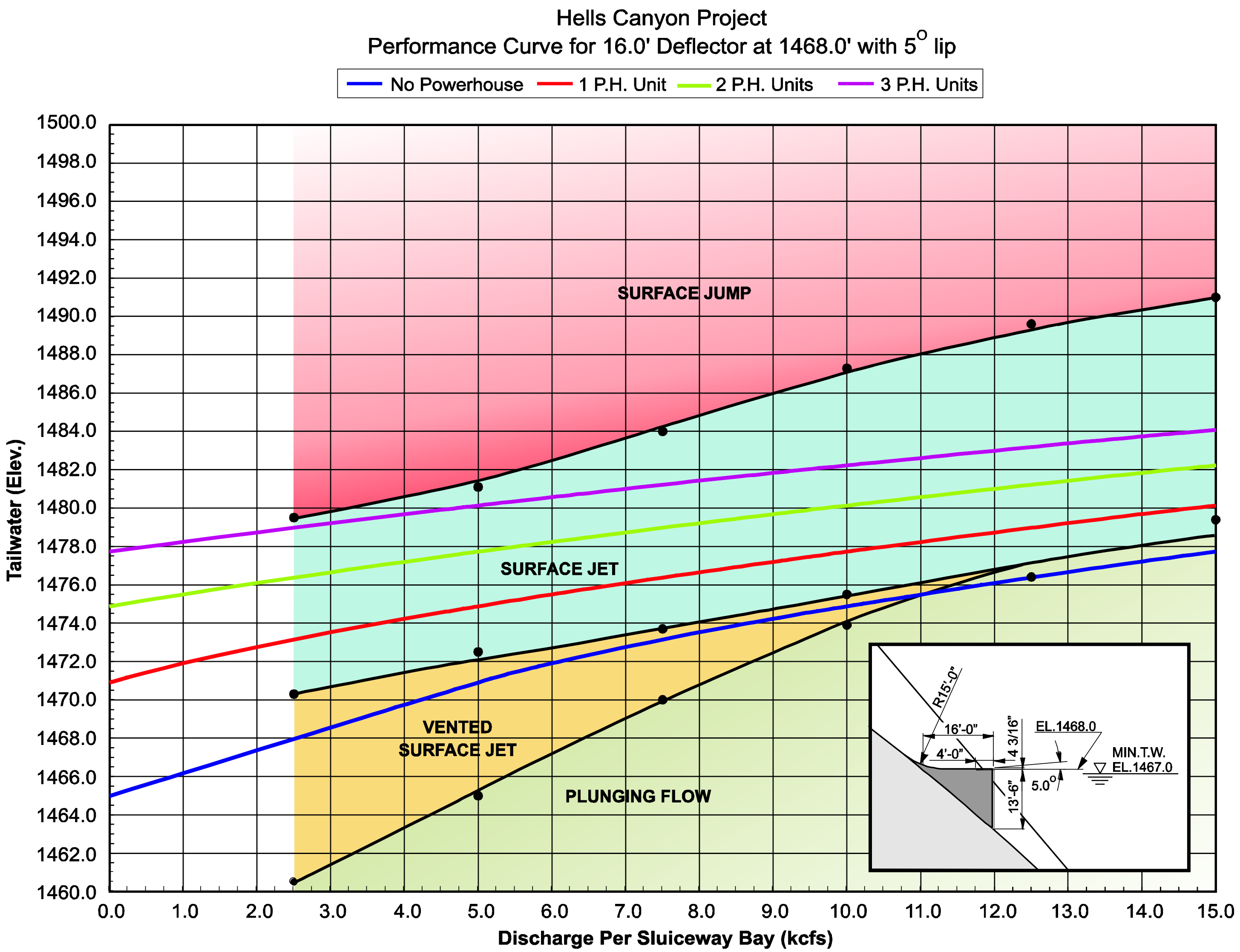


Figure F-4 Performance Curve for 16.0-Foot Deflector with 5° Lip at Elevation 1468.0 Feet

APPENDIX G

1:48 SECTIONAL MODEL OPERATIONS OF 16.0-FOOT DEFLECTOR WITH 5° LIP AT ELEVATION 1468.0 FEET

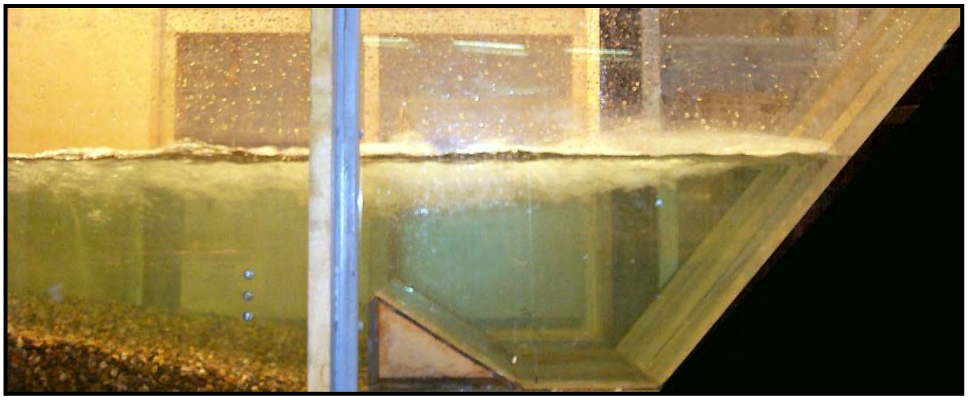


Figure G-1 Q=2.5 kcfs Per Sluiceway Bay with Tailwater Elevation of 1466.8 Feet

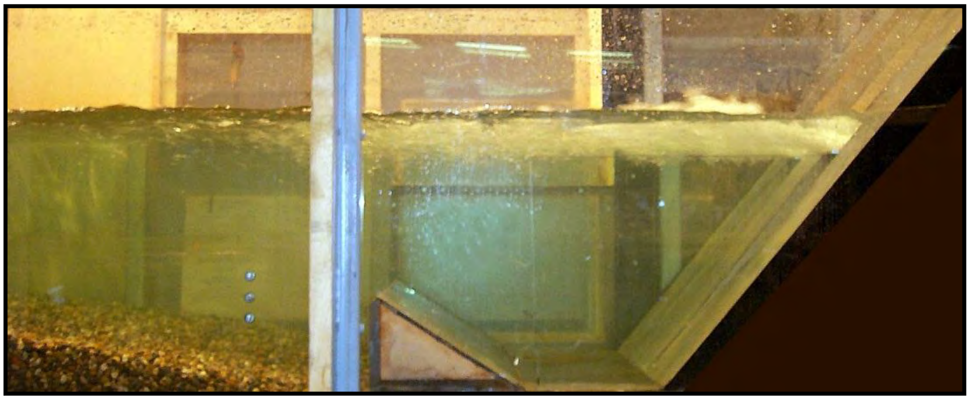


Figure G-2 Q=2.5 kcfs Per Sluiceway Bay with Tailwater Elevation of 1479.0 Feet

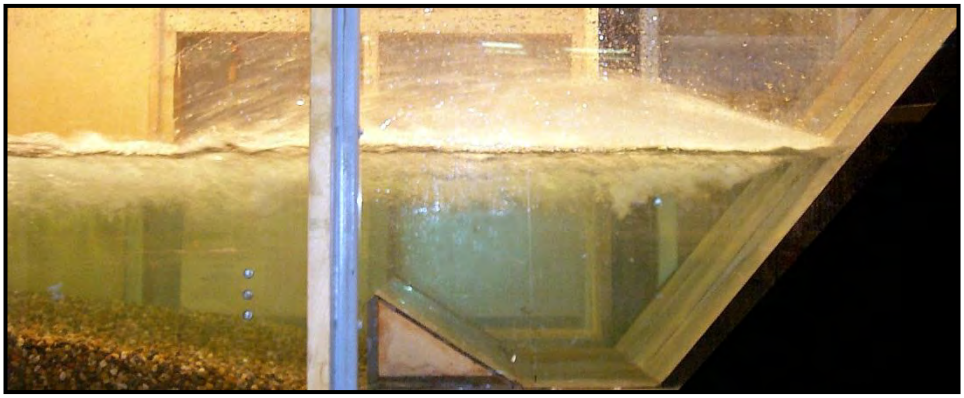


Figure G-3 Q=5.0 kcfs Per Sluiceway Bay with Tailwater Elevation of 1470.9 Feet

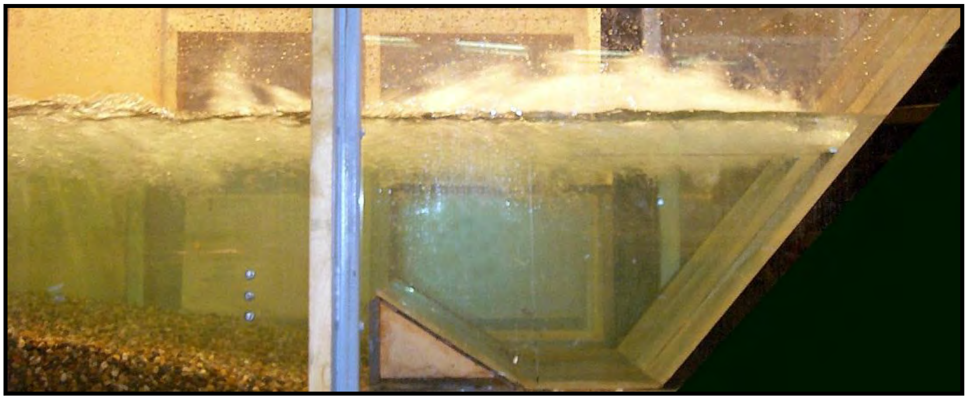


Figure G-4 Q=5.0 kcfs Per Sluiceway Bay with Tailwater Elevation of 1480.1 Feet

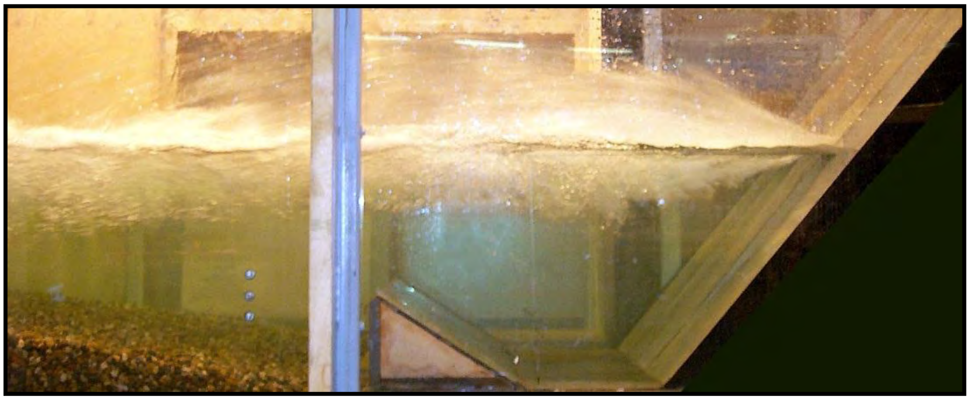


Figure G-5 Q=7.5 kcfs Per Sluiceway Bay with Tailwater Elevation of 1473.1 Feet

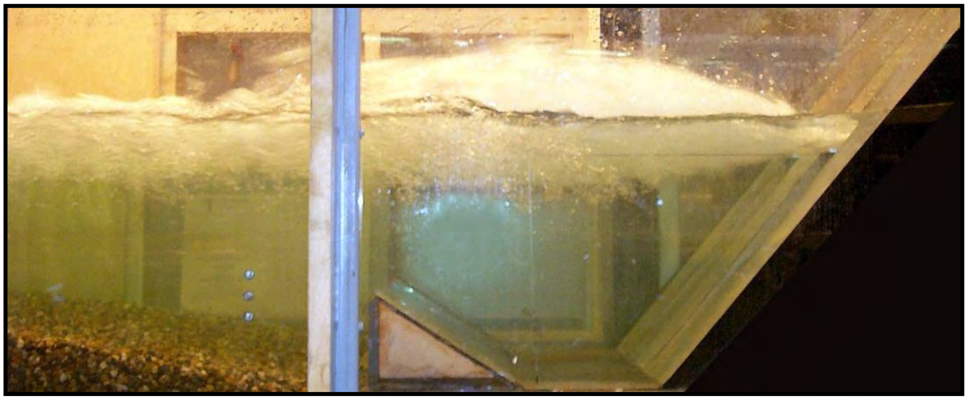


Figure G-6 Q=7.5 kcfs Per Sluiceway Bay with Tailwater Elevation of 1481.2 Feet

Figure G-7 Q=10.0 kcfs Per Sluiceway Bay with Tailwater Elevation of 1474.9 Feet

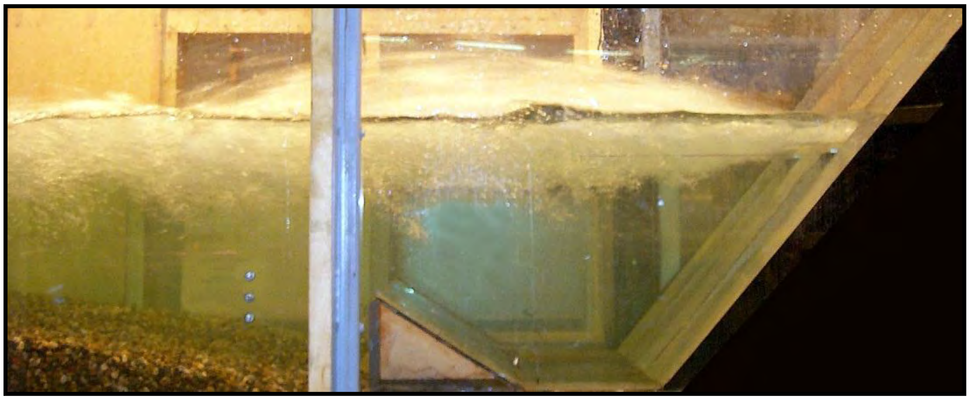


Figure G-8 Q=10.0 kcfs Per Sluiceway Bay with Tailwater Elevation of 1482.2 Feet

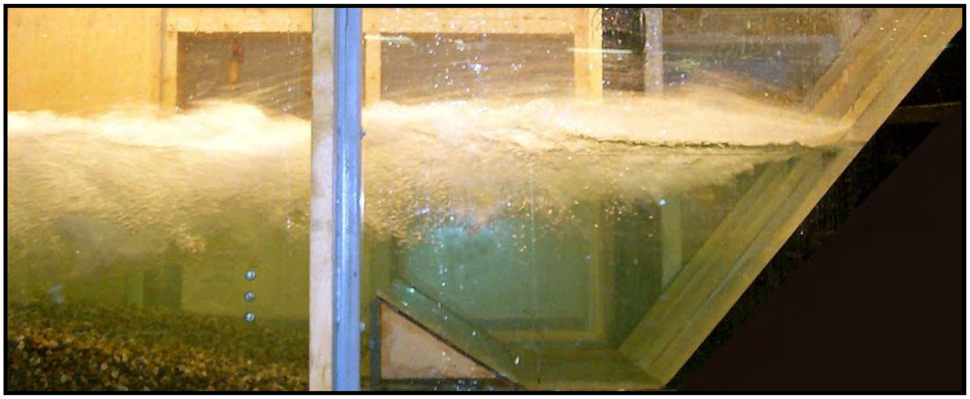


Figure G-9 Q=12.5 kcfs Per Sluiceway Bay with Tailwater Elevation of 1476.4 Feet

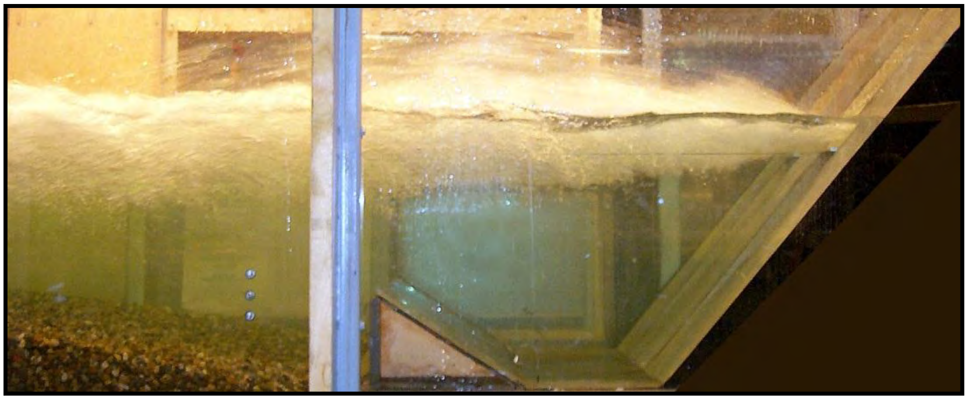


Figure G-10 Q=12.5 kcfs Per Sluiceway Bay with Tailwater Elevation of 1483.2 Feet

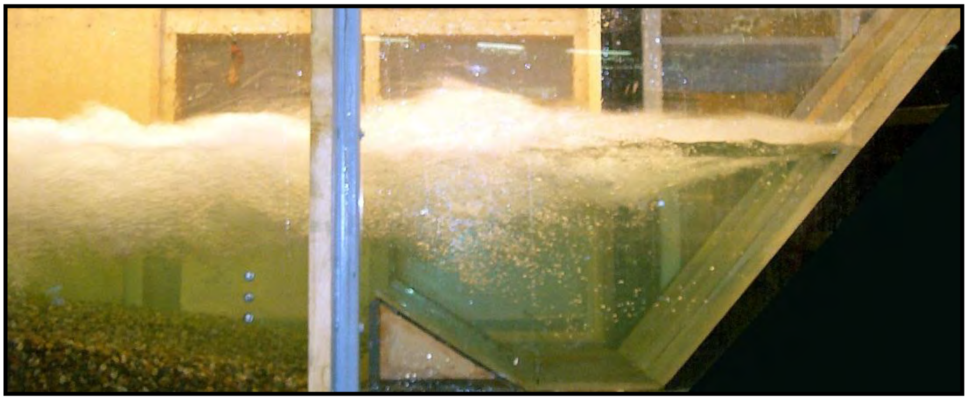


Figure G-11 Q=15.0 kcfs Per Sluiceway Bay with Tailwater Elevation of 1477.7 Feet

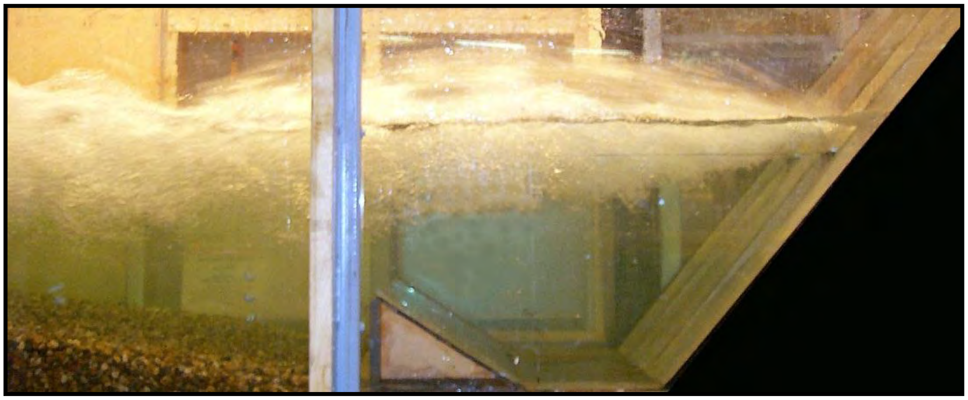


Figure G-12 Q=15.0 kcfs Per Sluiceway Bay with Tailwater Elevation of 1484.1 Feet

Deflector Characteristics

Length (ft):	16.0
Elevation (fmsl):	1468.0
Transition Radius (ft):	15.0
Lip Angle (deg.):	5.0

Video Counter Time		Run Date	Run Time		Discharge Per Sluiceway Bay (kcfs)	Tailwater Elevation (Prototype Feet)	Flow Regime
(Start)	(End)		(Start)	(End)			
0:00:00	0:01:30	7/13/00	8:39:34 AM	8:41:04 AM	2.5	1479.0	Surface Jet
0:01:30	0:03:00	7/13/00	8:45:07 AM	8:46:37 AM	2.5	1476.5	Surface Jet
0:03:00	0:04:30	7/13/00	8:50:03 AM	8:51:33 AM	2.5	1473.2	Surface Jet
0:04:30	0:06:00	7/13/00	9:03:08 AM	9:04:38 AM	2.5	1466.8	Vented Surface Jet
0:06:00	0:07:30	7/13/00	9:30:31 AM	9:32:01 AM	5.0	1480.1	Surface Jet
0:07:30	0:09:00	7/13/00	9:34:54 AM	9:36:24 AM	5.0	1477.7	Surface Jet
0:09:00	0:10:30	7/13/00	9:39:19 AM	9:40:49 AM	5.0	1474.9	Surface Jet
0:10:30	0:12:00	7/13/00	9:48:00 AM	9:49:30 AM	5.0	1470.9	Vented Surface Jet
0:12:00	0:13:30	7/13/00	10:16:23 AM	10:17:53 AM	7.5	1481.2	Surface Jet
0:13:30	0:15:00	7/13/00	10:20:08 AM	10:21:38 AM	7.5	1479.0	Surface Jet
0:15:00	0:16:30	7/13/00	10:24:17 AM	10:25:47 AM	7.5	1476.4	Surface Jet
0:16:30	0:18:00	7/13/00	10:31:46 AM	10:33:16 AM	7.5	1473.1	Vented Surface Jet
0:18:00	0:19:30	7/13/00	11:17:54 AM	11:19:24 AM	10.0	1482.2	Surface Jet
0:19:30	0:21:00	7/13/00	11:21:25 AM	11:22:55 AM	10.0	1480.1	Surface Jet
0:21:00	0:22:30	7/13/00	11:25:49 AM	11:27:19 AM	10.0	1477.7	Surface Jet
0:22:30	0:23:59	7/13/00	11:33:13 AM	11:34:42 AM	10.0	1474.9	Vented Surface Jet
0:23:59	0:25:29	7/13/00	12:08:16 PM	12:09:46 PM	12.5	1483.2	Surface Jet
0:25:29	0:26:59	7/13/00	12:12:27 PM	12:13:57 PM	12.5	1481.2	Surface Jet
0:26:59	0:28:29	7/13/00	12:16:50 PM	12:18:20 PM	12.5	1479.0	Surface Jet
0:28:29	0:29:59	7/13/00	12:21:17 PM	12:22:47 PM	12.5	1476.4	Plunging Jet
0:29:59	0:31:29	7/13/00	12:44:30 PM	12:46:00 PM	15.0	1484.1	Surface Jet
0:31:29	0:32:58	7/13/00	12:48:32 PM	12:50:01 PM	15.0	1482.2	Surface Jet
0:32:58	0:34:28	7/13/00	12:54:28 PM	12:55:58 PM	15.0	1480.1	Surface Jet
0:34:28	0:35:58	7/13/00	1:00:16 PM	1:01:46 PM	15.0	1477.7	Plunging Jet
0:35:58	0:37:28	7/19/00	1:49:53 PM	1:51:23 PM	5.0	1490.0	Surface Jump
0:37:28	0:38:58	7/19/00	2:00:22 PM	2:01:52 PM	5.0	1476.0	Surface Jet
0:38:58	0:40:28	7/19/00	2:13:11 PM	2:14:41 PM	5.0	1469.0	Vented Surface Jet
0:40:28	0:41:58	7/19/00	2:20:10 PM	2:21:40 PM	5.0	1462.0	Plunging Jet
0:41:58	0:43:28	7/19/00	2:37:35 PM	2:39:05 PM	10.0	1494.0	Surface Jump
0:43:28	0:44:58	7/19/00	2:44:52 PM	2:46:22 PM	10.0	1481.0	Surface Jet
0:44:58	0:46:28	7/19/00	2:52:30 PM	2:54:00 PM	10.0	1475.0	Vented Surface Jet
0:46:28	0:47:59	7/19/00	2:58:45 PM	3:00:16 PM	10.0	1470.0	Plunging Jet

Figure G-13 Video Log for Performance of Recommended Deflector

APPENDIX H

1:48 SECTIONAL MODEL VELOCITY PROFILES

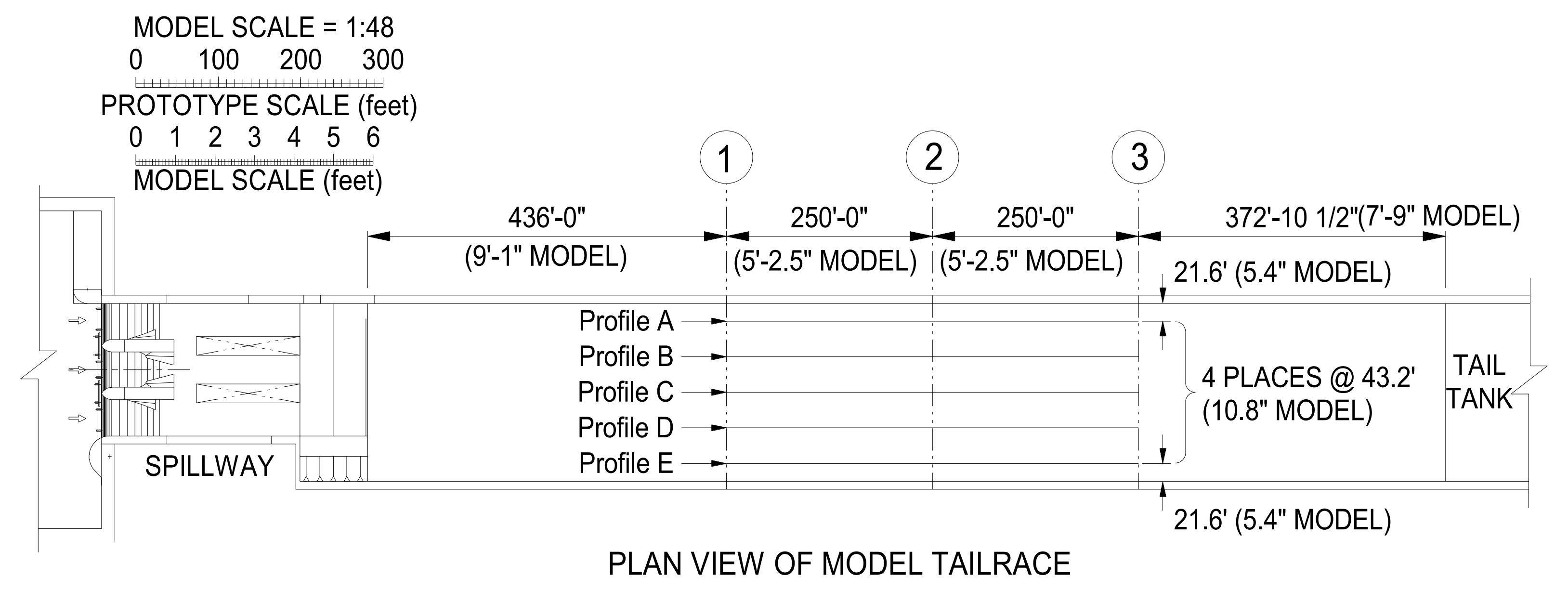


Figure H-1 Location of Velocity Profiles for 1:48 Sectional Model

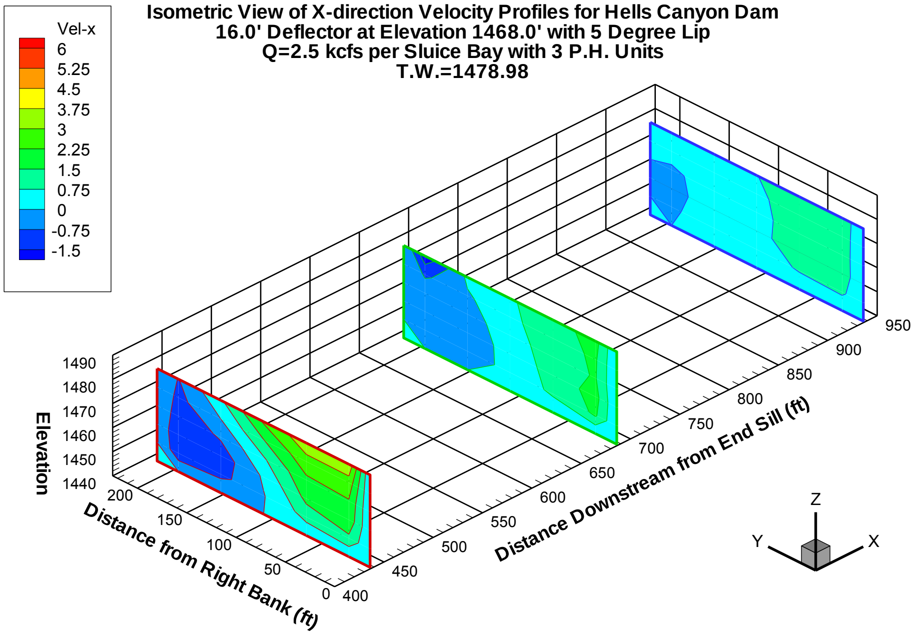


Figure H-2 Velocity Profiles for Q=2.5 kcfs Per Sluiceway Bay with Deflectors

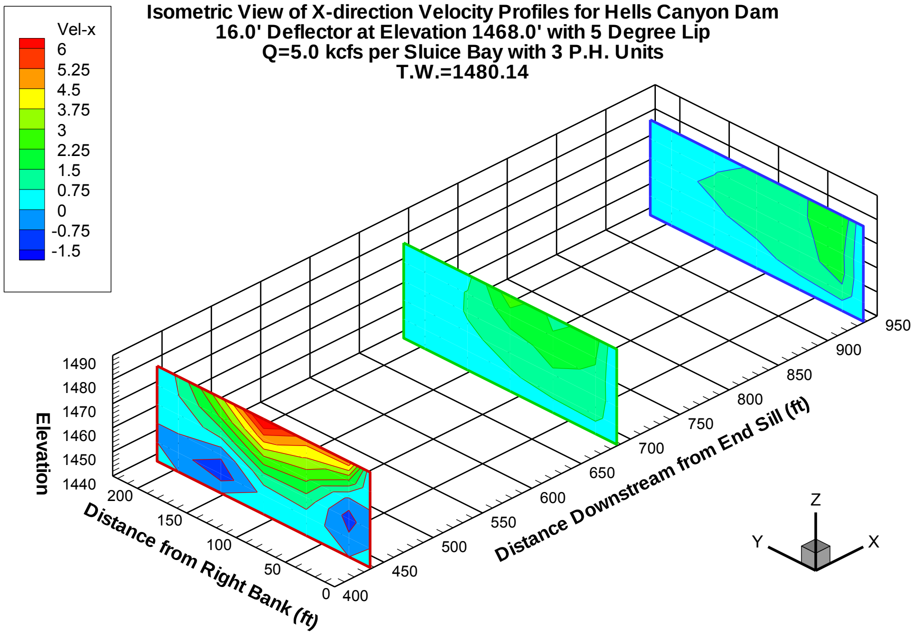


Figure H-3 Velocity Profiles for Q=5.0 kcfs Per Sluiceway Bay with Deflectors

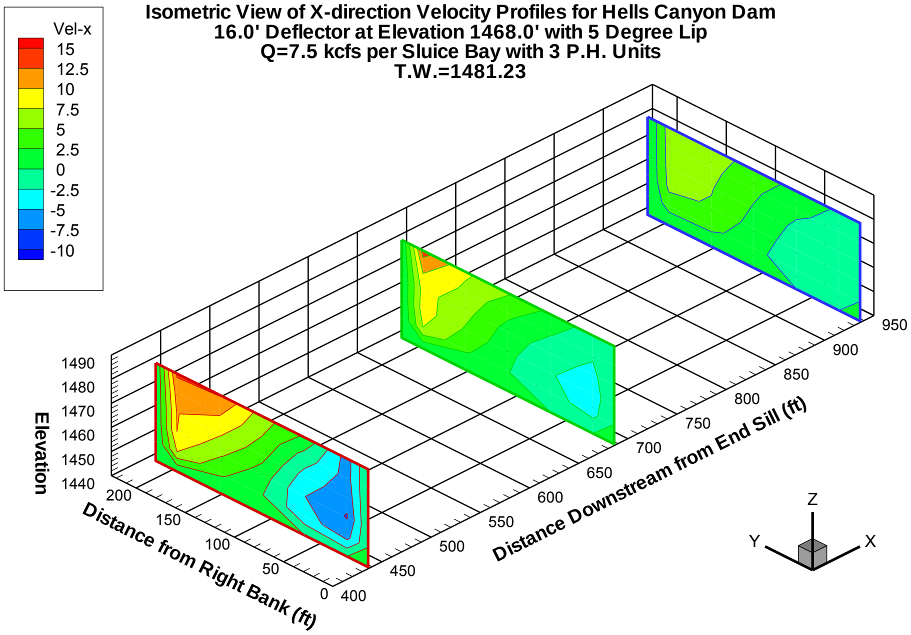


Figure H-4 Velocity Profiles for Q=7.5 kcfs Per Sluiceway Bay with Deflectors

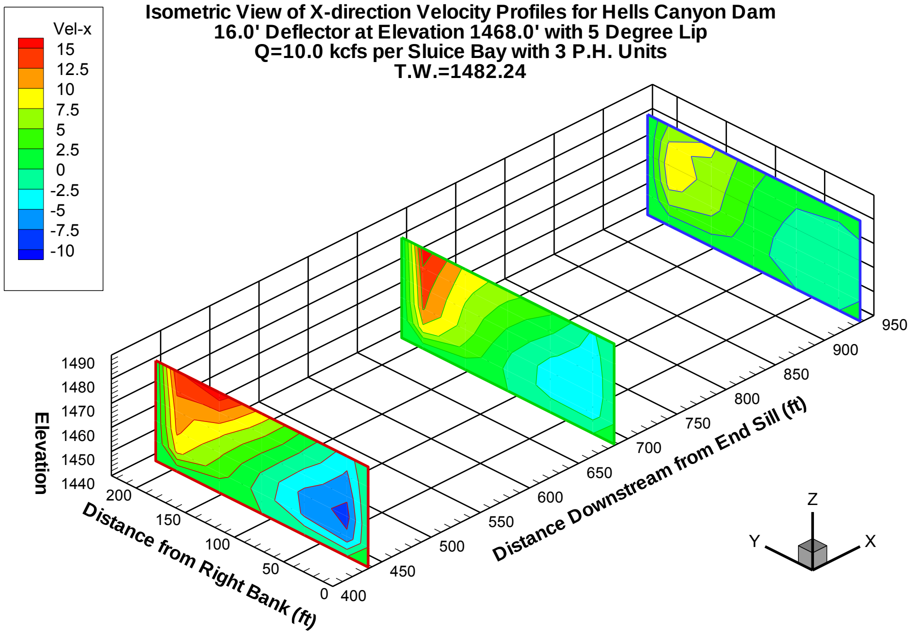
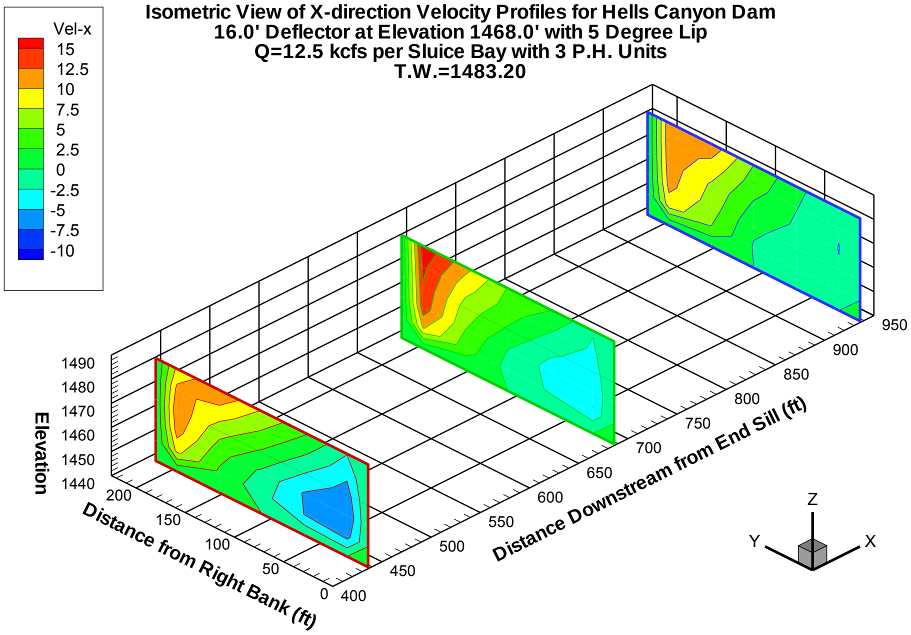
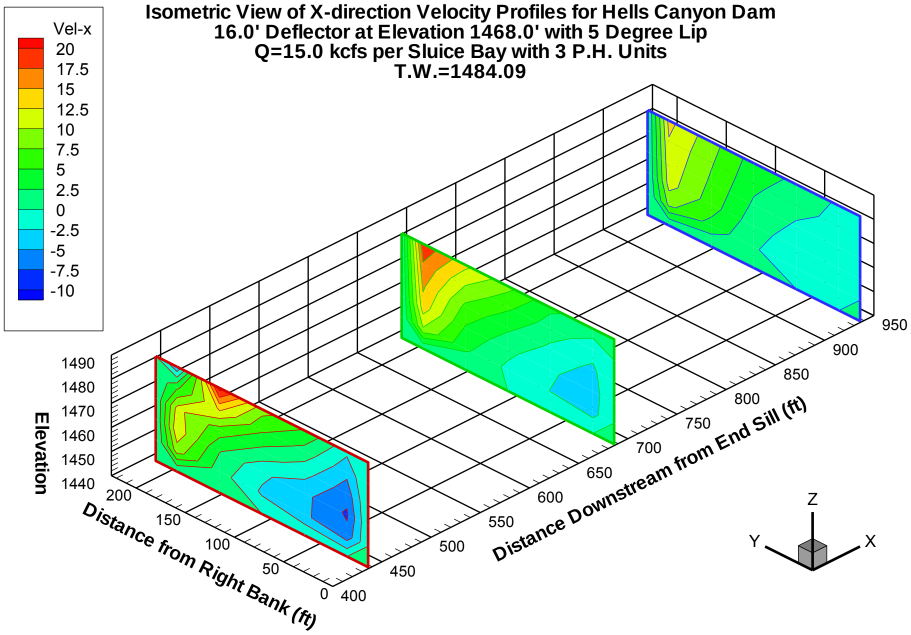


Figure H-5 Velocity Profiles for Q=10.0 kcfs Per Sluiceway Bay with Deflectors



Isometric View of X-direction Velocity Profiles for Hells Canyon Dam
16.0' Deflector at Elevation 1468.0' with 5 Degree Lip
Q=12.5 kcfs per Sluice Bay with 3 P.H. Units
T.W.=1483.20

Figure H-6 Velocity Profiles for Q=12.5 kcfs Per Sluiceway Bay with Deflectors



Isometric View of X-direction Velocity Profiles for Hells Canyon Dam
16.0' Deflector at Elevation 1468.0' with 5 Degree Lip
Q=15.0 kcfs per Sluice Bay with 3 P.H. Units
T.W.=1484.09

Figure H-7 Velocity Profiles for Q=15.0 kcfs Per Sluiceway Bay with Deflectors

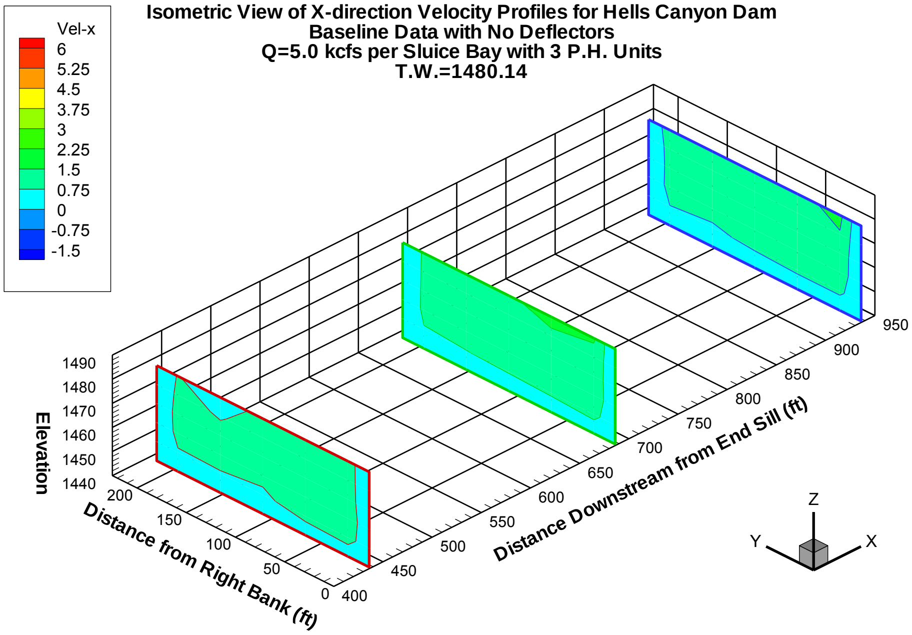


Figure H-8 Velocity Profiles for Q=5.0 kcfs Per Sluiceway Bay with No Deflectors

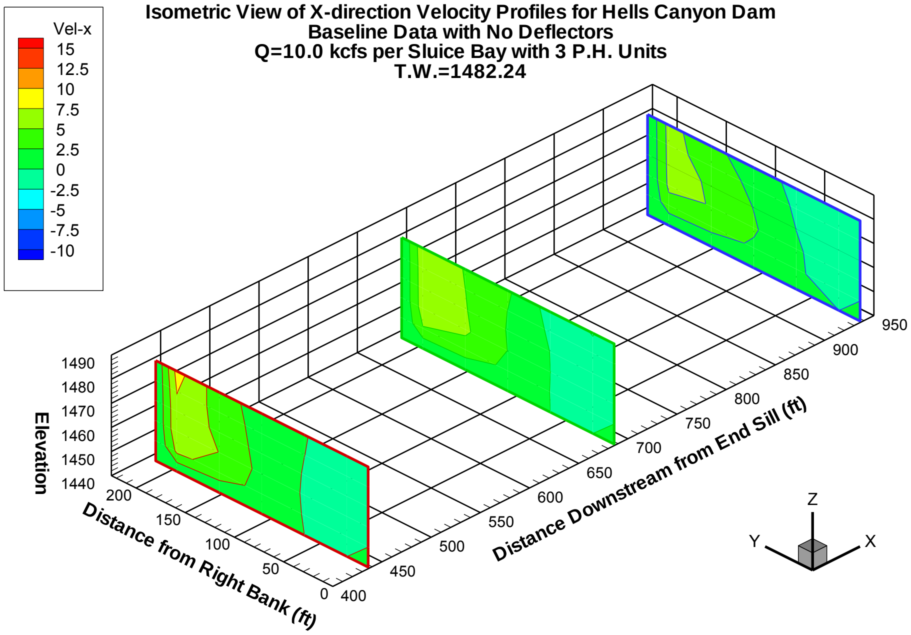


Figure H-9 Velocity Profiles for Q=10.0 kcfs Per Sluiceway Bay with No Deflectors

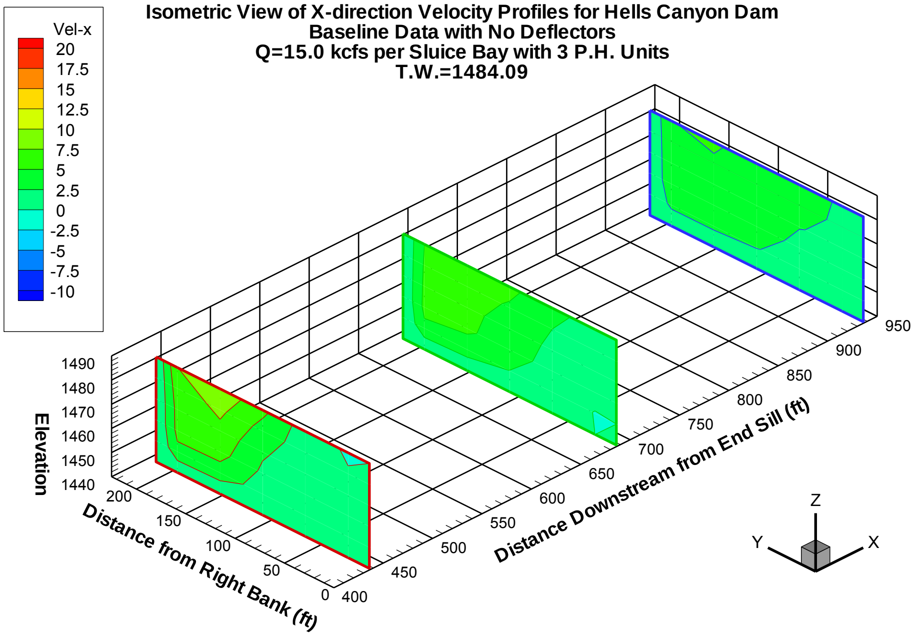
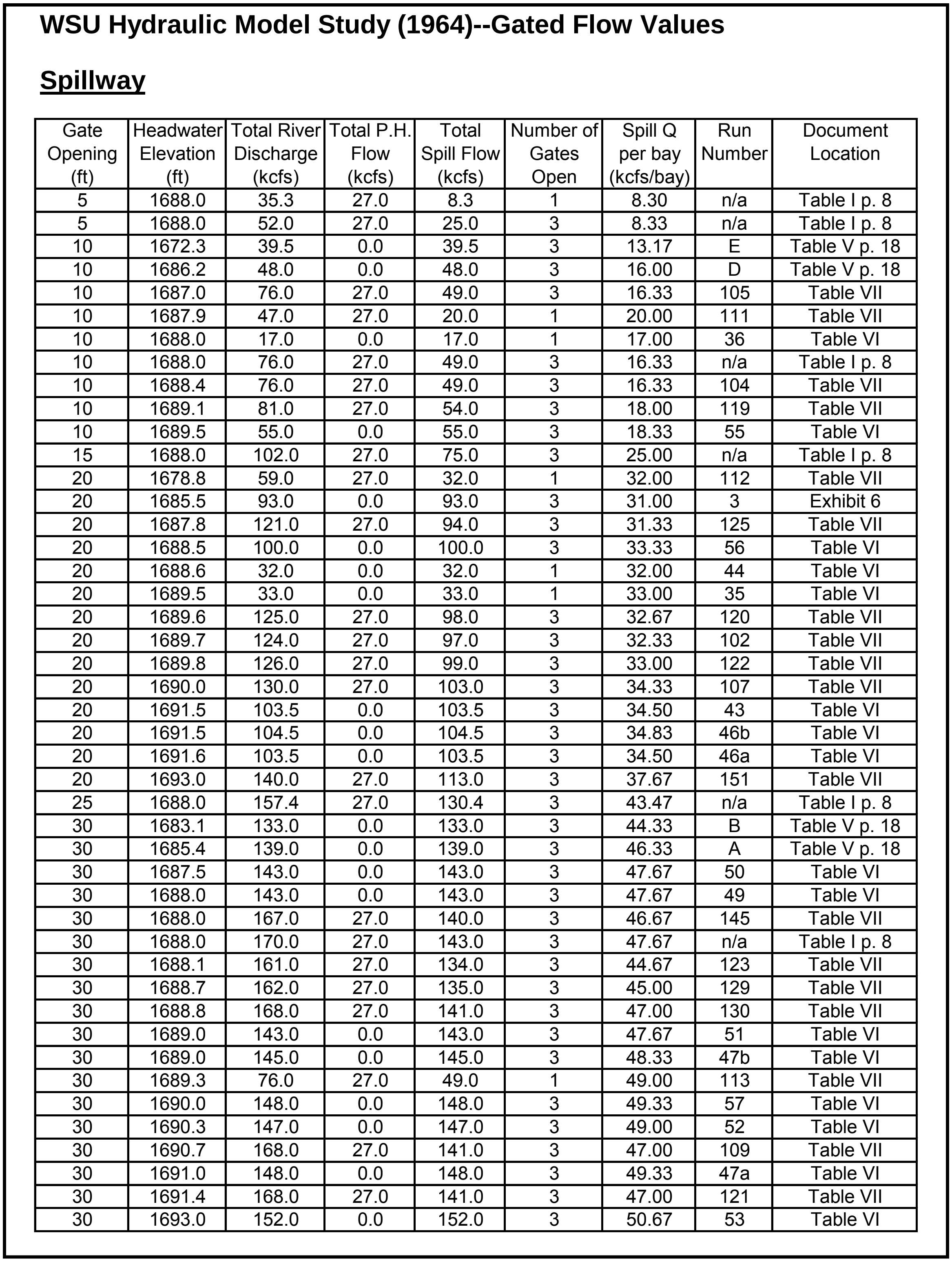


Figure H-10 Velocity Profiles for Q=15.0 kcfs Per Sluiceway Bay with No Deflectors

APPENDIX I

RESULTS REFERENCED FROM 1964 WSU MODEL STUDY OF HELLS CANYON DAM



WSU Hydraulic Model Study (1964)--Gated Flow Values

Spillway

Gate Opening (ft)	Headwater Elevation (ft)	Total River Discharge (kcfs)	Total P.H. Flow (kcfs)	Total Spill Flow (kcfs)	Number of Gates Open	Spill Q per bay (kcfs/bay)	Run Number	Document Location
5	1688.0	35.3	27.0	8.3	1	8.30	n/a	Table I p. 8
5	1688.0	52.0	27.0	25.0	3	8.33	n/a	Table I p. 8
10	1672.3	39.5	0.0	39.5	3	13.17	E	Table V p. 18
10	1686.2	48.0	0.0	48.0	3	16.00	D	Table V p. 18
10	1687.0	76.0	27.0	49.0	3	16.33	105	Table VII
10	1687.9	47.0	27.0	20.0	1	20.00	111	Table VII
10	1688.0	17.0	0.0	17.0	1	17.00	36	Table VI
10	1688.0	76.0	27.0	49.0	3	16.33	n/a	Table I p. 8
10	1688.4	76.0	27.0	49.0	3	16.33	104	Table VII
10	1689.1	81.0	27.0	54.0	3	18.00	119	Table VII
10	1689.5	55.0	0.0	55.0	3	18.33	55	Table VI
15	1688.0	102.0	27.0	75.0	3	25.00	n/a	Table I p. 8
20	1678.8	59.0	27.0	32.0	1	32.00	112	Table VII
20	1685.5	93.0	0.0	93.0	3	31.00	3	Exhibit 6
20	1687.8	121.0	27.0	94.0	3	31.33	125	Table VII
20	1688.5	100.0	0.0	100.0	3	33.33	56	Table VI
20	1688.6	32.0	0.0	32.0	1	32.00	44	Table VI
20	1689.5	33.0	0.0	33.0	1	33.00	35	Table VI
20	1689.6	125.0	27.0	98.0	3	32.67	120	Table VII
20	1689.7	124.0	27.0	97.0	3	32.33	102	Table VII
20	1689.8	126.0	27.0	99.0	3	33.00	122	Table VII
20	1690.0	130.0	27.0	103.0	3	34.33	107	Table VII
20	1691.5	103.5	0.0	103.5	3	34.50	43	Table VI
20	1691.5	104.5	0.0	104.5	3	34.83	46b	Table VI
20	1691.6	103.5	0.0	103.5	3	34.50	46a	Table VI
20	1693.0	140.0	27.0	113.0	3	37.67	151	Table VII
25	1688.0	157.4	27.0	130.4	3	43.47	n/a	Table I p. 8
30	1683.1	133.0	0.0	133.0	3	44.33	B	Table V p. 18
30	1685.4	139.0	0.0	139.0	3	46.33	A	Table V p. 18
30	1687.5	143.0	0.0	143.0	3	47.67	50	Table VI
30	1688.0	143.0	0.0	143.0	3	47.67	49	Table VI
30	1688.0	167.0	27.0	140.0	3	46.67	145	Table VII
30	1688.0	170.0	27.0	143.0	3	47.67	n/a	Table I p. 8
30	1688.1	161.0	27.0	134.0	3	44.67	123	Table VII
30	1688.7	162.0	27.0	135.0	3	45.00	129	Table VII
30	1688.8	168.0	27.0	141.0	3	47.00	130	Table VII
30	1689.0	143.0	0.0	143.0	3	47.67	51	Table VI
30	1689.0	145.0	0.0	145.0	3	48.33	47b	Table VI
30	1689.3	76.0	27.0	49.0	1	49.00	113	Table VII
30	1690.0	148.0	0.0	148.0	3	49.33	57	Table VI
30	1690.3	147.0	0.0	147.0	3	49.00	52	Table VI
30	1690.7	168.0	27.0	141.0	3	47.00	109	Table VII
30	1691.0	148.0	0.0	148.0	3	49.33	47a	Table VI
30	1691.4	168.0	27.0	141.0	3	47.00	121	Table VII
30	1693.0	152.0	0.0	152.0	3	50.67	53	Table VI

Figure I-1 Gated Spillway Discharges from 1964 WSU Model Study

WSU Hydraulic Model Study (1964)--Gated Flow Values

Sluiceway

Gate Opening (ft)	Headwater Elevation (ft)	Total River Discharge (kcfs)	Total P.H. Flow (kcfs)	Total Spill Flow (kcfs)	Number of Gates Open	Spill Q per bay (kcfs/bay)	Run Number	Document Location
1/4 Open	1608.0	6.8	0.0	6.8	1	6.80	31a	Exhibit 5
1/4 Open	1638.5	9.4	0.0	9.4	1	9.40	31b	Exhibit 5
1/4 Open	1681.0	11.8	0.0	11.8	1	11.80	31c	Exhibit 5
1/2 Open	1599.0	10.3	0.0	10.3	1	10.30	32a	Exhibit 5
1/2 Open	1629.0	14.3	0.0	14.3	1	14.30	32b	Exhibit 5
1/2 Open	1650.1	17.0	0.0	17.0	1	17.00	M	Table V p. 18
1/2 Open	1686.0	20.0	0.0	20.0	1	20.00	32c	Exhibit 5
1/2 Open	1688.0	20.8	0.0	20.8	1	20.80	N	Table V p. 18
3/4 Open	1624.0	21.4	0.0	21.4	1	21.40	O	Table V p. 18

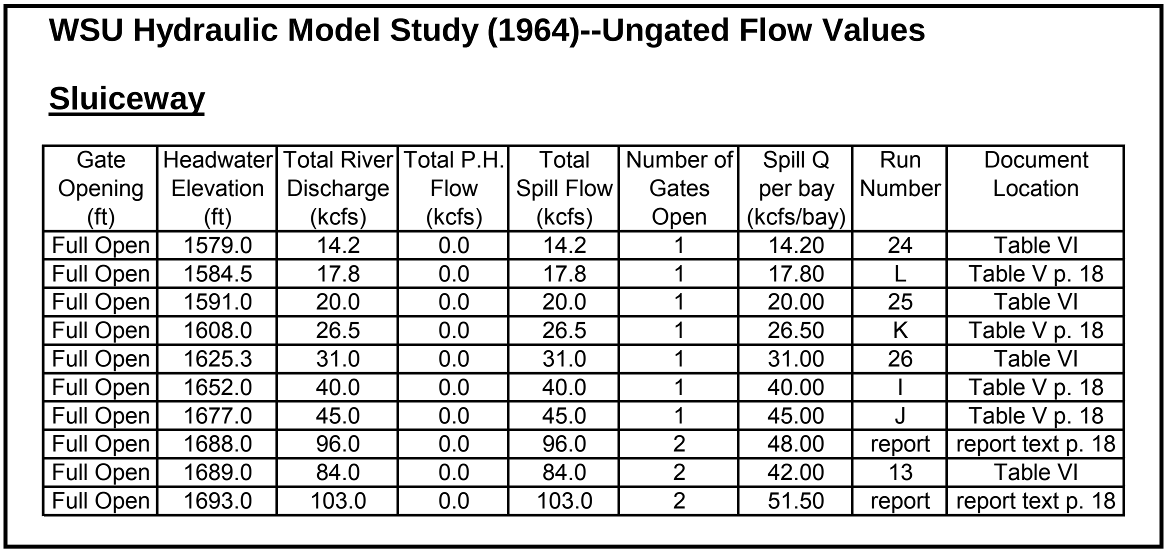
Figure I-2 Gated Sluiceway Discharges from 1964 WSU Model Study

WSU Hydraulic Model Study (1964)--Ungated Flow Values

Spillway

Gate Opening (ft)	Headwater Elevation (ft)	Total River Discharge (kcfs)	Total P.H. Flow (kcfs)	Total Spill Flow (kcfs)	Number of Gates Open	Spill Q per bay (kcfs/bay)	Run Number	Document Location
Full Open	1655.0	29.5	0.0	29.5	3	9.83	1	Table VI
Full Open	1655.0	12.5	0.0	12.5	1	12.50	23	Table VI
Full Open	1657.8	40.5	0.0	40.5	3	13.50	18	Exhibit 6
Full Open	1658.0	39.5	0.0	39.5	3	13.17	F	Table V p. 18
Full Open	1662.0	53.0	0.0	53.0	3	17.67	2	Table VI
Full Open	1666.6	26.0	0.0	26.0	1	26.00	22	Table VI
Full Open	1670.5	93.0	0.0	93.0	3	31.00	17	Exhibit 6
Full Open	1676.4	125.0	0.0	125.0	3	41.67	C	Table V p. 18
Full Open	1676.5	39.5	0.0	39.5	1	39.50	G	Table V p. 18
Full Open	1676.8	42.0	0.0	42.0	1	42.00	21	Table VI
Full Open	1679.5	136.0	0.0	136.0	3	45.33	16	Exhibit 6
Full Open	1682.0	160.0	0.0	160.0	3	53.33	6	Exhibit 6
Full Open	1682.0	50.0	0.0	50.0	1	50.00	20	Table VI
Full Open	1686.2	205.0	27.0	178.0	3	59.33	152	Table VII
Full Open	1687.2	58.0	0.0	58.0	1	58.00	H	Table V p. 18
Full Open	1688.0	210.0	27.0	183.0	3	61.00	n/a	Table I p. 8
Full Open	1688.0	186.0	0.0	186.0	3	62.00	report	report text p. 18
Full Open	1690.0	193.0	0.0	193.0	3	64.33	15	Table VI
Full Open	1692.5	207.0	0.0	207.0	3	69.00	9	Table VI
Full Open	1693.0	210.0	0.0	210.0	3	70.00	report	report text p. 18

Figure I-3 Ungated Spillway Discharges from 1964 WSU Model Study



WSU Hydraulic Model Study (1964)--Ungated Flow Values

Sluiceway

Gate Opening (ft)	Headwater Elevation (ft)	Total River Discharge (kcfs)	Total P.H. Flow (kcfs)	Total Spill Flow (kcfs)	Number of Gates Open	Spill Q per bay (kcfs/bay)	Run Number	Document Location
Full Open	1579.0	14.2	0.0	14.2	1	14.20	24	Table VI
Full Open	1584.5	17.8	0.0	17.8	1	17.80	L	Table V p. 18
Full Open	1591.0	20.0	0.0	20.0	1	20.00	25	Table VI
Full Open	1608.0	26.5	0.0	26.5	1	26.50	K	Table V p. 18
Full Open	1625.3	31.0	0.0	31.0	1	31.00	26	Table VI
Full Open	1652.0	40.0	0.0	40.0	1	40.00	I	Table V p. 18
Full Open	1677.0	45.0	0.0	45.0	1	45.00	J	Table V p. 18
Full Open	1688.0	96.0	0.0	96.0	2	48.00	report	report text p. 18
Full Open	1689.0	84.0	0.0	84.0	2	42.00	13	Table VI
Full Open	1693.0	103.0	0.0	103.0	2	51.50	report	report text p. 18

Figure I-4 Ungated Sluiceway Discharges from 1964 WSU Model Study

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Exhibit 7.3-2

Hydraulic modeling for Hells Canyon Dam spillway deflector design: Phase two – three-dimensional model

HYDRAULIC MODELING FOR HELLS CANYON DAM SPILLWAY DEFLECTOR DESIGN: PHASE TWO – THREE-DIMENSIONAL MODEL

by

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Submitted to
Idaho Power Company
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Iowa City, Iowa 52242-1585

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EXECUTIVE SUMMARY

This report documents hydraulic model studies by IIHR Hydroscience and Engineering (IIHR) on the 1:48 scale spillway and three-dimensional tailrace model for Hells Canyon Dam. In Phase One spillway deflectors were designed to reduce air entrainment and total dissolved gas (TDG) by redirecting plunging spillway jets. The original sectional model was also used to develop discharge rating curves for spillway and sluiceway gates at Hells Canyon Dam. The Phase One model used a narrow flume for the tailrace and did not include any detailed tailrace bathymetry or powerhouse flows. The Phase Two model was then used to investigate tailrace erosion potential and deflector air entrainment performance with three-dimensional tailrace bathymetry and modeled powerhouse flows.

Phase Two research revealed that deflector air entrainment performance was preserved when the tailrace bathymetry was incorporated into the model. When compared to spill operations without deflectors, deflectors did not increase erosion potential at the project design flood level of 300,000 cfs (total river). However deflectors did significantly change tailrace flow and erosion patterns. Deflectors increased tailrace erosion potential at flowrates above 15,000 cfs per sluiceway bay. The tailrace near the fish trap entrance began to flow upstream during all deflector operations. Generally tailrace velocities had higher downstream components near the surface and upstream components near the bottom for all deflector operations.

Model observations indicated that spill operations should change after deflector installation. For total spill flowrates of 30,000 cfs or less, only sluiceways should be opened evenly. At spill flowrates between 30,000 and 200,000 cfs, only upper crest gates should be opened evenly. Above 200,000 cfs both fully opened crest gates and evenly opened sluiceway gates should be used. A training CD with digital video clips was included with this report to document flow conditions, leftbank wave characteristics, and erosion potential with different gate operations.

ACKNOWLEDGMENTS

Idaho Power Company (IPC) sponsored the IIHR hydraulic model studies for spillway deflector development at Hells Canyon Dam. The authors thank Ms. Sharon Parkinson and Mr. Ralph Myers of IPC for their input, support, and guidance throughout the project. The authors are also grateful to Mr. Duncan Hay of Oakwood Consulting for his contributions to the success of this study.

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1. INTRODUCTION

This report documented IIHR hydraulic model studies of the 1:48 scale spillway and three-dimensional tailrace model for Hells Canyon Dam. This report included Phase One performance curve verification, tailrace erosion potential documentation, tailrace velocity profiles, downstream wave height dissipation estimates, and video documentation for dam operators.

In Phase One spillway deflectors were designed to reduce air entrainment and total dissolved gas (TDG) by redirecting plunging spillway jets. This research suggested a promising deflector design. The original sectional model was also used to develop discharge rating curves for spillway and sluiceway gates at Hells Canyon Dam. The Phase One model used a narrow flume for the tailrace and did not include any detailed tailrace bathymetry or powerhouse flows.

The Phase Two model included tailrace bathymetry to nearly 3000 feet downstream and allowed investigation of spillway performance during powerhouse operations. Performance curve data was retaken to insure that powerhouse operations would not interfere with deflector air entrainment performance. Bed surveys compared downstream bed material movement with and without deflectors installed in the sluiceway bays for a variety of spillway and powerhouse operations. Additional Phase Two research documented tailrace velocity patterns and rock pullback potential.

2. EXPERIMENTAL APPROACH

In the Phase One report, the Hells Canyon model was Froude-scaled for dynamic and geometric similitude. Table 2.1 listed conversion factors for each variable:

Variable	**Relationship**	**Model : Prototype**
Length	L_r = Length Ratio	1 : 48
Slope	$S_r = L_r / L_r = 1$	1 : 1
Velocity	V_r = L_r^(1/2)	1 : 6.928
Time	T_r = L_r^(1/2)	1 : 6.928
Acceleration	$A_r = V_r / T_r = 1$	1 : 1
Discharge	$Q_r = V_r * A_r$ = L_r^(5/2)	1 : 15963
Density	$\rho_r = 1$ (Water)	1 : 1
Force	$F_r = \rho_r$ * L_r^3 = L_r^3	1 : 110592
Pressure	$P_r = \rho_r * L_r = L_r$	1 : 48
Reynolds Number	Re_r = L_r^(3/2)	1 : 332.6

Table 2.1. Dimensionless scale factors for 1:48 Froude-scaled models

2.1 Structure of Hydraulic Model Study

The Hells Canyon model studies project team consisted of Dr. Larry Weber of IIHR, Ms. Sharon Parkinson and Mr. Ralph Myers of IPC, and Mr. Duncan Hay of Oakwood Consulting. Using the Phase One head tank and spillway model, comprehensive three-dimensional tailrace bathymetry and powerhouse flow features were incorporated as shown in Figure 2.1. The spillway section, powerhouse units, left and right bank training walls, forebay area, and about 3200 prototype feet of downstream tailrace were included.

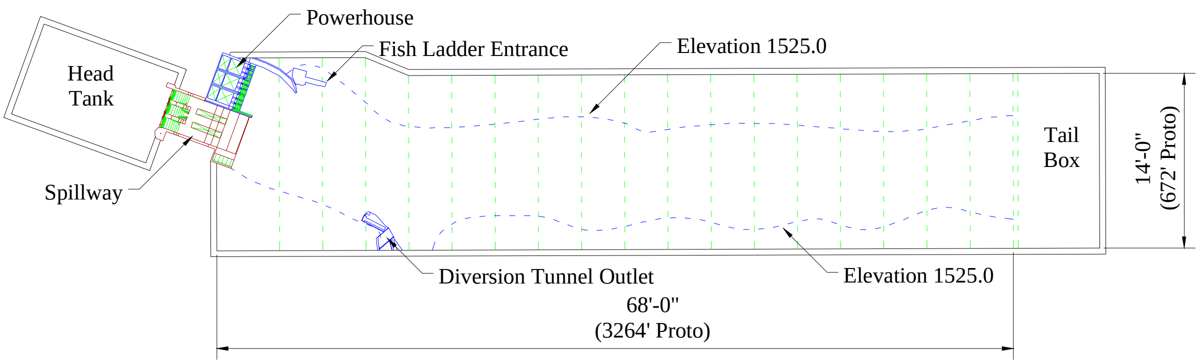


Figure 2.1 Layout of 1:48 three-dimensional comprehensive model

2.2 Head Tank and Spillway Construction

The steel-framed head tank section was 8 feet wide (384 prototype feet) by 12 feet long (576 prototype feet) by 8 feet high. The size and elements of this tank, shown in Figure 2.2, provided quiescent flow conditions approaching the spillway section. The pipes feeding the head tank terminated with a section of perforated PVC piping acting as a diffuser. A false wall composed of 16-gauge (0.06 inch thick) perforated plate with 3/16-inch diameter holes was placed inside the head tank to provide uniform flow conditions. The perforated plate had a porosity, or open area, of 32.6%. Covering the lower three feet of perforated plate with a solid sheet of tin prevented flow upwelling within the head tank. Plexiglas walls allowed researchers to observe flow entering the spillway and sluiceway gates.

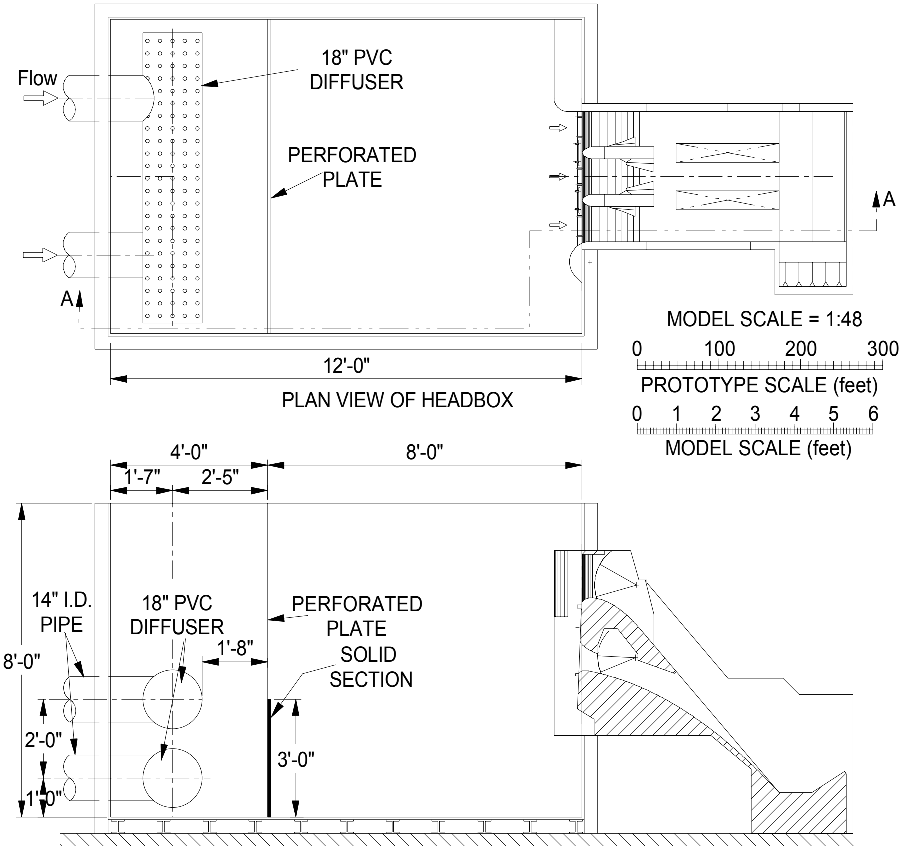


Figure 2.2. Details and components of 1:48 model head tank

A 1:48 scale reproduction of the spillway was attached to the head tank. All three upper spillways and two lower sluiceways were constructed from a continuous section of high-density overlay plywood. Metal spillway and sluiceway tainter gates were individually controlled by rods with setscrews. A metal plate covered with PVC sheeting simulated the apron, and a PVC wedge was positioned on the apron plate to form the end sill. The spillway face, ogee spillway and sluiceway crests, upstream left and right training walls, and pier noses were covered with tin plate.

2.3 Powerhouse Construction

The powerhouse structure was constructed from high density overlay (HDO) plywood. Model powerhouse drawings were shown in Figure 2.3. Flowrate to each of the three powerhouse units was independently adjusted by butterfly valves and measured with orifice meters. Regressed orifice coefficients were 0.4561, 0.4578, and 0.4587, and the average coefficient value of 0.4575 was used for all model calculations.

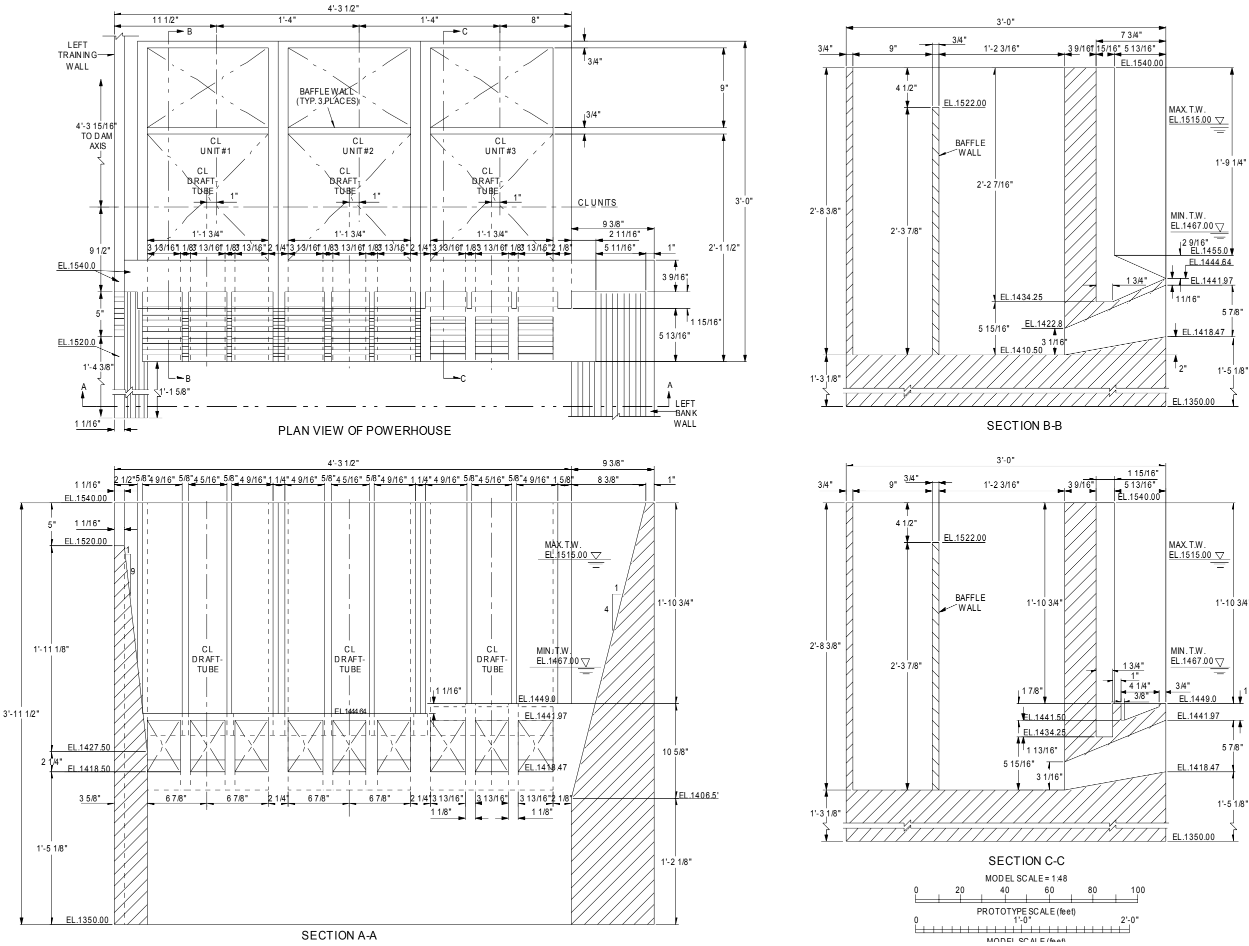


Figure 2.3. Powerhouse structure

2.4 Rightbank Fish Facility Construction

The prototype rightbank fish facility shown in Figure 2.4 was geometrically simplified and built with HDO plywood. The fish ladder entrance and attraction flows were not modeled.

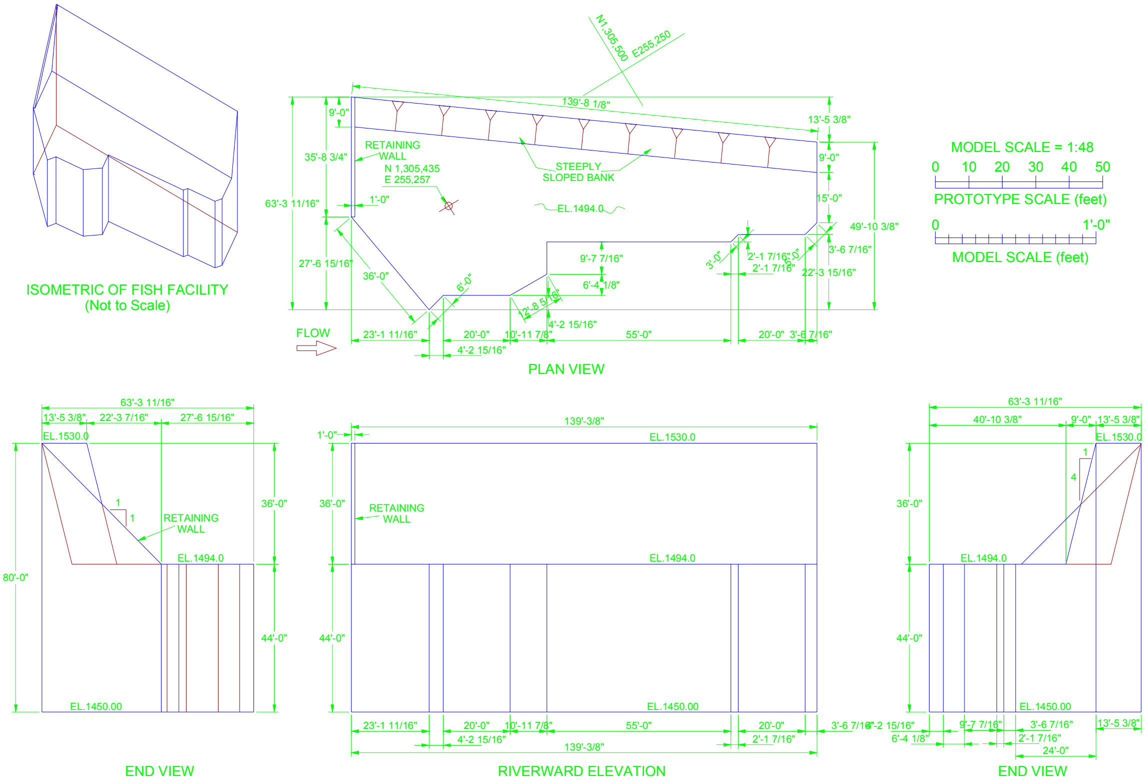


Figure 2.4. Rightbank fish facility

2.5 Diversion Tunnel Construction

The prototype diversion tunnel shown in Figure 2.5 was also geometrically simplified and installed on the model. The walls were constructed from HDO plywood and the tunnel was formed with tin plate.

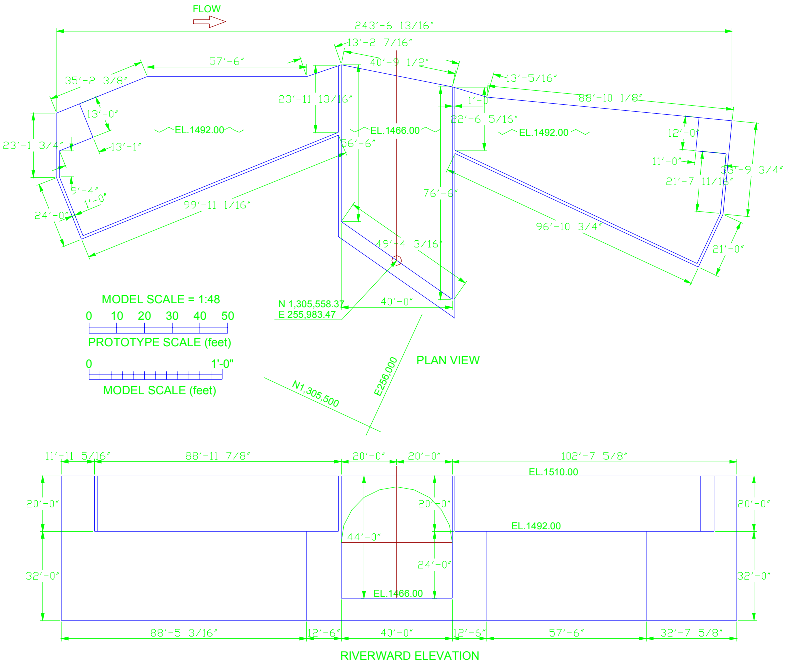


Figure 2.5. Diversion tunnel outlet

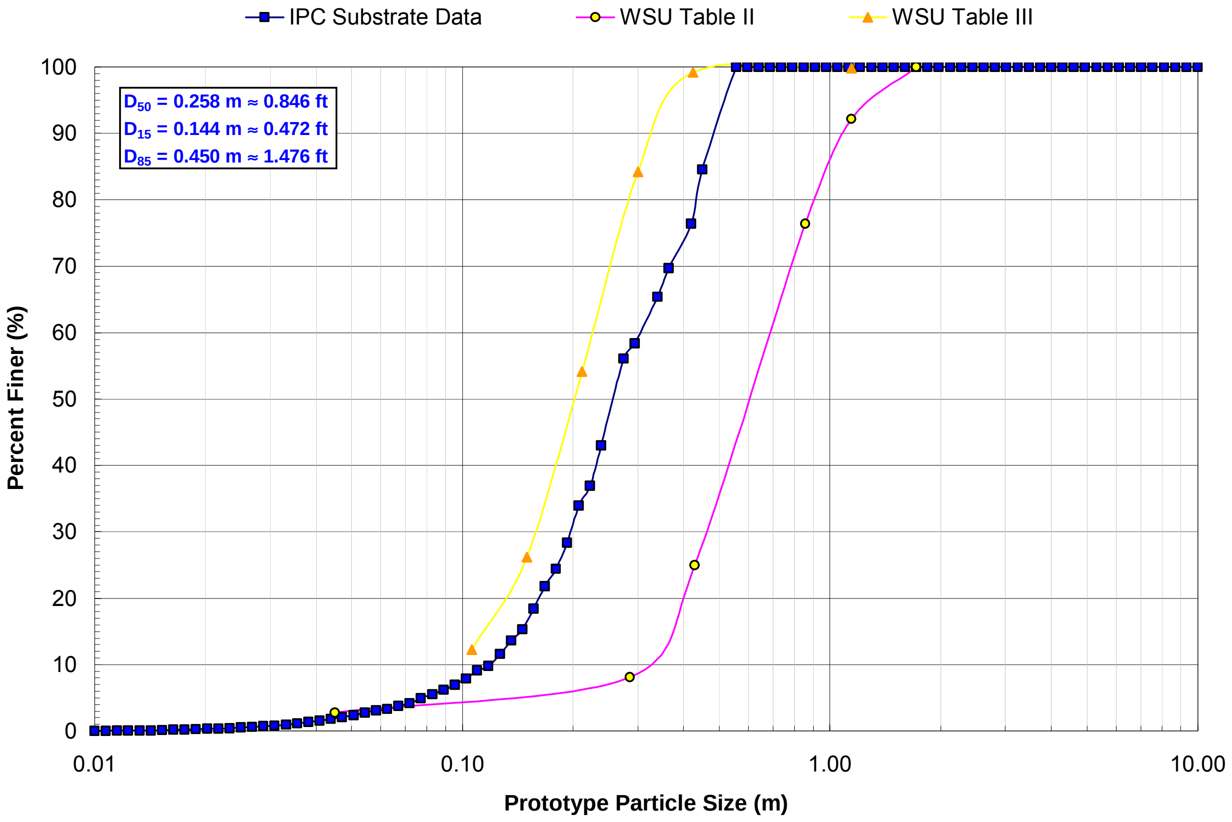


Figure 2.6. Prototype tailrace material from (IPC and WSU reports)

2.6 Bathymetric Material Selection

Field data was obtained from IPC and the 1964 “Hydraulic Model Studies of the Hells Canyon Hydroelectric Project” report from Washington State University (WSU). Prototype sieve analyses in Figure 2.6 estimated the 60% passing diameter of alluvial tailrace material at 0.85 prototype feet (0.21 model inches). Model bathymetric material was “Road Rite Chips” and “Porous Backfill” material. The 60% passing diameter of model material was 0.21 inches from the sieve analyses in Figure 2.7.

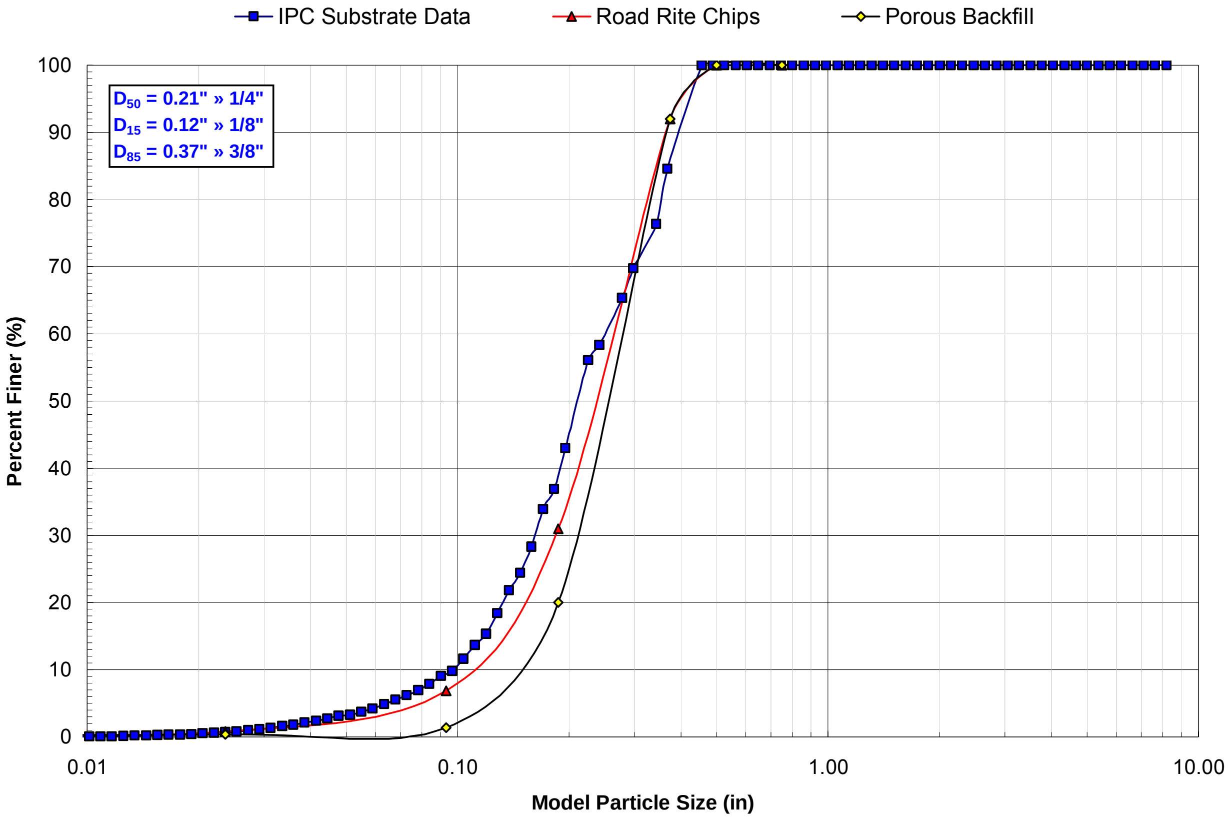


Figure 2.7. Model tailrace material

2.7 Tailrace Template Construction

The model tailrace was formed with male templates suspended from horizontal aluminum box beams. The template locations were plotted as dashed green lines in Figure 2.8.

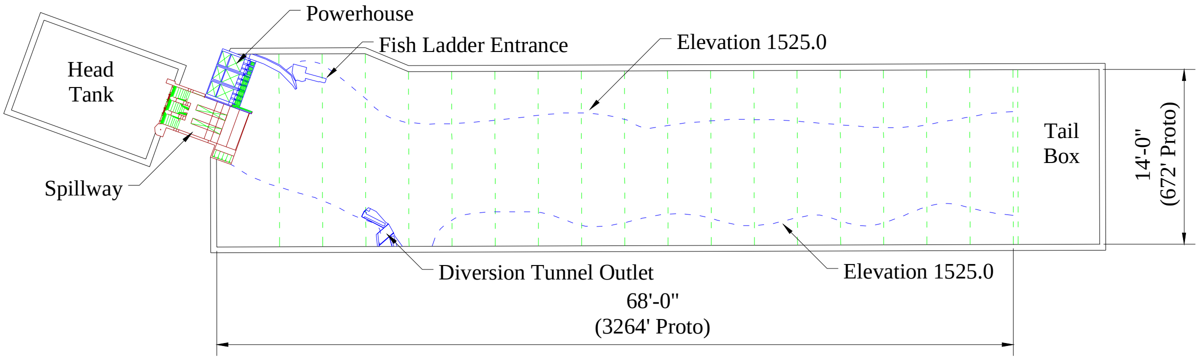


Figure 2.8. Model template locations

Field bathymetric survey data was imported into AutoCAD LandDeveloper to produce the template cross-sections shown in Figures 2.9 to 2.11. Field data was not collected for the rapids area near the diversion tunnel outlet so model sections there were interpolated from adjacent sections. The field data in upstream sections 1 and 2 was replaced with a constant grade down to the endsill after noting discrepancies between survey data and IPC observations. Section 17 was not modeled after the tailgates were moved upstream to increase tailbox flow capacity. In Figures 2.9 to 2.11 a water surface elevation of 1480 feet (39.6 meters) illustrated a 40,000 cfs total river flow depth.

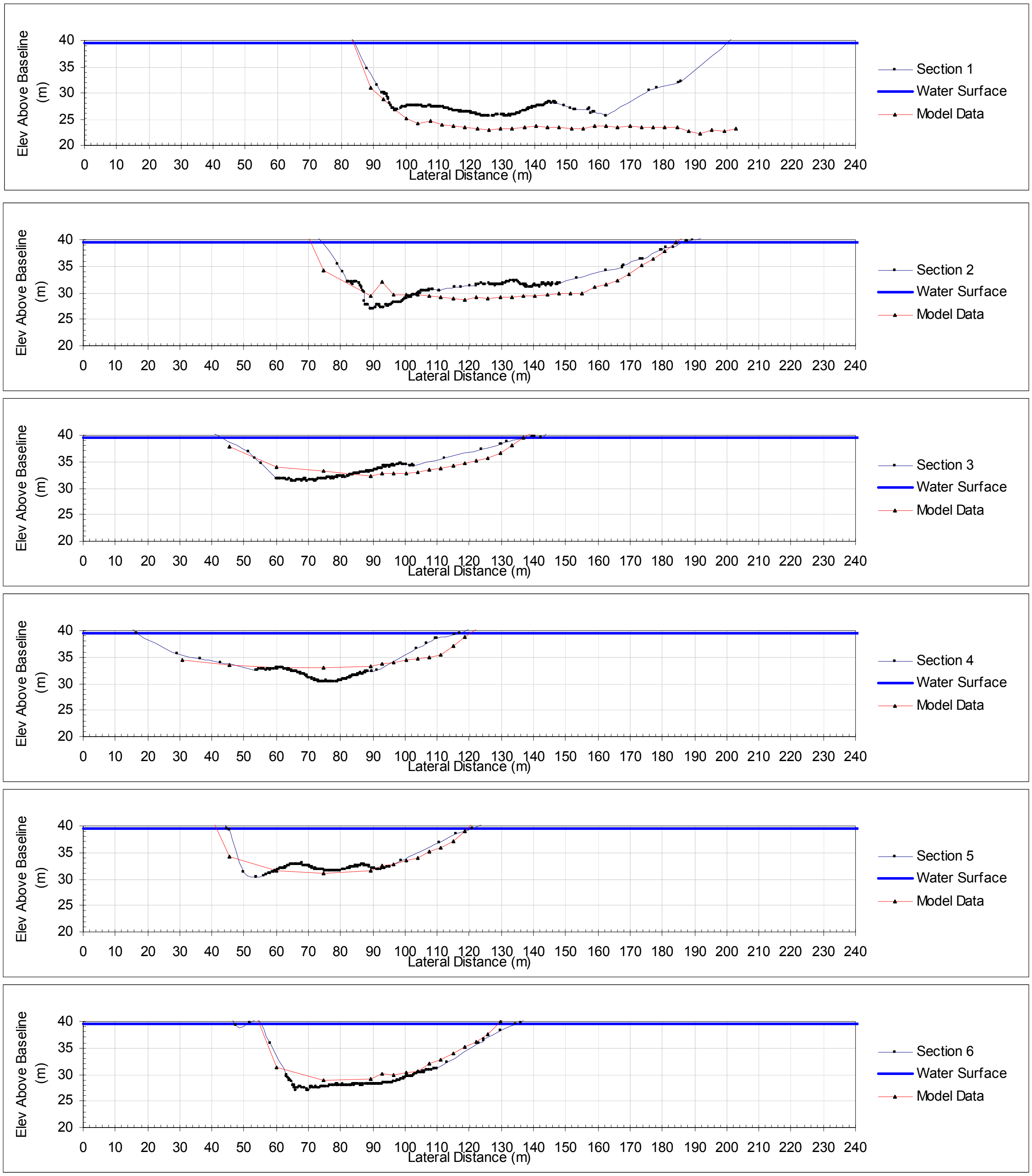


Figure 2.9. Tailrace templates 1 to 6

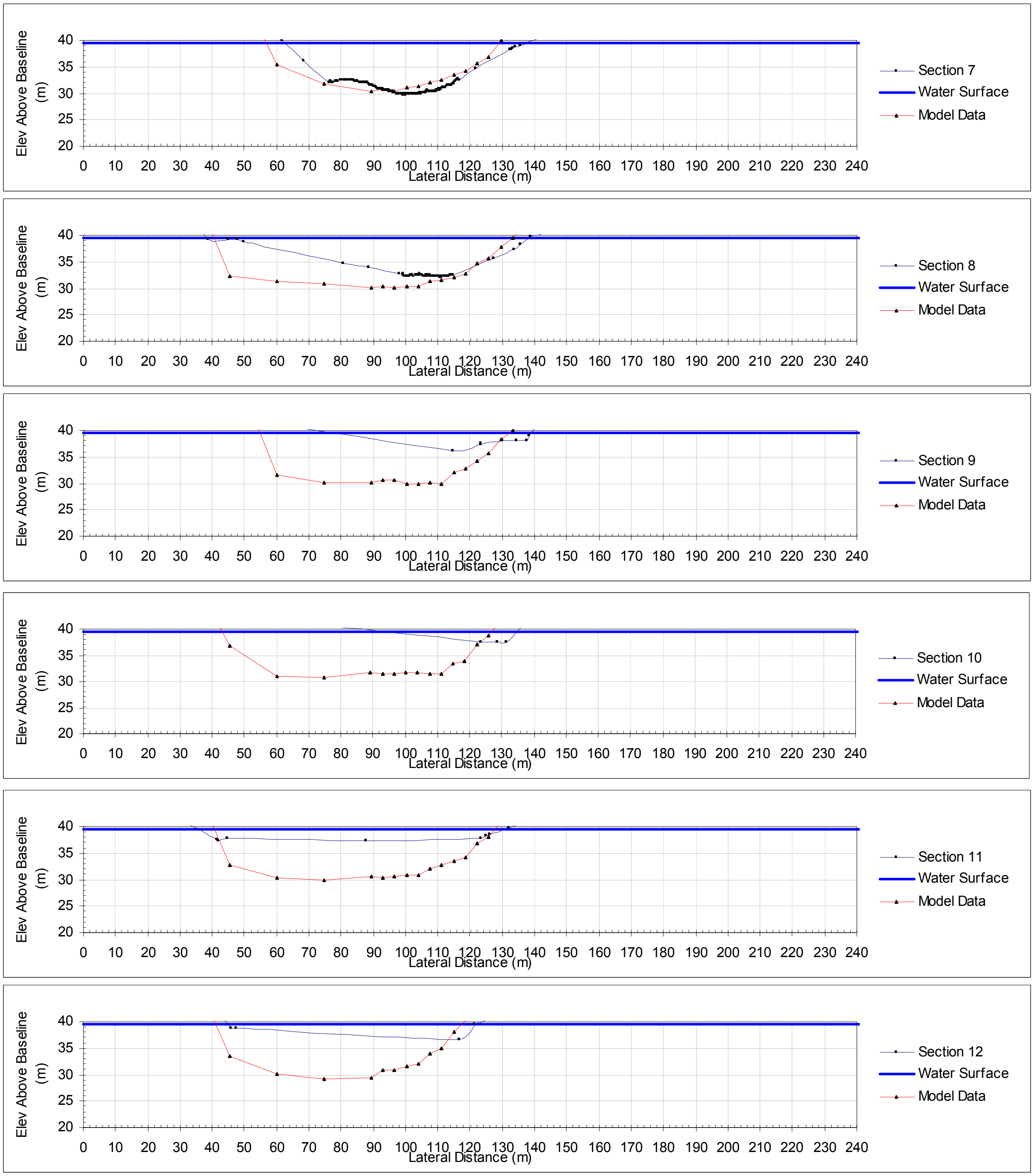


Figure 2.10. Tailrace templates 7 to 12

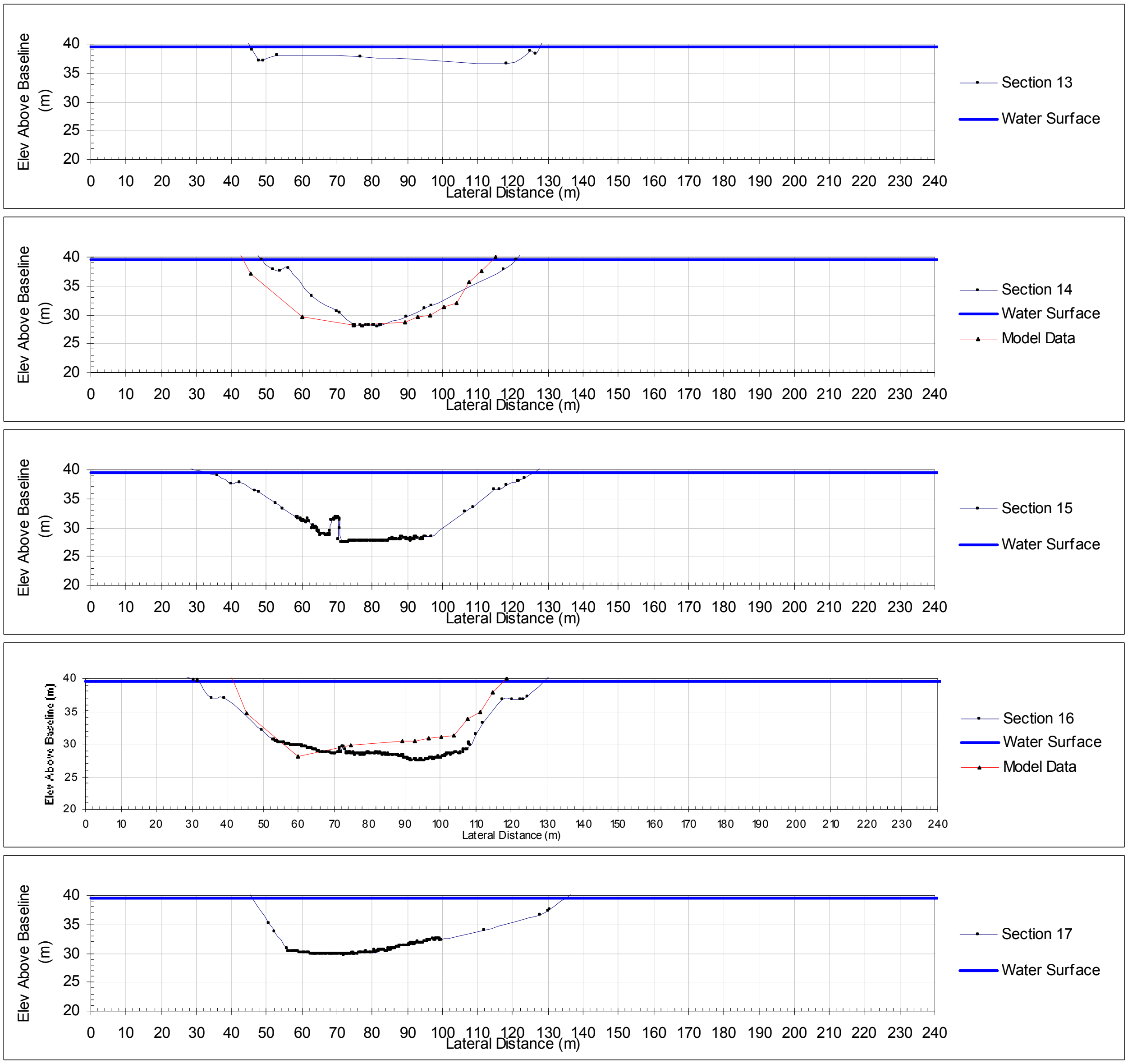


Figure 2.11. Tailrace templates 13 to 17

2.8 Equipment and Initial Operation

Two low-head pumps supplied flow for the model. A 60-hp pump delivered smaller flows through an 8-inch diameter pipe with a 6-inch orifice, and a 75-hp pump supplied larger flows through a 14-inch diameter pipe with a 12-inch orifice. Discharge coefficients for the 6-inch and 12-inch orifices were C=1.145 and C=5.22, respectively. An 8-foot manometer measured head differential, Δh, across the orifice allowing computation of prototype discharge, Q_p, from the standard orifice equation: $Q_p = C(\Delta h)^{0.5}(48)^{2.5}$.

Headwater and tailwater elevations were measured using stilling pots with point gages. The upstream stilling pot was at the field tailwater measurement location between the spillway training wall and powerhouse Unit 1. Another point gage near the diversion tunnel outlet measured the tailwater elevation at approximately 920 prototype feet (19 model feet) downstream of the end sill. The downstream gage was just upstream of the prototype boat ramp location at about 2900 feet downstream of the endsill. Point gage reference elevations were surveyed with an automatic level and referenced relative to the model spillway crest. Headwater elevation was recorded in a calm area near the left forebay training wall. Water level oscillations were minimal because of the distance from the inflow diffuser. Large stilling pots dampened wave fluctuations in the tailrace flume, providing accurate tailwater measurements.

Tainter gates controlled discharge through spillway and sluiceway bays. A gate position relationship was derived from each individual gate's geometry. Various angles and distances were obtained from construction drawings or measured on the model, and a direct correlation between positioning rod length and vertical gate opening above gate seal elevation was established. Distances marked on metal positioning rods corresponded to a specific vertical gate opening. The marks were spaced to provide gate openings every one or two prototype feet. The Phase One report included a detailed discharge rating curve comparing gate opening and flowrate per sluiceway bay.

3. VERIFICATION OF DEFLECTOR PERFORMANCE

Lateral flows and recirculation effects were difficult to evaluate during two-dimensional sectional model operation. Since these effects could have altered the recommended deflector's performance curve, the three-dimensional model was used to verify the deflector's performance. The comprehensive model provided three-dimensional performance characteristics for the recommended deflector design. Critical points obtained for final performance curve development during the two-dimensional model study were verified with the three-dimensional model. Powerhouse flow entrainment caused by deflector-induced lateral flow and recirculation effects was also investigated. Entrainment was examined using comparative velocity profiles and flow visualization. A series of velocity measurements were taken along a longitudinal section extending downstream from the training wall separating the spillway and the powerhouse. Data was obtained for conditions with and without the recommended deflector at spill discharges of 2.5, 5.0, 10.0, and 15.0 kcfs per sluiceway bay with 30 kcfs of total powerhouse flow.

3.1 Water Surface Profiles

Tailwater elevation at Hells Canyon prototype was measured at a gage near on the left side of the training wall between the powerhouse and spillway. The original two-dimensional model did not have a powerhouse so the model tailwater was measured 920 feet downstream, where flow velocity files approached a more uniform distribution. In the three-dimensional tailrace model, a stilling pot gage was placed at 920 feet downstream near the diversion tunnel outlet to correlate two- and three-dimensional performance curve data.

Stream-wise water surface profiles were needed to link model diversion tunnel gage water surface elevations with prototype water surface gage elevations. IPC provided an equation relating the powerhouse gage tailwater elevation to total river discharge, but during model data collection it was noted that the powerhouse gage was strongly influenced by powerhouse discharge. The powerhouse gage was observed to be more dependent on Unit 1 flowrate than on total river flowrate. This was a concern because small changes in tailwater elevation could negatively affect deflector performance curves and air entrainment. The prototype tailwater equation given for the Hells Canyon Project was:

For $Q<72500$ cfs, $HW = 1470.867118 + 0.000291265*Q - 0.00000000105413*Q^2 - 27608.30872/Q$

For $Q>72500$ cfs, $HW = 1476.758242 + 0.000127473*Q$ (straight line fit between the maximum design tailwater and tailwater at 72,500 cfs)

A study compared water surface elevation at different prototype gage locations. For reference, a United States Geological Survey (USGS) station about 3200 feet downstream of the dam provided river elevations at about 300 feet downstream of the downstream model stilling pot. Noting that model flowrates were generally more than the 98% exceedence flowrate of 60,000 cfs total river, the research team looked at peak flowrates versus tailwater elevation data from the USGS gage data and compared this to the HCP tailwater equation. The USGS site http://water.usgs.gov/peak/?site_no=13290450 provided data for station 13290450. Figure 3.1 shows a plot comparing tailwater elevation at the powerhouse and 3200 feet downstream sites.

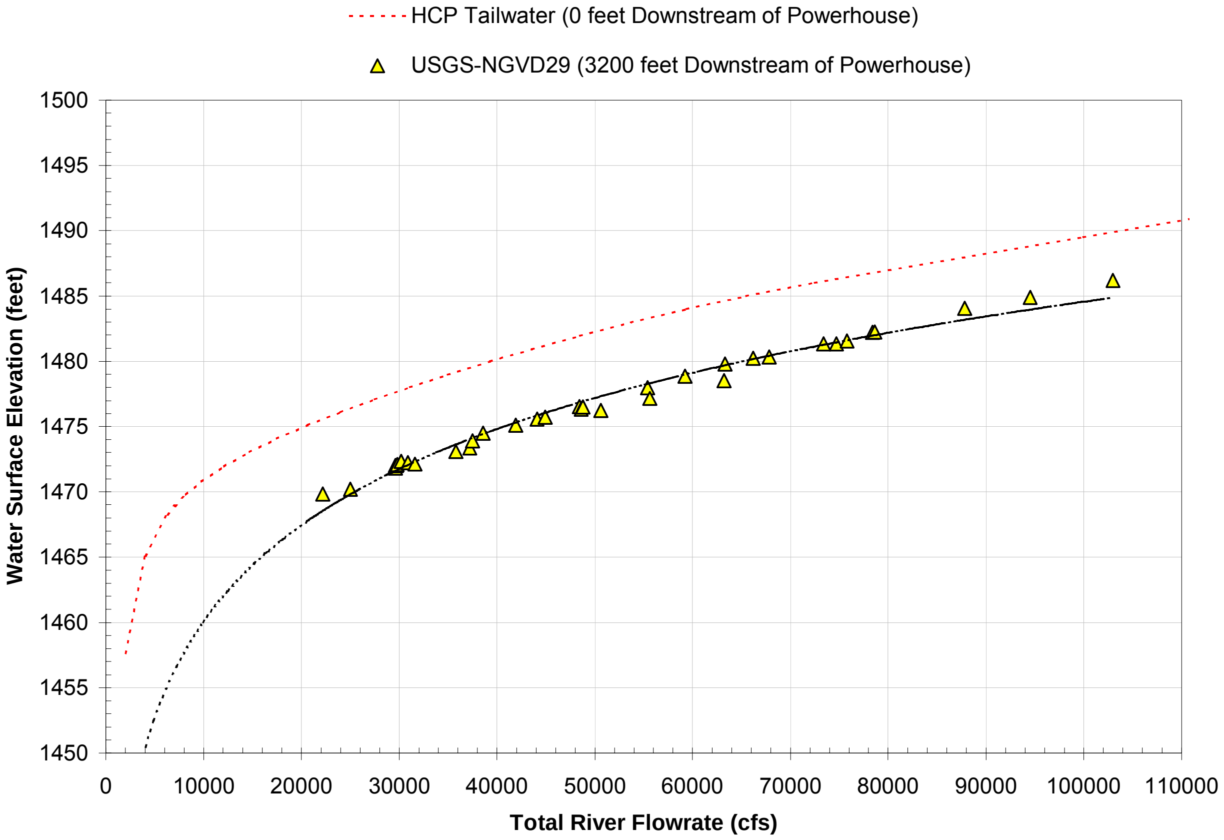


Figure 3.1. Prototype tailwater elevation given river flowrate and distance downstream

The prototype data in figure 3.1 shows a drop of five to six feet in water surface elevation from the powerhouse gage to the USGS gage. The model could not calculate the natural river's absolute tailwater elevation because tailwater was set with tailgates. Tailwater differences between the three model water surface gages were calculated as a next best alternative. In the field, water surface elevations tended to decrease further downstream. In the model, this trend was not evident between the powerhouse and most downstream water surface gages. Figure 3.2 shows the model elevation difference between powerhouse, diversion tunnel, and most downstream gages.

Note: Tailwater elevation set to match prototype at diversion tunnel gage

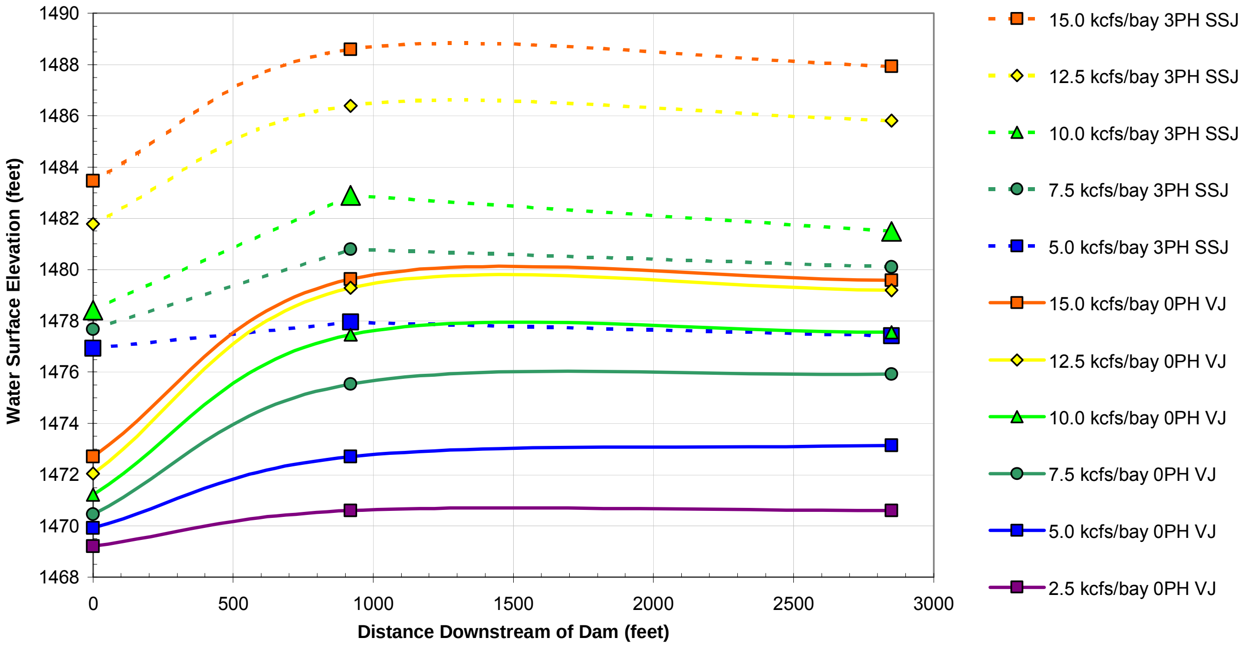


Figure 3.2. Model tailwater elevation at various gages and flow conditions

In Figure 3.2 model tailwater elevation was observed to be a function of distance downstream, but water surface elevation increased with downstream distance. In Figure 3.2 “0 PH VJ” meant no flow through the powerhouses and a vented jet or plunging flow coming from the sluiceways, and “3 PH SSJ” corresponded to all three powerhouse units operating and submerged surface jet or surface-oriented flow coming from the sluiceways. In both cases, plunging and surface-oriented, the model shows a one foot to seven foot water surface increase from the powerhouse gage (0 feet downstream) to the most downstream gage (2850 feet downstream). This was more clearly illustrated in figure 3.3.

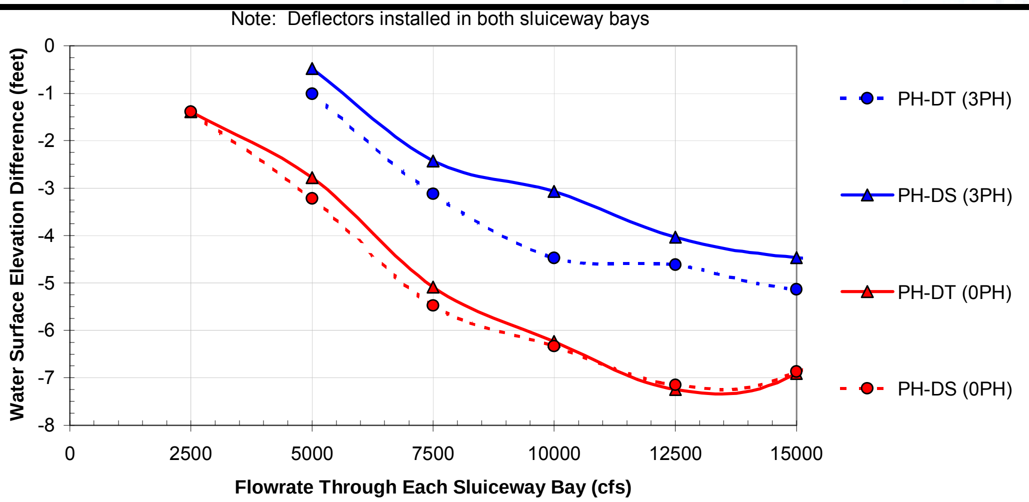


Figure 3.3. Water surface differential as a function of sluiceway flowrate

In Figure 3.3, "PH" was the powerhouse water surface elevation, "DT" was the diversion tunnel water surface elevation (920 feet downstream of the powerhouse), and "DS" was the water surface elevation at the most downstream gage (2850 feet downstream of the powerhouse). Since the powerhouse water surface elevation gage was more dependent on powerhouse and spill flow patterns than on total river flowrate, the model performance curves could not be reliably converted from measuring tailwater at the diversion tunnel to measuring tailwater at the powerhouse gage. Tailwater elevations for the performance curves were collected at the model diversion tunnel gage (920 feet downstream of the endsill). This was the same location that the tailwater elevation was recorded in the Phase I research. Since field operators measured tailwater at the powerhouse gage, field performance curve tailwater elevations may need to be adjusted by the field piezometric head differential between the powerhouse and 920 feet downstream.

3.2 Performance Curve Data

The two- and three-dimensional model performance curve data were significantly different. Figure 3.4 shows initiation of the surface jet flow regime at a much lower tailwater elevation in the three-dimensional model than in the two-dimensional model. Under normal operating conditions with three powerhouse units operating, the three-dimensional model predicted submerged surface jet flow regimes for flowrates of less than eight kcfs per sluiceway bay while the two-dimensional model predicted surface jet (non-submerged) flow regimes. With only one powerhouse unit was operating, the three-dimensional model predicted vented surface jet flow regimes for flowrates around 12.5 kcfs per bay while the two-dimensional model predicted surface jet flow regimes.

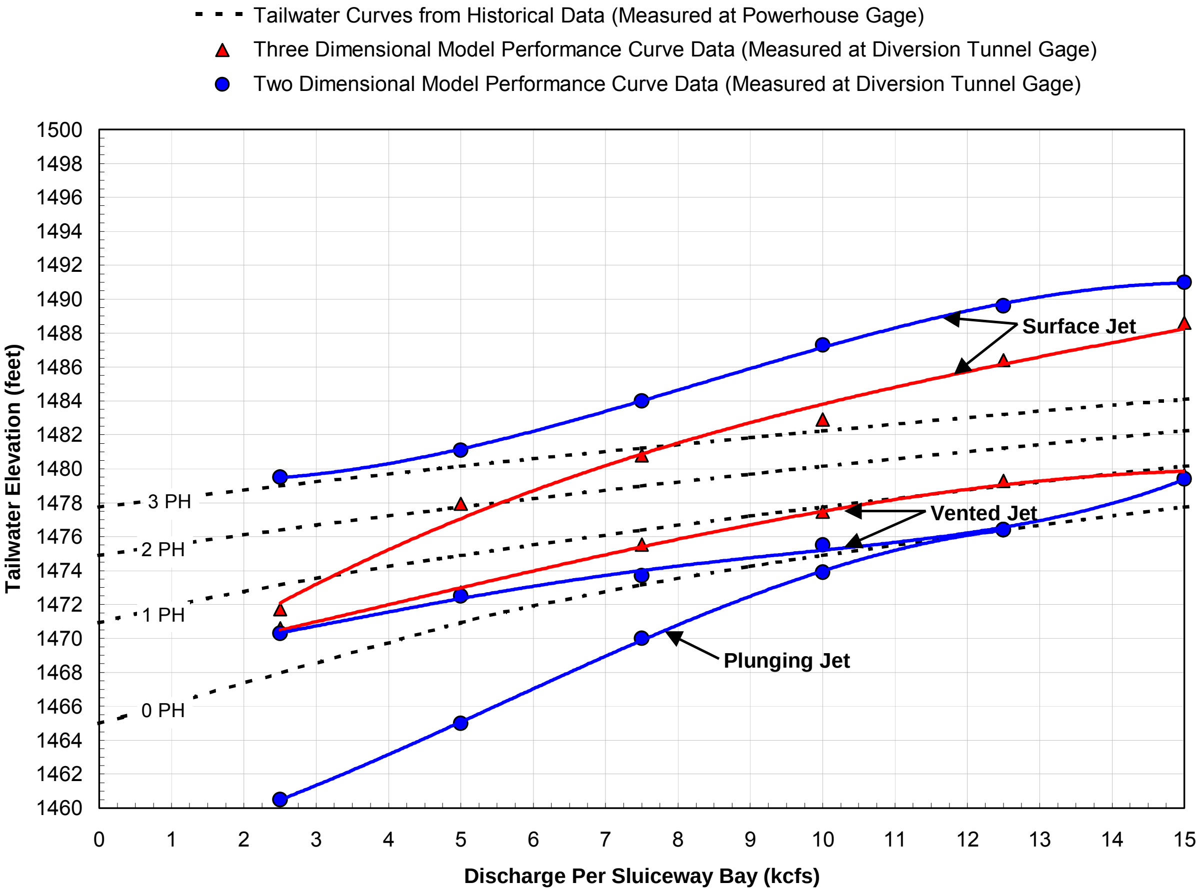


Figure 3.4. Performance curve predictions with two- and three-dimensional models

Even though the three-dimensional model predicts a much narrower band for surface jet flow regime than predicted with the two-dimensional model, a new deflector design was not recommended. Increasing deflector lip elevation would have raised the vented jet regime into the two or three powerhouse unit operating tailwater conditions. Lowering deflector lip elevation would have forced the deflector to operate under a more submerged surface jet flow regime. The research team felt that maximizing operations in the surface jet flow regime produced the best air entrainment performance. Even though the performance curve was different between the two- and three-dimensional models, the surface jet flow regime was still maximized with the deflector lip elevation at 1468.0 feet. A summary of performance curve data for the two- and three-dimensional models was presented in Table 3.1.

	Two-Dimensional Model Performance Curve Data				Three-Dimensional Model Data	
Flowrate	Surface Jump	Surface Jet	Vented Surface Jet	Plunging Flow	Surface Jet	Vented Surface Jet
kcfs per bay	Start Elevation	Start Elevation	Start Elevation	Start Elevation	Start Elevation	Start Elevation
2.5	1490.0	1479.5	1470.3	1460.5	1471.7	1470.6
5.0	1500.0	1481.1	1472.5	1465.0	1477.9	1472.7
7.5	1500.0	1484.0	1473.7	1470.0	1480.8	1475.5
10.0	1500.0	1487.3	1475.5	1473.9	1482.9	1477.5
12.5	1500.0	1489.6	1476.4	1476.4	1486.4	1479.3
15.0	1500.0	1491.0	1479.4		1488.6	1479.6
20.0					1492.6	1478.4

Table 3.1. Tabular results of performance curve verification

4. DOCUMENTATION OF TAILRACE EROSION POTENTIAL

Inclusion of a mobile bed in the comprehensive model allowed examination of local scour patterns and bank erosion. Baseline river bathymetry was formed using templates developed from field survey data. After operating the model at set discharges for specific periods, local scour depths and bankline erosion areas were surveyed using a transit and documented with digital video and photographs.

The deflector-produced recirculation effects showed potential for drawing downstream riverbed material back onto the apron. Material pulled onto the apron was observed for ball milling potential. Ball milling was abrasive circular motion or impact motion normal to surfaces with potential to cause structural damage to spillway, apron, or deflector surfaces. The plunging nature of the original spillway design without deflectors minimized ball milling, but the recommended deflectors the created a surface jet and increased the potential for pulling riverbed material onto the apron. Observations made during the erosion tests identified ball milling potential, especially during operation with deflectors.

All tailrace erosion tests maintained the full powerhouse discharge condition of 30 kcfs and normal headwater elevation of 1686.0 feet. The only variation in headwater elevation occurred for discharges approaching 300 kcfs, which required higher forebay elevations to pass the desired flow rates. For each test photographic and video documentation of riverbed scour patterns, bankline erosion potential, ball milling potential, and tailrace flow conditions was made and included on the attached research data compact disk. Figures reporting changes for various flow conditions were presented in terms of prototype feet and cubic yards.

4.1 Limits and assumptions of tailrace erosion tests

Prototype tailrace was primarily a shallow layer of alluvial material deposited on solid bedrock. While the prototype bedrock layer was much closer to the riverbed surface, the model had over 100 feet of loose angular material available for erosion. (One exception to this was a fixed concrete layer along the model right bankline.) Because the model did not have an erosion-limiting bedrock layer in most places, the model was expected to conservatively over-estimate erosion depths.

The model could not predict absolute field erosion depths without a limiting bedrock layer so it only compared erosion patterns and relative depths between dam operations with and without sluiceway deflectors.

4.2 Baseline conditions

After raking the model to match bathymetric template profiles, the original baseline bed was photographed in Figures 4.1 through 4.3.

Figure 4.1. Baseline condition looking upstream

Figure 4.2. Baseline condition looking downstream

Figure 4.3. Baseline condition looking at fish ladder entrance

4.3 Uniform Sluiceway Gate Operations

Sluiceway flowrates under 10 kcfs per bay were not surveyed. They did not cause any bathymetric change of more than two feet or pull bed material onto the apron. Photographs in Figures 4.4 and 4.5 were taken during and after the 5 kcfs per bay flow condition.

Figure 4.4. Sluiceway jets at 5 kcfs per bay

Figure 4.5. Looking downstream after 5 kcfs per sluiceway bay

The 10 kcfs per sluiceway bay condition shown in Figures 4.6 and 4.7 pulled rock material onto the apron. Powerhouse flow from all three units was laterally entrained onto the apron and into the sluiceway jets. After two prototype days of runtime, five prototype cubic yards of fine material were pulled onto the apron, primarily from a six foot deep hole about 350 feet downstream of the endsill near the rightbank bedrock layer. Bankline collapse deposited seven feet of material near the fish ladder entrance. A bathymetric survey was plotted in Figure 4.8.

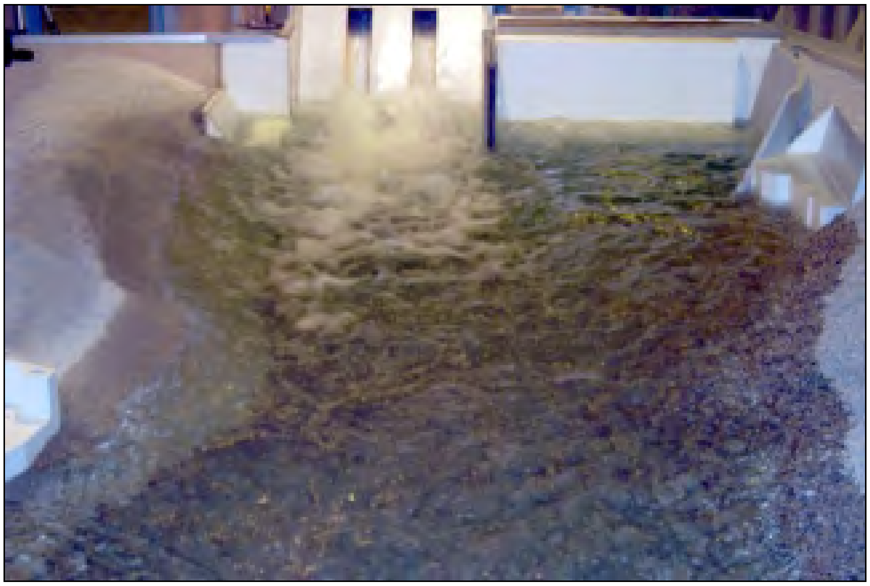
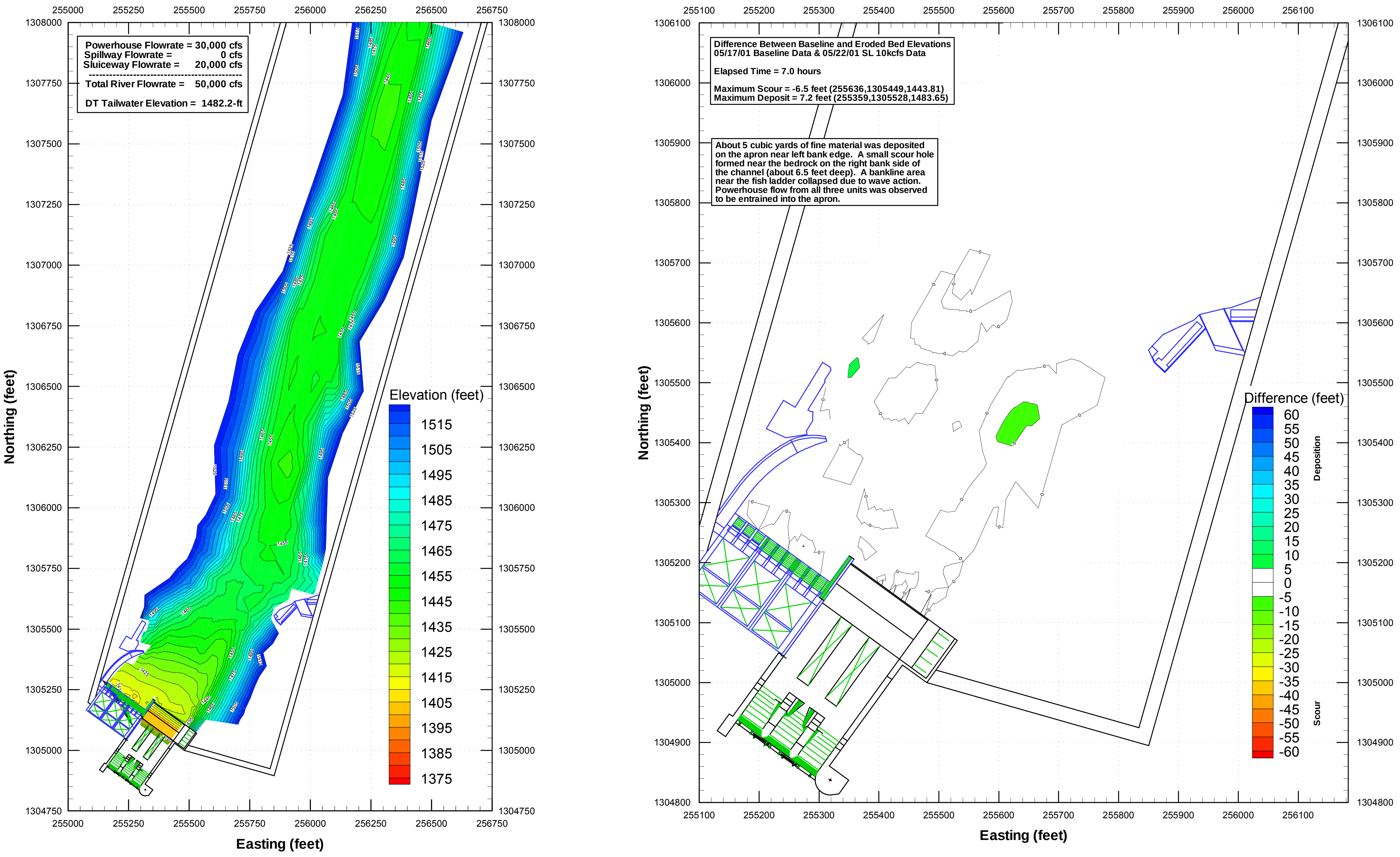


Figure 4.6. Sluiceway jets at 10 kcfs per bay

Figure 4.7. Looking upstream after 10 kcfs per sluiceway bay



Powerhouse Flowrate = 30,000 cfs
Spillway Flowrate = 0 cfs
Sluiceway Flowrate = 20,000 cfs

Total River Flowrate = 50,000 cfs

DT Tailwater Elevation = 1482.2-ft

Difference Between Baseline and Eroded Bed Elevations
05/17/01 Baseline Data & 05/22/01 SL 10kcfs Data

Elapsed Time = 7.0 hours

Maximum Scour = -6.5 feet (255636,1305449,1443.81)
Maximum Deposit = 7.2 feet (255359,1305528,1483.65)

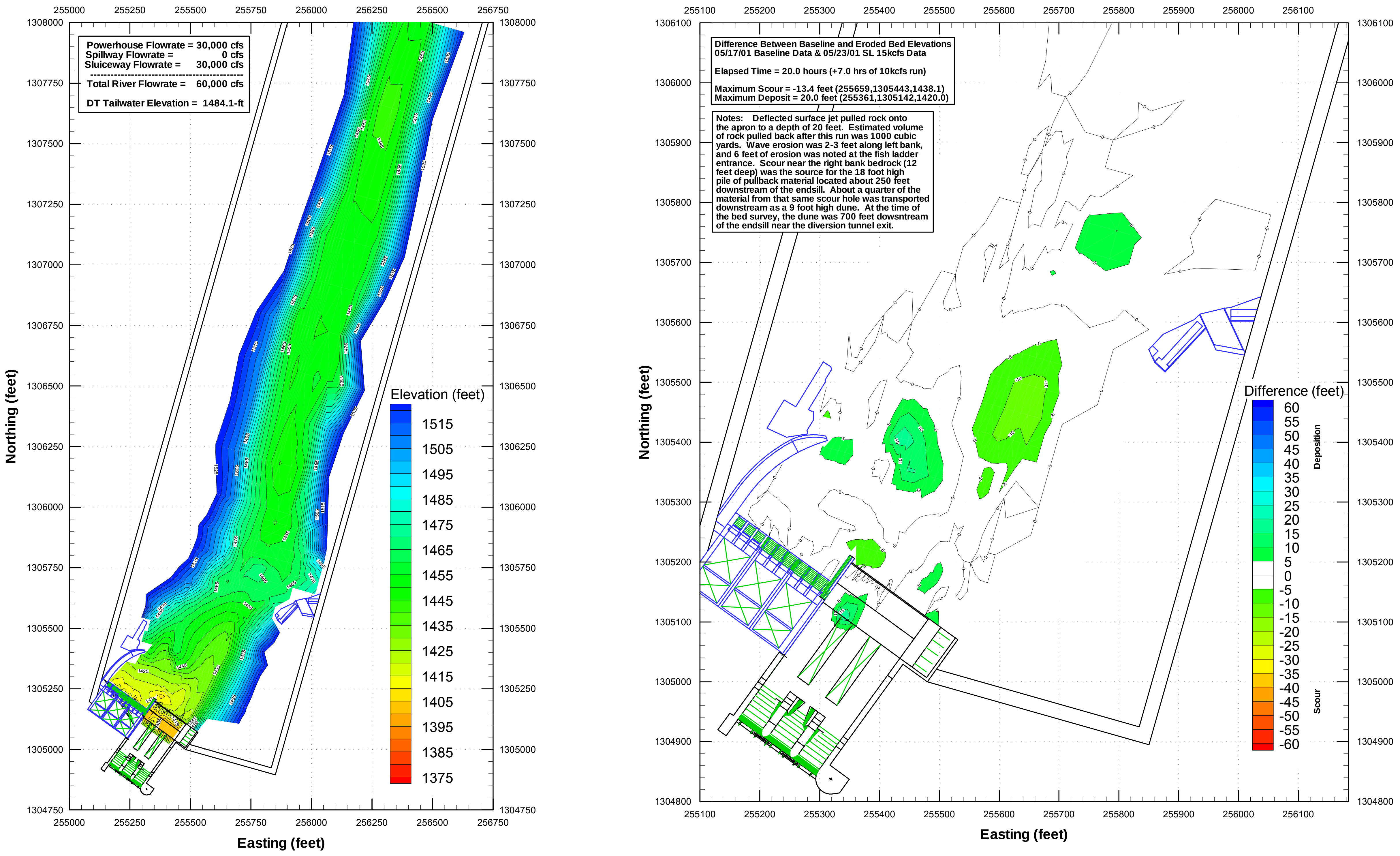
About 5 cubic yards of fine material was deposited on the apron near left bank edge. A small scour hole formed near the bedrock on the right bank side of the channel (about 6.5 feet deep). A bankline area near the fish ladder collapsed due to wave action. Powerhouse flow from all three units was observed to be entrained into the apron.

Figure 4.8. Bathymetric contours after 10 kcfs per sluiceway bay

The 15 kcfs per sluiceway bay condition shown in Figures 4.9 and 4.10 pulled 1000 prototype cubic yards of bed material onto the apron. After 5.8 prototype days (in addition to the 2.0 days at lower flowrates), a thirteen-foot deep hole was scoured about 350 feet downstream of the endsill near the rightbank bedrock layer. An 18-foot high gravel bar was deposited about 250 feet downstream of the powerhouse. Powerhouse flow from all three units was again entrained into the sluiceway jets. Figure 4.11 showed the bathymetric survey results.

Figure 4.9. Looking upstream after 15 kcfs per sluiceway bay

Figure 4.10. Fish ladder entrance erosion after 15 kcfs per sluiceway bay



Powerhouse Flowrate = 30,000 cfs
Spillway Flowrate = 0 cfs
Sluiceway Flowrate = 30,000 cfs

Total River Flowrate = 60,000 cfs

DT Tailwater Elevation = 1484.1-ft

Difference Between Baseline and Eroded Bed Elevations
05/17/01 Baseline Data & 05/23/01 SL 15kcfs Data

Elapsed Time = 20.0 hours (+7.0 hrs of 10kcfs run)

Maximum Scour = -13.4 feet (255659,1305443,1438.1)
Maximum Deposit = 20.0 feet (255361,1305142,1420.0)

Notes: Deflected surface jet pulled rock onto the apron to a depth of 20 feet. Estimated volume of rock pulled back after this run was 1000 cubic yards. Wave erosion was 2-3 feet along left bank, and 6 feet of erosion was noted at the fish ladder entrance. Scour near the right bank bedrock (12 feet deep) was the source for the 18 foot high pile of pullback material located about 250 feet downstream of the endsill. About a quarter of the material from that same scour hole was transported downstream as a 9 foot high dune. At the time of the bed survey, the dune was 700 feet dowsntream of the endsill near the diversion tunnel exit.

Figure 4.11. Bathymetric contours after 15 kcfs per sluiceway bay

The 20 kcfs per sluiceway bay condition pulled 15,000 prototype cubic yards of material onto the apron. This material was over forty feet deep and reached the deflector vertical face (Figure 4.12). After 6.9 prototype days (in addition to 7.8 days at lower flowrates), a 20-foot deep hole was scoured about 350 feet downstream of the endsill near the rightbank bedrock layer, and a 20-foot high gravel bar was deposited downstream of the powerhouse. Lateral entrainment from the powerhouse scoured a 23-foot deep hole near the training wall (Figure 4.13).

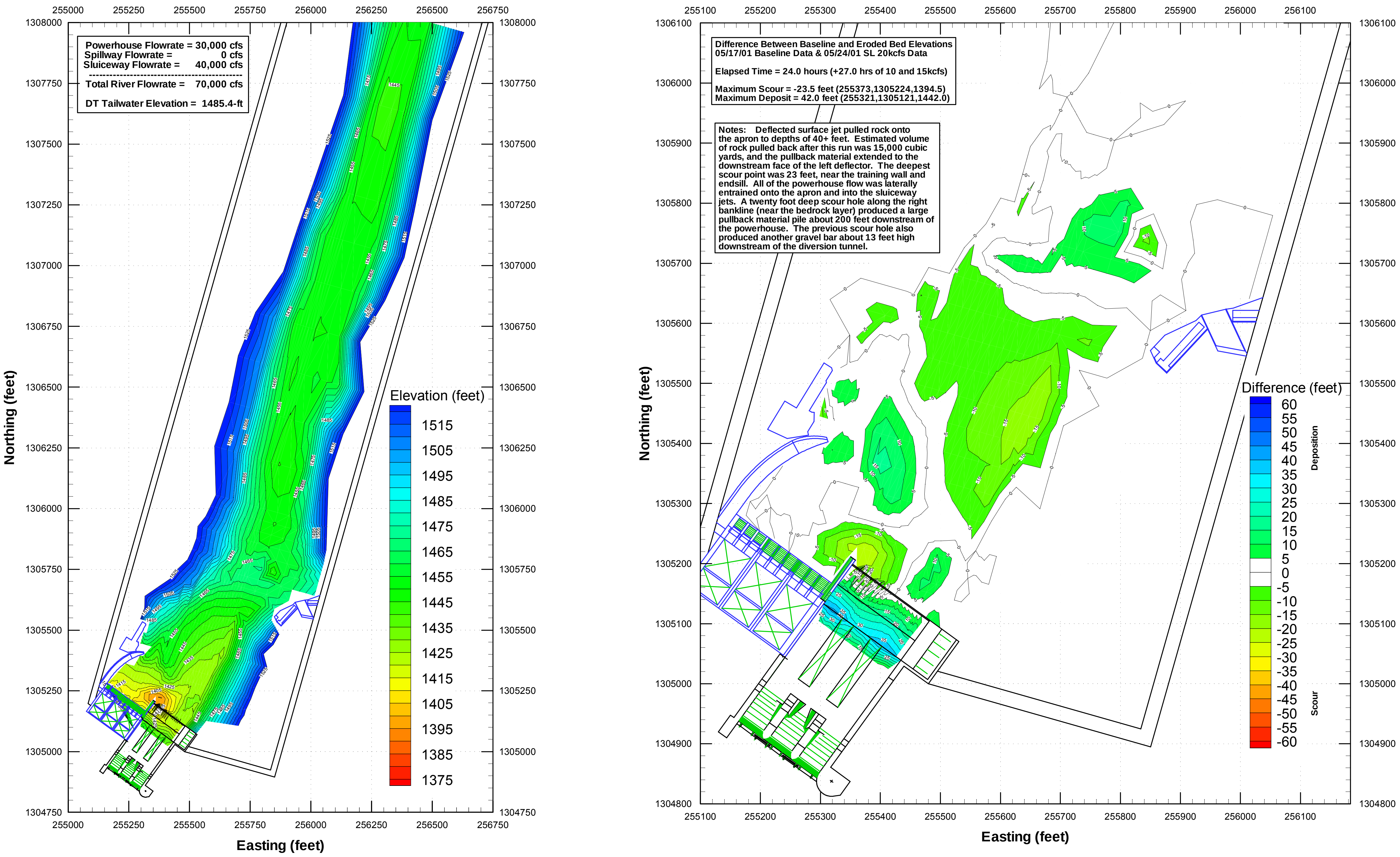
Figure 4.12. Rock pullback material touching vertical face of deflector

Figure 4.13. Looking upstream after 20 kcfs per sluiceway bay

The fish ladder entrance was undermined as shown in Figure 4.14. Downstream of the diversion tunnel outlet a ten-foot high gravel bar formed from material scoured out of the upstream rightbank bedrock hole (Figure 4.15). Next to the gravel bar a 20-foot scour hole was developing. As the sluiceway jets traveled downstream, they interacted with eddies near the diversion tunnel outlet. A clockwise swirl formed in the waters near the diversion tunnel. Figure 4.16 showed the bathymetric survey results.

Figure 4.14. Fish ladder entrance erosion after 20 kcfs per sluiceway bay

Figure 4.15. Erosion patterns after 20 kcfs per sluiceway bay



Powerhouse Flowrate = 30,000 cfs
Spillway Flowrate = 0 cfs
Sluiceway Flowrate = 40,000 cfs
Total River Flowrate = 70,000 cfs

DT Tailwater Elevation = 1485.4-ft

Difference Between Baseline and Eroded Bed Elevations
05/17/01 Baseline Data & 05/24/01 SL 20kcfs Data

Elapsed Time = 24.0 hours (+27.0 hrs of 10 and 15kcfs)

Maximum Scour = -23.5 feet (255373,1305224,1394.5)
Maximum Deposit = 42.0 feet (255321,1305121,1442.0)

Notes: Deflected surface jet pulled rock onto the apron to depths of 40+ feet. Estimated volume of rock pulled back after this run was 15,000 cubic yards, and the pullback material extended to the downstream face of the left deflector. The deepest scour point was 23 feet, near the training wall and endsill. All of the powerhouse flow was laterally entrained onto the apron and into the sluiceway jets. A twenty foot deep scour hole along the right bankline (near the bedrock layer) produced a large pullback material pile about 200 feet downstream of the powerhouse. The previous scour hole also produced another gravel bar about 13 feet high downstream of the diversion tunnel.

Figure 4.16. Bathymetric contours after 20 kcfs per sluiceway bay

4.4 Uniform Spillway Crest Gate Operations

The term “upper crest gate” was used interchangeably with “spillway bay” in this report and referred to the three upper gated outlets of Hells Canyon Dam. “Sluiceway” referred to the two lower gated outlets only. Spillway crest gate flowrates under 13.3 kcfs per bay were not surveyed since they did not cause bathymetric changes of over two feet or pull bed material onto the apron. The photographs in Figures 4.17 and 4.18 were taken during and after the 5 kcfs per bay flow condition.

Figure 4.17. Spillway jets at 5 kcfs per crest gate

Figure 4.18. Looking upstream after 5 kcfs per crest gate

The 6.7 kcfs spillway flow condition was shown in Figure 4.19, and the 10 kcfs spillway flow condition was shown in Figure 4.20.

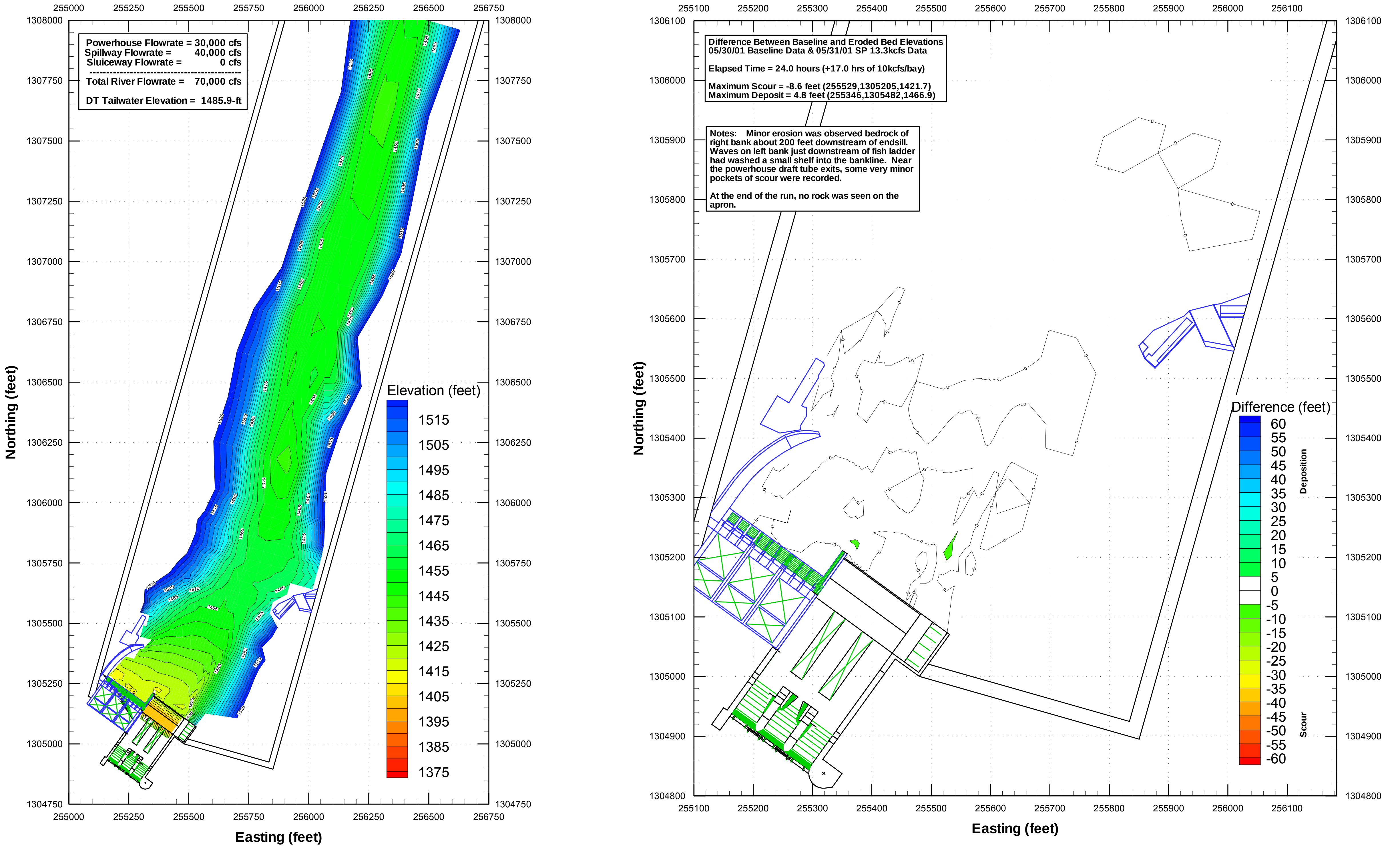
Figure 4.19. Spillway jets at 6.7 kcfs per crest gate

Figure 4.20. Spillway jets at 10.0 kcfs per crest gate

The post 13.3 kcfs per crest gate condition shown in Figures 4.21 and 4.22 scoured an eight-foot deep hole about 150 prototype feet downstream of the endsill near the rightbank bedrock layer. After 6.9 prototype days of runtime (in addition to 7.8 days at lower flowrates), a five-foot deep scour hole developed near the spillway training wall. Powerhouse flow from the three units was not entrained onto the apron. Figure 4.23 showed bathymetric survey results.

Figure 4.21. Looking upstream after 13.3 kcfs per crest gate

Figure 4.22. Looking downstream after 13.3 kcfs per crest gate



Notes: Minor erosion was observed bedrock of right bank about 200 feet downstream of endsill. Waves on left bank just downstream of fish ladder had washed a small shelf into the bankline. Near the powerhouse draft tube exits, some very minor pockets of scour were recorded.

At the end of the run, no rock was seen on the apron.

Figure 4.23. Bathymetric contours after 13.3 kcfs per spillway bay

After 6.9 prototype days of runtime (in addition to the 11.8 days at lower flowrates), the 20 kcfs per crest gate in Figures 4.24 and 4.25 scoured a 12-foot deep hole about 250 feet downstream of the endsill near the bedrock layer.

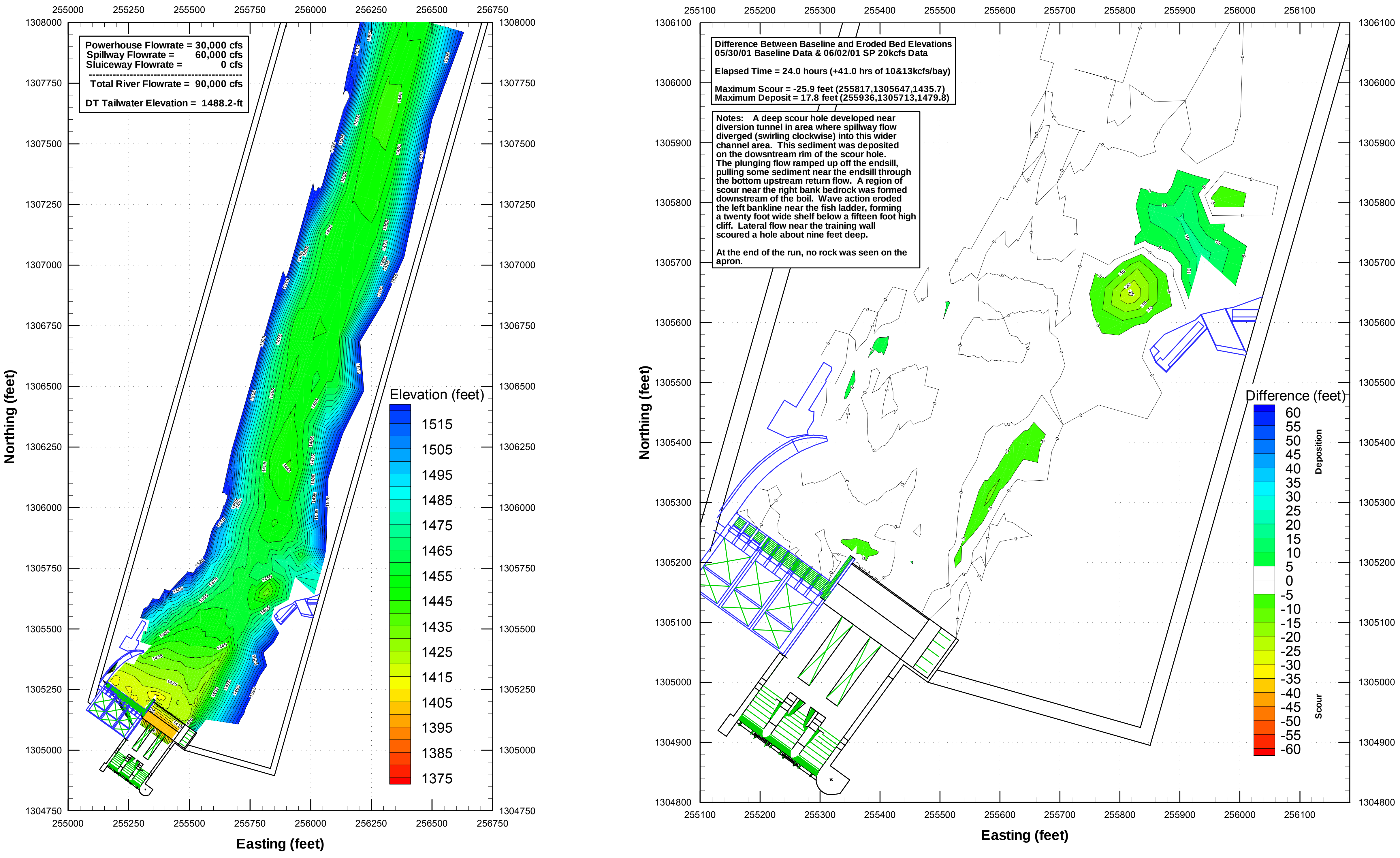
Figure 4.24. Spillway jets at 20 kcfs per crest gate

Figure 4.25. Looking upstream during 20 kcfs per crest gate

A large 26-foot deep hole was eroded near the diversion tunnel outlet (Figure 4.26), and downstream of this hole an 18-foot high gravel bar was deposited. Another eight foot deep scour hole developed near the training wall (Figure 4.27). Minor bankline collapse and wave action contributed to deposits on the left bank near the fish ladder entrance. Figure 4.28 showed bathymetric survey results.

Figure 4.26. Looking upstream after 20 kcfs per crest gate

Figure 4.27. Tailrace scour after 20 kcfs per crest gate



Powerhouse Flowrate = 30,000 cfs
Spillway Flowrate = 60,000 cfs
Sluiceway Flowrate = 0 cfs

Total River Flowrate = 90,000 cfs

DT Tailwater Elevation = 1488.2-ft

Difference Between Baseline and Eroded Bed Elevations
05/30/01 Baseline Data & 06/02/01 SP 20kcfs Data

Elapsed Time = 24.0 hours (+41.0 hrs of 10&13kcfs/bay)

Maximum Scour = -25.9 feet (255817,1305647,1435.7)
Maximum Deposit = 17.8 feet (255936,1305713,1479.8)

Notes: A deep scour hole developed near diversion tunnel in area where spillway flow diverged (swirling clockwise) into this wider channel area. This sediment was deposited on the dowsntream rim of the scour hole. The plunging flow ramped up off the endsill, pulling some sediment near the endsill through the bottom upstream return flow. A region of scour near the right bank bedrock was formed downstream of the boil. Wave action eroded the left bankline near the fish ladder, forming a twenty foot wide shelf below a fifteen foot high cliff. Lateral flow near the training wall scoured a hole about nine feet deep.

At the end of the run, no rock was seen on the apron.

Figure 4.28. Bathymetric contours after 20 kcfs per spillway bay

After 11.3 prototype days of runtime (in addition to the 18.8 days at lower flowrates), the 30 kcfs per crest gate shown in Figures 4.29 and 4.30 scoured a 20-foot deep hole about 350 feet downstream of the endsill near the bedrock layer. A 12-foot scour hole developed near the training wall, and 11 feet of material was deposited behind the endsill. Wave action contributed to scour on the left bank near the fish ladder entrance.

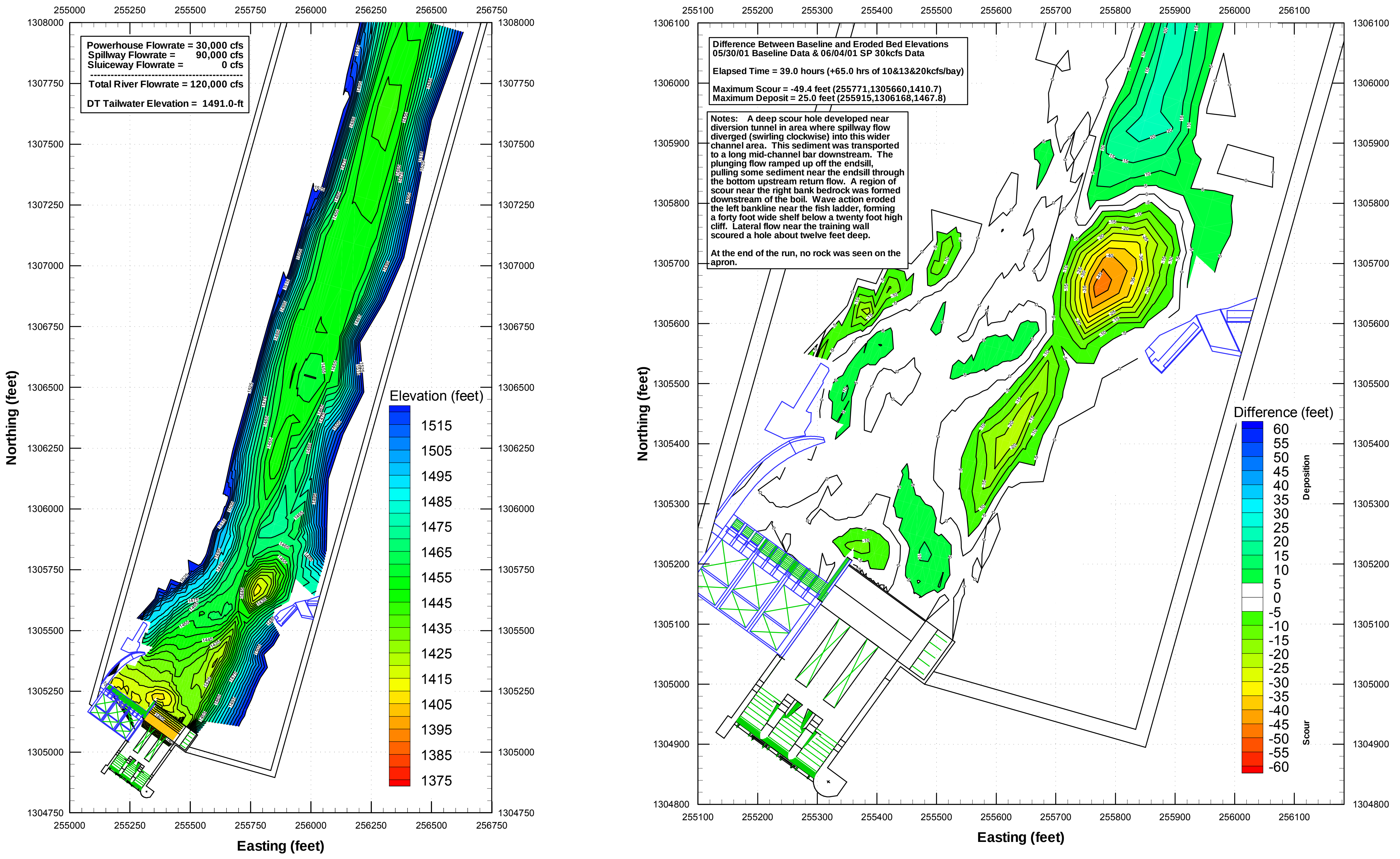
Figure 4.29. Spillway jets at 30 kcfs per crest gate

Figure 4.30. Looking upstream during 30 kcfs per crest gate

A 49-foot deep hole was eroded near the diversion tunnel outlet (Figure 4.31), and a 25-foot high gravel bar was deposited in the middle of the downstream channel (Figure 4.32). Figure 4.33 showed bathymetric survey results.

Figure 4.31. Looking upstream after 30 kcfs per crest gate

Figure 4.32. Tailrace scour after 30 kcfs per crest gate



Powerhouse Flowrate = 30,000 cfs
Spillway Flowrate = 90,000 cfs
Sluiceway Flowrate = 0 cfs

Total River Flowrate = 120,000 cfs

DT Tailwater Elevation = 1491.0-ft

Difference Between Baseline and Eroded Bed Elevations
05/30/01 Baseline Data & 06/04/01 SP 30kcfs Data

Elapsed Time = 39.0 hours (+65.0 hrs of 10&13&20kcfs/bay)

Maximum Scour = -49.4 feet (255771,1305660,1410.7)
Maximum Deposit = 25.0 feet (255915,1306168,1467.8)

Notes: A deep scour hole developed near diversion tunnel in area where spillway flow diverged (swirling clockwise) into this wider channel area. This sediment was transported to a long mid-channel bar downstream. The plunging flow ramped up off the endsill, pulling some sediment near the endsill through the bottom upstream return flow. A region of scour near the right bank bedrock was formed downstream of the boil. Wave action eroded the left bankline near the fish ladder, forming a forty foot wide shelf below a twenty foot high cliff. Lateral flow near the training wall scoured a hole about twelve feet deep.

At the end of the run, no rock was seen on the apron.

Figure 4.33. Bathymetric contours after 30 kcfs per spillway bay

After 8.9 prototype days of runtime (in addition to the 30.0 days at lower flowrates), the 40 kcfs per crest gate in Figures 4.34 and 4.35 scoured a 40-foot deep hole about 350 feet downstream of the endsill near the bedrock layer. Another twelve foot deep scour hole developed near the training wall (Figure 4.37). Wave action scoured a sixty foot wide shelf and twenty foot high cliff the left bank downstream of the fish ladder entrance.

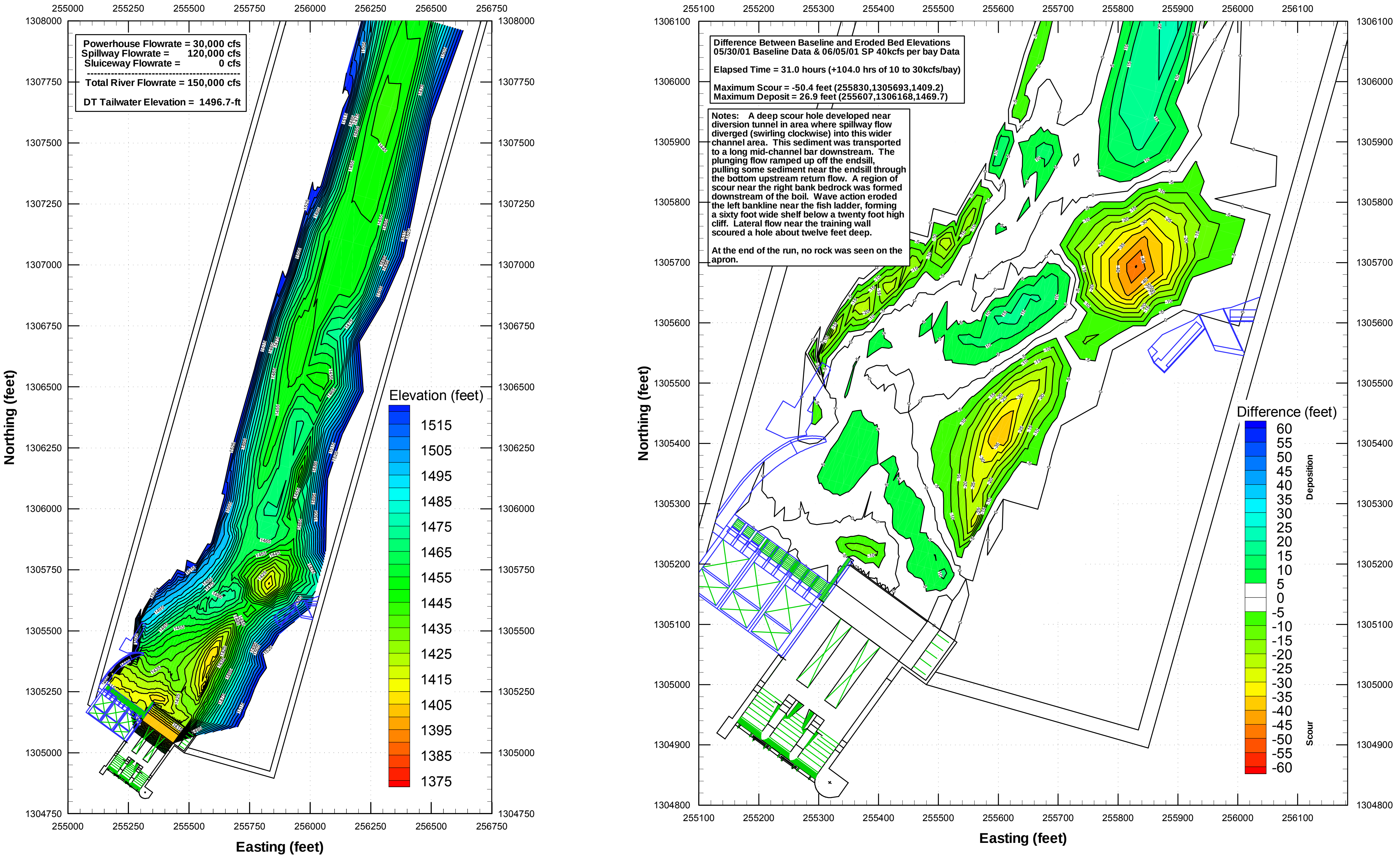
Figure 4.34. Spillway jets at 40 kcfs per crest gate

Figure 4.35. Looking upstream during 40 kcfs per crest gate

A 50-foot deep hole was eroded near the diversion tunnel outlet (Figure 4.36), and an 18-foot high gravel bar was deposited in the middle of the downstream channel. Figure 4.37 illustrated the fish ladder entrance scour, and Figure 4.38 showed bathymetric survey results.

Figure 4.36. Looking upstream after 40 kcfs per crest gate

Figure 4.37. Fish ladder entrance scour after 40 kcfs per crest gate



Powerhouse Flowrate = 30,000 cfs
Spillway Flowrate = 120,000 cfs
Sluiceway Flowrate = 0 cfs
Total River Flowrate = 150,000 cfs

DT Tailwater Elevation = 1496.7-ft

Difference Between Baseline and Eroded Bed Elevations
05/30/01 Baseline Data & 06/05/01 SP 40kcfs per bay Data

Elapsed Time = 31.0 hours (+104.0 hrs of 10 to 30kcfs/bay)

Maximum Scour = -50.4 feet (255830,1305693,1409.2)
Maximum Deposit = 26.9 feet (255607,1306168,1469.7)

Notes: A deep scour hole developed near diversion tunnel in area where spillway flow diverged (swirling clockwise) into this wider channel area. This sediment was transported to a long mid-channel bar downstream. The plunging flow ramped up off the endsill, pulling some sediment near the endsill through the bottom upstream return flow. A region of scour near the right bank bedrock was formed downstream of the boil. Wave action eroded the left bankline near the fish ladder, forming a sixty foot wide shelf below a twenty foot high cliff. Lateral flow near the training wall scoured a hole about twelve feet deep.

At the end of the run, no rock was seen on the apron.

Figure 4.38. Bathymetric contours after 40 kcfs per spillway bay

After 6.9 prototype days of runtime (in addition to the 40.0 days at lower flowrates), the 50 kcfs per crest gate in Figures 4.39 and 4.41 scoured a 56-foot deep hole about 350 feet downstream of the endsill near the bedrock layer. A twelve-foot deep scour hole developed near the training wall. Wave action scoured a 100-foot wide shelf and thirty-foot high cliff the left bank downstream of the fish ladder entrance (Figures 4.40 and 4.42).

Figure 4.39. Spillway jets at 50 kcfs per crest gate

Figure 4.40. Waves breaking on fish ladder entrance during 50 kcfs per crest gate

Figure 4.41. Right bank scour after 50 kcfs per crest gate

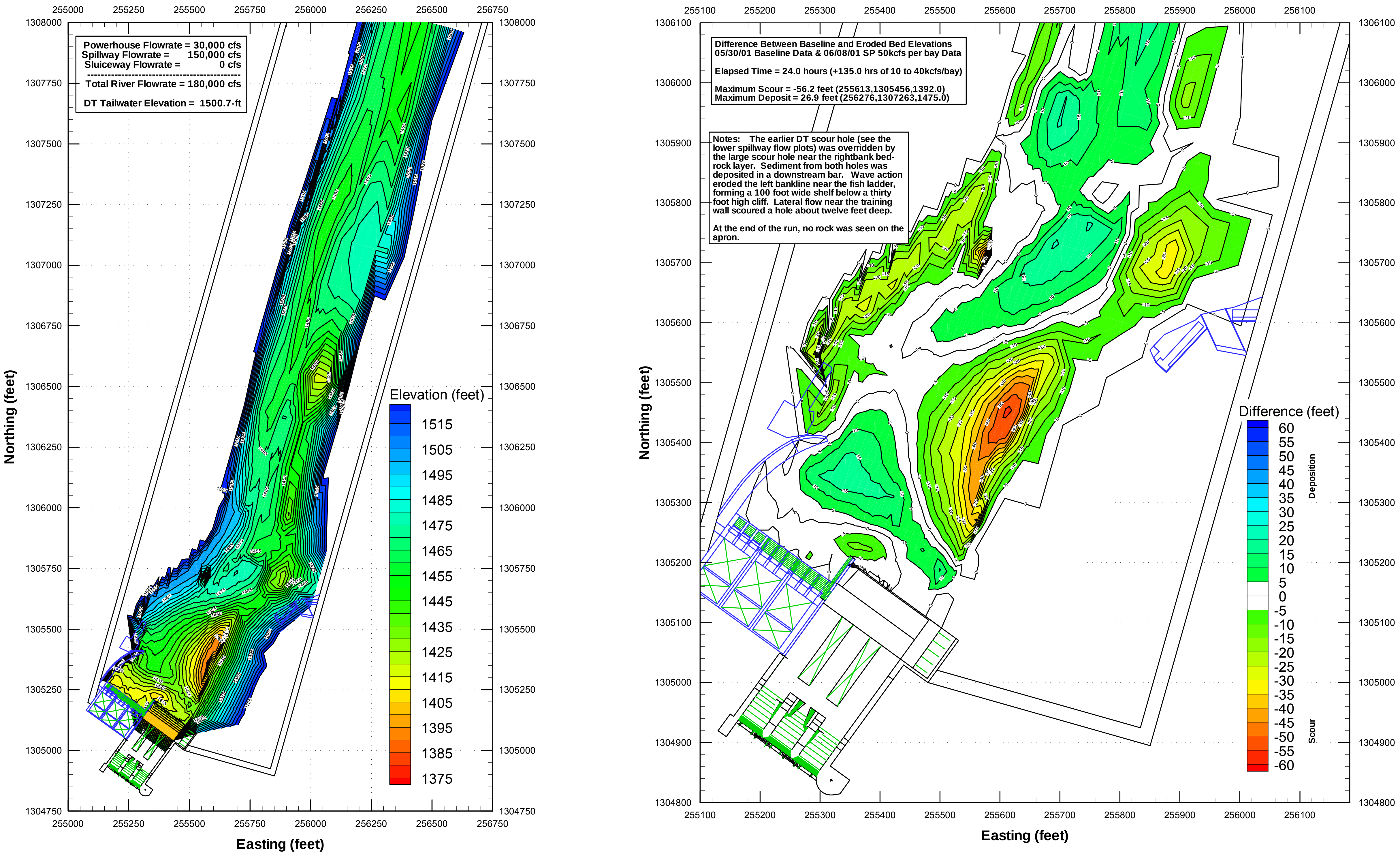
Figure 4.42. Fish ladder entrance scour after 50 kcfs per crest gate

The previous 50-foot deep hole (40 kcfs per crest gate) near the diversion tunnel outlet was partially backfilled to a new scour depth of thirty feet (Figures 4.43 and 4.44), but the mid-channel ridge downstream increased in height to 27 feet.

Figure 4.43. Looking upstream after 50 kcfs per crest gate

Figure 4.44. Diversion tunnel outlet scour patterns after 50 kcfs per crest gate

Bathymetric survey results for 50 kcfs per crest gate were plotted in Figure 4.45. A leftbank bankline collapse and a rightbank wave-eroded cliff (both about 2100 feet downstream of the endsill) were noted on the elevation contour plot.



Powerhouse Flowrate = 30,000 cfs
Spillway Flowrate = 150,000 cfs
Sluiceway Flowrate = 0 cfs

Total River Flowrate = 180,000 cfs

DT Tailwater Elevation = 1500.7-ft

Difference Between Baseline and Eroded Bed Elevations
05/30/01 Baseline Data & 06/08/01 SP 50kcfs per bay Data

Elapsed Time = 24.0 hours (+135.0 hrs of 10 to 40kcfs/bay)

Maximum Scour = -56.2 feet (255613,1305456,1392.0)
Maximum Deposit = 26.9 feet (256276,1307263,1475.0)

Notes: The earlier DT scour hole (see the lower spillway flow plots) was overridden by the large scour hole near the rightbank bedrock layer. Sediment from both holes was deposited in a downstream bar. Wave action eroded the left bankline near the fish ladder, forming a 100 foot wide shelf below a thirty foot high cliff. Lateral flow near the training wall scoured a hole about twelve feet deep.

At the end of the run, no rock was seen on the apron.

Figure 4.45. Bathymetric contours after 50 kcfs per spillway bay

After 6.1 prototype days of runtime (in addition to the 45.9 days at lower flowrates), the 67 kcfs per crest gate in Figures 4.46 and 4.47 scoured a 55-foot deep hole about 350 feet downstream of the endsill near the bedrock layer. A twelve foot deep scour hole developed near the training wall. Wave action scoured a 125 foot wide shelf and 20 to 25 foot high cliff the left bank downstream of the fish ladder entrance.

Figure 4.46. Spillway jets at 67 kcfs per crest gate

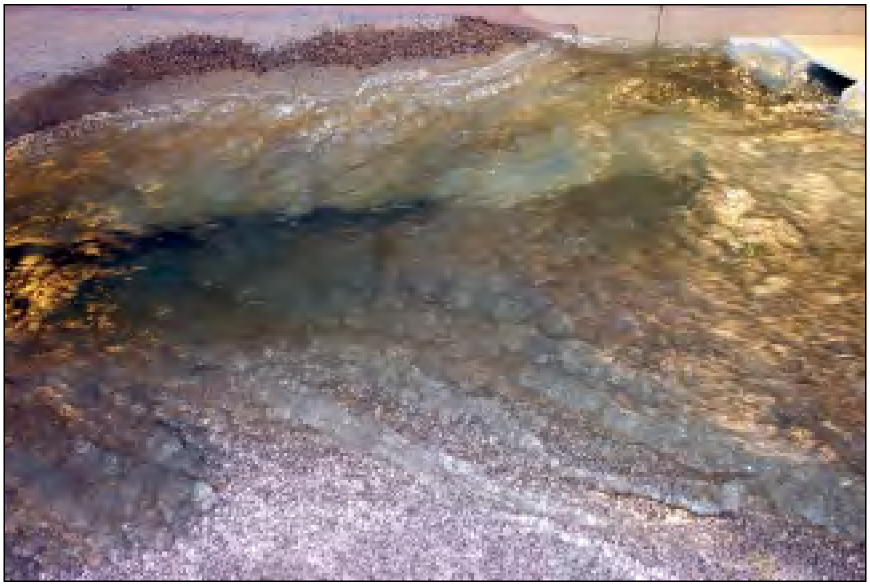
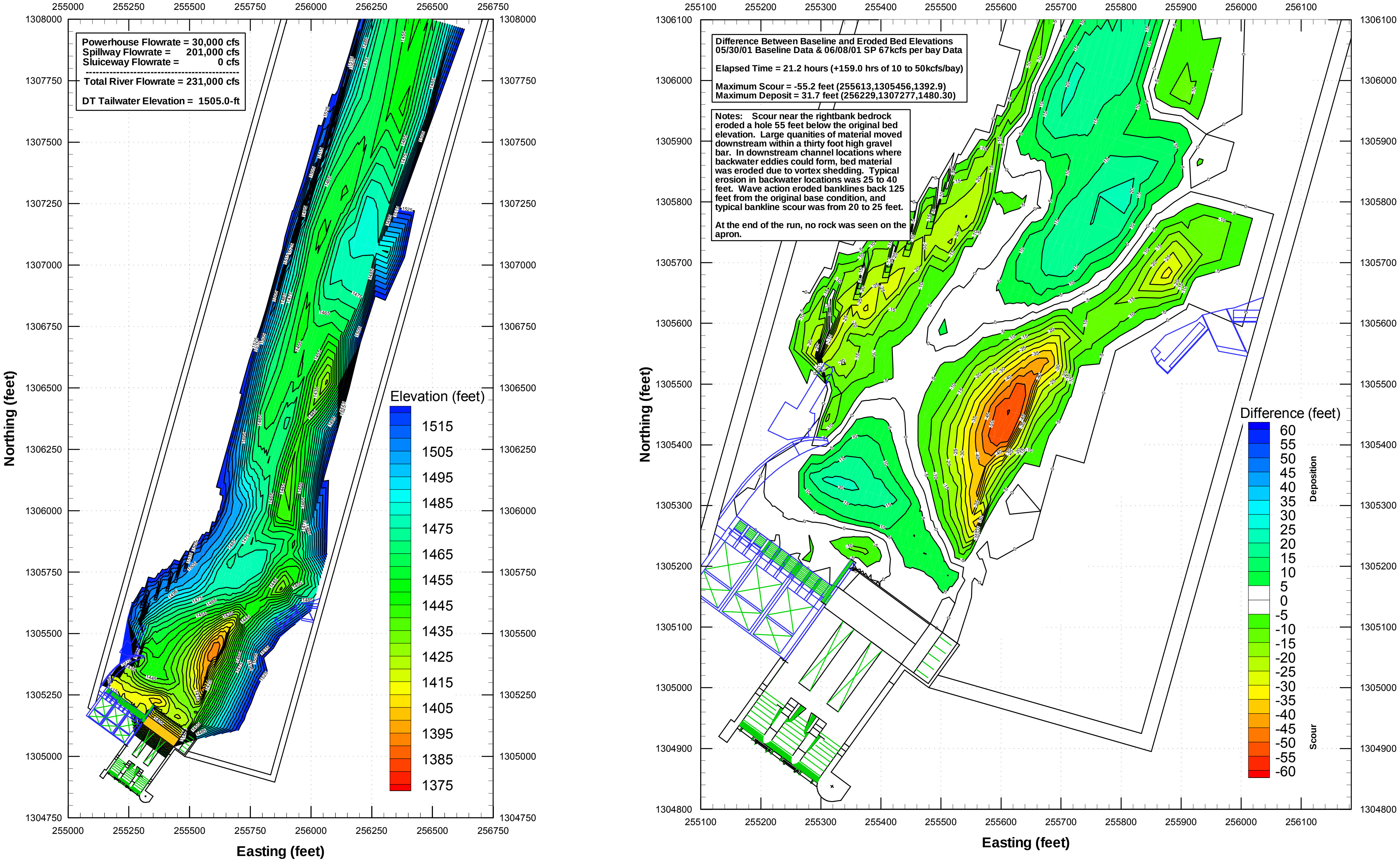


Figure 4.47. Downstream erosion during 67 kcfs per crest gate

The fish ladder entrance was undermined as shown in Figure 4.48. A 30-foot deep hole was also scoured near the diversion tunnel outlet (Figure 4.49), and a 32-foot high gravel bar was deposited in the middle of the downstream channel. Figure 4.50 showed bathymetric survey results.

Figure 4.48. Looking upstream after 67 kcfs per crest gate

Figure 4.49. Downstream erosion after 67 kcfs per crest gate



Powerhouse Flowrate = 30,000 cfs
Spillway Flowrate = 201,000 cfs
Sluiceway Flowrate = 0 cfs

Total River Flowrate = 231,000 cfs

DT Tailwater Elevation = 1505.0-ft

Difference Between Baseline and Eroded Bed Elevations
05/30/01 Baseline Data & 06/08/01 SP 67kcfs per bay Data

Elapsed Time = 21.2 hours (+159.0 hrs of 10 to 50kcfs/bay)

Maximum Scour = -55.2 feet (255613,1305456,1392.9)
Maximum Deposit = 31.7 feet (256229,1307277,1480.30)

Notes: Scour near the rightbank bedrock eroded a hole 55 feet below the original bed elevation. Large quanities of material moved downstream within a thirty foot high gravel bar. In downstream channel locations where backwater eddies could form, bed material was eroded due to vortex shedding. Typical erosion in backwater locations was 25 to 40 feet. Wave action eroded banklines back 125 feet from the original base condition, and typical bankline scour was from 20 to 25 feet.

At the end of the run, no rock was seen on the apron.

Figure 4.50. Bathymetric contours after 67 kcfs per spillway bay

4.5 Extreme High Flowrate Gate Operations

The sluiceway deflectors were designed for operation when total dissolved gas levels are important, and the upper spillway gates were designed for high spill discharges when energy dissipation and dam safety become imperative. Extremely high flow conditions, up to 300 kcfs, required discharges through both spillways and sluiceways.

Using the design discharge of 300 kcfs total river, model runs compared tailrace erosion with and without spillway deflectors. The bed was re-raked to baseline elevations after the 67 kcfs per crest gate run (Figure 4.47) before starting each set of design discharge runs. Each run was allowed to continue for approximately 3.0 prototype days. The initial bed condition reflected running an additional 49.1 prototype days at lower flowrates (40 to 231 kcfs river flowrates with no sluiceway bays open).

4.5.1 Baseline Design Discharge with No Deflectors

The baseline design discharge run forced 70 kcfs through the sluiceway bays, 201 kcfs through the crest gates, and 30 kcfs through the powerhouse to achieve a total river flowrate of 301 kcfs. After running for 3.0 prototype days, the model flow patterns were photographed and presented in Figures 4.51 through 4.55.

Figure 4.51. Stilling basin during design discharge

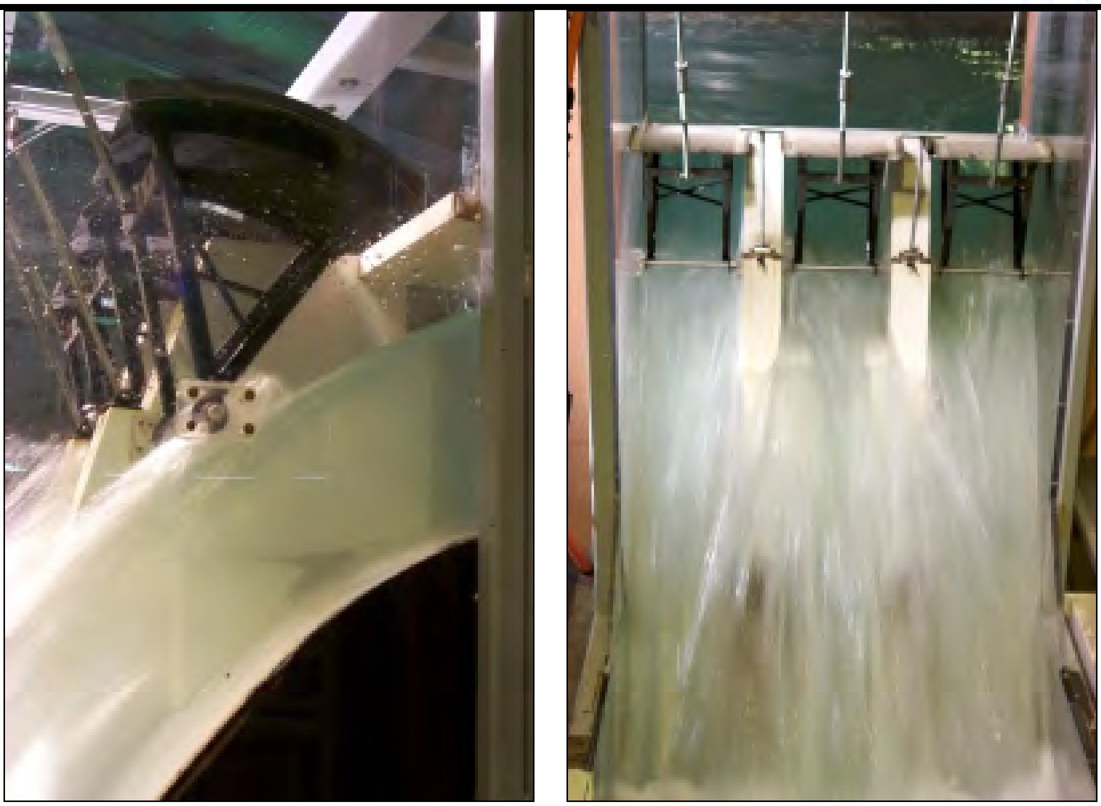


Figure 4.52. Side and elevation views of spillway bays during design discharge

Figure 4.53. Boil created during design discharge

Figure 4.54. Panoramic view of spillway and stilling basin

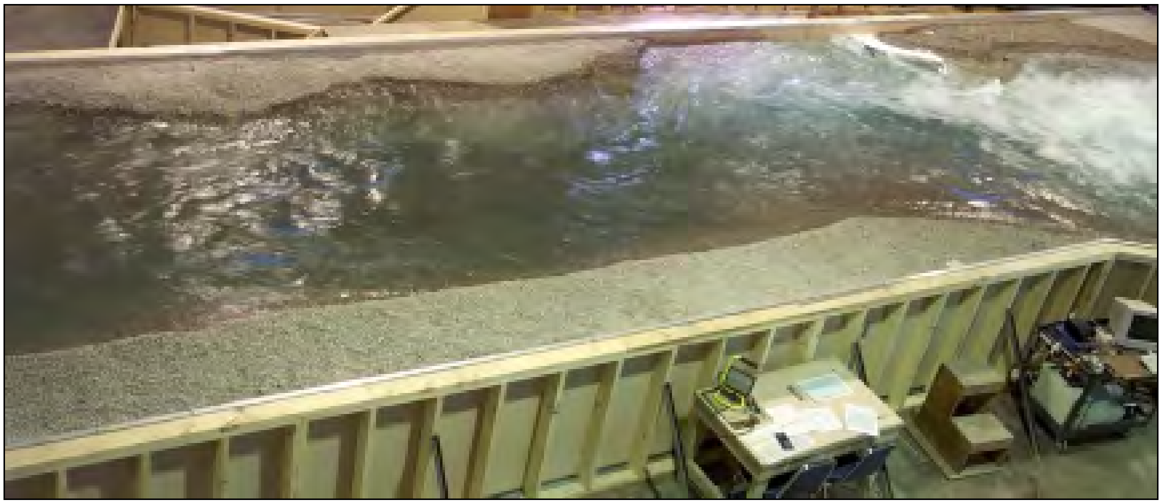


Figure 4.55. Panoramic view of downstream flow patterns

Erosion patterns of the baseline design discharge condition followed trends seen at lower flowrate conditions with large elliptical scour holes near the rightbank bedrock and diversion tunnel outlet. A 65-foot deep scour hole formed near the diversion tunnel outlet. About 2500 feet downstream of the endsill the maximum scour depth was recorded at 72 feet, but this was primarily due to bankline erosion and not riverbed bottom scour. Scour along the rightbank bedrock layer was 60 feet, and wave erosion along the leftbank near the fish ladder entrance was also 60 feet deep. Lateral entrainment eroded a 35 feet deep hole near the spillway training wall. Much of the tailrace near the powerhouse was scoured twenty feet below original bed contours. Deposits from wave erosion created a leftbank-attached ridge nearly 27 feet thick (elevation 1503 feet). Photographs of the model bathymetry were taken and presented in Figures 4.56 to 4.61.

Figure 4.56. Clean apron after design discharge

Figure 4.57. Scour near powerhouse and fish ladder entrance

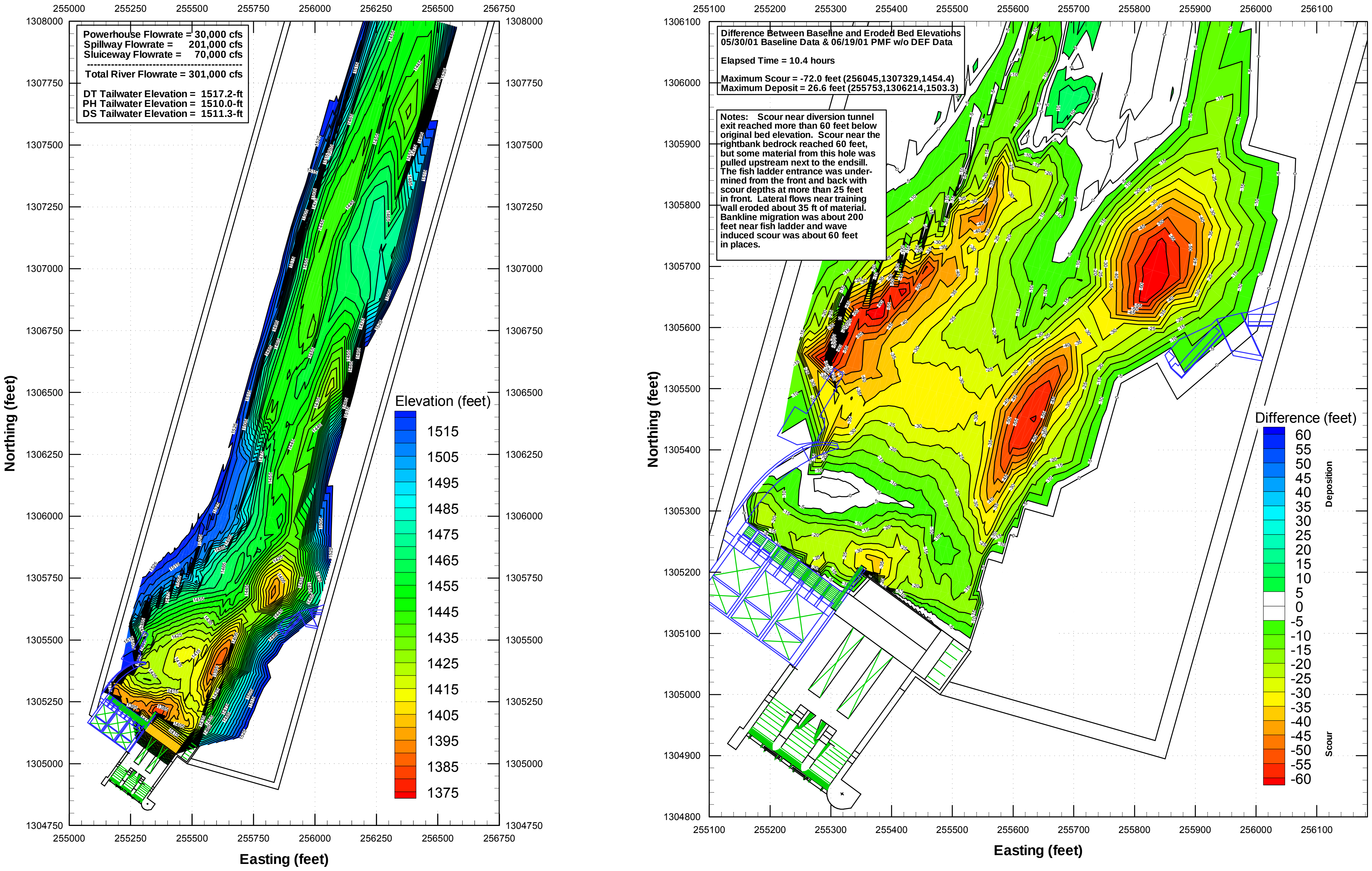
Figure 4.58. Wave erosion and undermining around fish ladder entrance

Figure 4.59. Looking upstream after design discharge event

Figure 4.60. Scour hole near diversion tunnel

Figure 4.61. Rock deposits on bedrock and diversion tunnel structure

Bathymetric survey data was plotted in Figure 4.62.



Notes: Scour near diversion tunnel exit reached more than 60 feet below original bed elevation. Scour near the rightbank bedrock reached 60 feet, but some material from this hole was pulled upstream next to the endsill. The fish ladder entrance was undermined from the front and back with scour depths at more than 25 feet in front. Lateral flows near training wall eroded about 35 ft of material. Bankline migration was about 200 feet near fish ladder and wave induced scour was about 60 feet in places.

Figure 4.62. Bathymetric contours after design discharge without deflectors installed

4.5.2 Design Discharge with Deflectors Installed in Sluiceway Bays

After running at 301 kcfs for 3.0 prototype days, model flow patterns were photographed and presented in Figures 4.63 through 4.66.

Figure 4.63. Spillway jets during design discharge

Figure 4.64. Looking upstream at design discharge with deflectors

Figure 4.65. Waves breaking over fish ladder entrance

Figure 4.66. Overall flow pattern of design discharge with deflectors

The most crucial discovery in the design discharge experiments was that deflectors pulled material onto the apron and could cause ball milling (Figure 4.67). The baseline condition did not pull any material onto the apron (Figure 4.56).

Figure 4.67. Material on apron after design discharge with deflectors

Erosion patterns for the design discharge condition with deflectors were similar but scour holes were not as deep. Compared to the baseline run scour of 65 feet, scour near the diversion tunnel was only about 60 feet deep. Scour along the rightbank bedrock layer was 45 feet (compared to the baseline 60 feet), and wave erosion along the leftbank was 40 feet (compared to the baseline 60 feet). Lateral entrainment eroded a hole 15 feet deep near the spillway training wall, and much of the tailrace near the powerhouse was scoured to twenty feet below the original bed contours. Deposits from wave erosion created a downstream leftbank-attached ridge nearly 36 feet thick. Photographs of model bathymetry were presented in Figures 4.68 to 4.71.

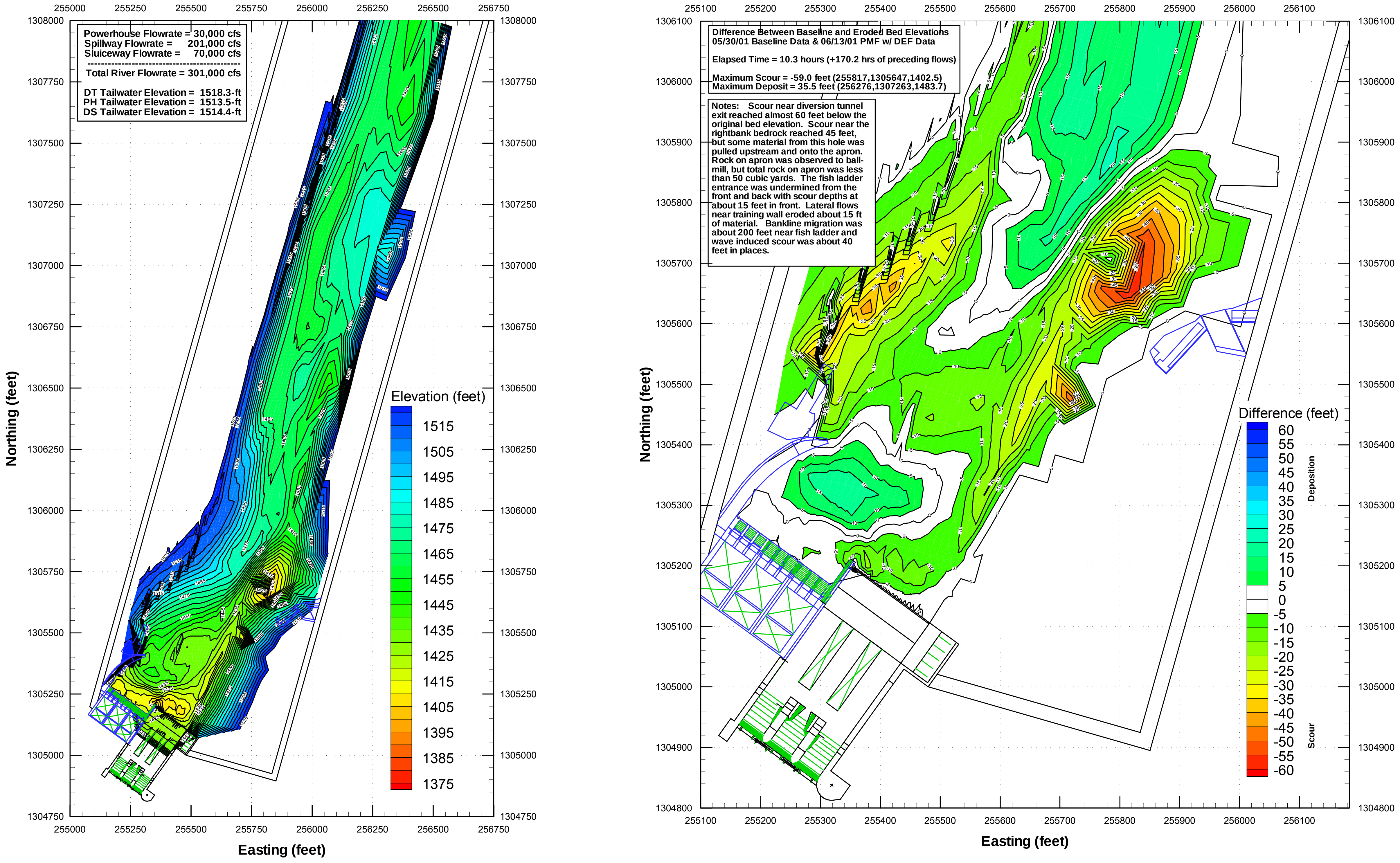
Figure 4.68. Erosion patterns near powerhouse and fish ladder entrance

Figure 4.69. Scour and pullback near rightbank bedrock layer

Figure 4.70. Scour hole near diversion tunnel outlet

Figure 4.71. Scour patterns downstream

Bathymetric survey data from the design discharge with deflectors was plotted in Figure 4.72.



Powerhouse Flowrate = 30,000 cfs
Spillway Flowrate = 201,000 cfs
Sluiceway Flowrate = 70,000 cfs

Total River Flowrate = 301,000 cfs

DT Tailwater Elevation = 1518.3-ft
PH Tailwater Elevation = 1513.5-ft
DS Tailwater Elevation = 1514.4-ft

Difference Between Baseline and Eroded Bed Elevations
05/30/01 Baseline Data & 06/13/01 PMF w/ DEF Data

Elapsed Time = 10.3 hours (+170.2 hrs of preceding flows)

Maximum Scour = -59.0 feet (255817,1305647,1402.5)
Maximum Deposit = 35.5 feet (256276,1307263,1483.7)

Notes: Scour near diversion tunnel exit reached almost 60 feet below the original bed elevation. Scour near the rightbank bedrock reached 45 feet, but some material from this hole was pulled upstream and onto the apron. Rock on apron was observed to ball-mill, but total rock on apron was less than 50 cubic yards. The fish ladder entrance was undermined from the front and back with scour depths at about 15 feet in front. Lateral flows near training wall eroded about 15 ft of material. Bankline migration was about 200 feet near fish ladder and wave induced scour was about 40 feet in places.

Figure 4.72. Bathymetric contours after design discharge with deflectors installed

Spill Passage Condition		**Flowrate**	**Prototype Elapsed Days**					**Description of Rock Movement in Various Locations**									**Erosion Limits**	
		Per Bay kcfs	At This Flowrate	+	At Lower Flowrates	=	Total Time Elapsed	Rock On Apron	Downstream of Endsill	Downstream of Powerhouse	Spillway Training Wall	Rightbank Bedrock	Fish Ladder Entrance	Leftbank Bankline	Near Diversion Tunnel Outlet	Downstream Channel	Maximum Scour Depth	Maximum Deposit Thickness
Lower Sluiceways	With Deflector	10	2.0	+	0.0	=	2.0	5 cubic yards of fines	Minor Movement	Minor Movement	Minor Movement	6.5 ft hole	Minor Movement	7.2 ft of deposits	None	None	6.5 ft (RB bedrock)	7.2 ft (LB Bankline)
Lower Sluiceways	With Deflector	15	5.8	+	2.0	=	7.8	1000 cubic yards at 20 feet deep	About 5 ft of pullback	18 ft high bar at 250 ft D/S	5 ft of scour	13 ft hole	6 ft of scour	3 to 4 ft of wave erosion	9 ft high bar at 700 ft D/S	None	13.4 ft (RB bedrock)	20.0 ft (Apron)
Lower Sluiceways	With Deflector	20	6.9	+	7.8	=	14.7	15,000 cubic yards at 40 feet deep	About 10 ft of pullback	15 ft high bar at 200 ft D/S	23 ft of scour	20 ft hole	10 ft of scour	5 ft of erosion	13 ft high bar in mid-channel; 10 ft scour along bank	None	23.5 ft (Training Wall)	42.0 ft (Apron)
Upper Spillway Bays	Without Deflector	6.7	4.9	+	0.0	=	4.9	None	None	Minor Movement	None	None	None	None	None	None	None	None
Upper Spillway Bays	Without Deflector	13.3	6.9	+	4.9	=	11.8	None	None	Minor Movement	5 ft of scour	8 ft hole at 150 ft D/S	None	Minor Deposits	None	None	8.6 ft (RB Bedrock)	4.8 ft (Fish Ladder Entrance)
Upper Spillway Bays	Without Deflector	20	6.9	+	11.8	=	18.8	None	Minor Movement	Minor Movement	9 ft of scour	12 ft hole	5 ft of deposits	20 ft wide shelf with 15 ft of erosion	15 ft high bar in mid-channel; 25 ft scour along bank	None	25.9 ft (Diversion Tunnel)	17.8 ft (Diversion Tunnel)
Upper Spillway Bays	Without Deflector	30	11.3	+	18.8	=	30.0	None	11 ft of pullback	Minor Movement	12 ft of scour	20 ft hole	5 ft of deposits	40 ft wide shelf with 20 ft of erosion	45 ft of riverbed scour	20 ft deposits in mid-channel	49.4 ft (Diversion Tunnel)	25.0 ft (D/S mid-channel)
Upper Spillway Bays	Without Deflector	40	8.9	+	30.0	=	39.0	None	Less than 10 ft of pullback	Minor Movement	12 ft of scour	40 ft hole	5 ft of deposits	60 ft wide shelf with 20 ft of erosion	50 ft of riverbed scour	20 ft deposits in mid-channel	50.4 ft (Diversion Tunnel)	26.9 ft (D/S mid-channel)
Upper Spillway Bays	Without Deflector	50	6.9	+	39.0	=	45.9	None	10 ft of pullback	15 ft high bar	12 ft of scour	56 ft hole	15 ft of scour	100 ft wide shelf with 30 ft of erosion	30 ft of riverbed scour	27 ft deposits in mid-channel; 40 ft erosion along bank	56.2 ft (RB bedrock)	26.9 ft (D/S mid-channel)
Upper Spillway Bays	Without Deflector	67	6.1	+	45.9	=	52.0	None	5 ft of pullback	20 ft high bar	12 ft of scour	55 ft hole	15 ft of scour	150 ft wide shelf with 45 ft of erosion	30 ft of riverbed scour	32 ft deposits in mid-channel; 25 ft erosion along bank	55.2 ft (RB bedrock)	31.7 ft (D/S mid-channel)
Upper Spillway Bays and Lower Sluiceways	Without Deflector in any Bays	67, 35	3.0	+	52.0	=	55.0	None	20 ft of scour	25 ft of scour	35 ft of scour	60 ft hole	At least 25 ft of scour	200 ft wide shelf with 60 ft of erosion	65 ft of riverbed scour	27 ft high deposits; 72 ft erosion in one spot	72.0 ft (D/S Leftbank)	26.6 ft (D/S mid-channel)
Upper Spillway Bays and Lower Sluiceways	With Deflector in Lower Sluiceways	67, 35	3.0	+	52.0	=	55.0	More than 50 cubic yards	10 ft of scour	15 ft of scour	15 ft of scour	45 ft hole	At least 15 ft of scour	200 ft wide shelf with 40 ft of erosion	59 ft of riverbed scour	36 ft deposits in mid-channel; 50 ft erosion along bank	59.0 ft (RB bedrock)	35.5 ft (D/S mid-channel)

Notes: 3 powerhouse units at 10 kcfs each for all runs
Sluiceway flowrates below 10 kcfs per bay were not included in elapsed time
Spillway flowrates of 5 kcfs and 10 kcfs per bay were not included in elapsed time
"Downstream channel" location corresponds to reach beyond 1000 feet downstream of endsill
"Leftbank bankline" and "rightbank bedrock" correspond to around 300 feet downstream of endsill

Table 4.1. Tabular results of erosion tests

4.5.3 Conclusions of Extreme High Flowrate Gate Operations

While ball milling potential increased with deflector installation, tailrace erosion (scour depth and volume) decreased. Deflectors did not increase the depth of tailrace erosion. Locations of concern with and without sluiceway deflectors were:

1) deep scour downstream of the spillway training wall,
2) undermining of the fish ladder entrance,
3) deep scour near the diversion tunnel outlet,
4) and bankline erosion along the left bankline.

4.6 Sweep-Off Tests

Sweep-off tests were conducted at sluiceway flowrates of 10, 15, and 20 kcfs per sluiceway bay to evaluate the potential for rock removal after pullback has occurred. After operating until pullback stabilized, the sluiceway gates were closed, and the spillway gates were uniformly opened in 2500 cfs per crest gate increments until all material was removed from the stilling basin. The minimum discharge producing total sweep-out was recorded. Full powerhouse discharge condition of 30 kcfs and a normal headwater elevation of 1686.0 feet were maintained for all test runs. It was noted that model sweep-off time might not be Froude-scaled, but model run times were multiplied by the Froude time scaling value listed in Table 2.1.

For flowrates of 10 kcfs per sluiceway bay and less, rock pullback was limited to five cubic yards or less. Complete rock sweep-off was attained by opening the three spillway gates to 5000 cfs per crest gate for at least 15 prototype minutes. (However model sweep-off time might not be Froude-scaled.) Minimal ball milling was observed during the sweep-off flowrates. For sluiceway flowrates of 15 kcfs per bay, rock pullback was about 1000 cubic yards and required higher spillway flowrates for sweep-off. The minimum spillway flowrate was 7500 cfs per crest gate for at least 30 minutes. Ball milling potential was very high with large amounts of rock material impacting the spillway surfaces.

For sluiceway flowrates of 20 kcfs per bay (higher than the design flowrate), rock pullback could be expected to reach the bottom of the deflector (more than forty feet deep in the apron). Estimated volume of pullback material in the model runs was about 15,000 prototype cubic yards. Rock pullback material had filled in the area downstream of the endsill, and sweep-off flowrates had to push rock out of the apron and over the downstream pullback piles. Using 7500 cfs per crest gate, the model swept 90% of material off the apron in about seven hours. About 250 cubic yards of material remained on the apron and over 1000 cubic yards of material remained on the shelf between the spillway and rightbank training wall. The material on the shelf was not swept off with 10,000 cfs per crest gate or 15,000 cfs per crest gate, but after increasing the flowrate to 20,000 cfs per crest gate for a few minutes all of the material left on the apron was swept out.

5. EVALUATION OF DOWNSTREAM FLOW CONDITIONS

Velocity profiles and cross-sections were used to predict deflector influence on tailrace flow patterns and provide data sets for future numerical models of the Hells Canyon Dam tailrace. General velocity profiles compared jet dissipation from the diversion tunnel exit to the downstream boundary of the model. High flow profiles compared jet dissipation and flow profiles between the endsill and diversion tunnel outlet.

5.1 General Velocity Profiles

Basic changes in downstream flow patterns after installation of the recommended sluiceway deflectors were explored using the three-dimensional model. Velocity measurements were collected with a SonTek Acoustic Doppler Velocimeter (ADV). Velocity data was taken at bathymetric templates 5, 10, and 14 to provide a comparison of flow patterns and jet dissipation between upper crest gates and lower sluiceways with deflectors at 10,000 and 30,000 cfs spill. The bathymetric template locations corresponded to about 900, 1800, and 2600 feet downstream of the endsill.

Velocity data was plotted in Figures 5.1 through 5.4. Figures 5.1 and 5.2 provided baseline velocities for flow passage through the upper spillway crest gates. Figures 5.3 and 5.4 provided comparison velocities for flow through the sluiceway bays with deflectors.

In Figures 1 and 3 the sluiceway velocities were slightly higher along the right bank than the crest gate flow velocities 888 feet downstream, but this difference diminished as downstream distance increased. After 2616 feet downstream, velocity profiles for sluiceway and crest gate operations were nearly indistinguishable. In Figures 5.2 and 5.4 sluiceway flow velocities 888 feet downstream were concentrated near the surface. Observations during the data collection indicated that the surface flow patterns and velocity azimuths were often changing due to interactions between downstream jets and eddies near the diversion tunnel outlet. After 2616 feet downstream, velocity profiles for sluiceway and crest gate operations were nearly indistinguishable.

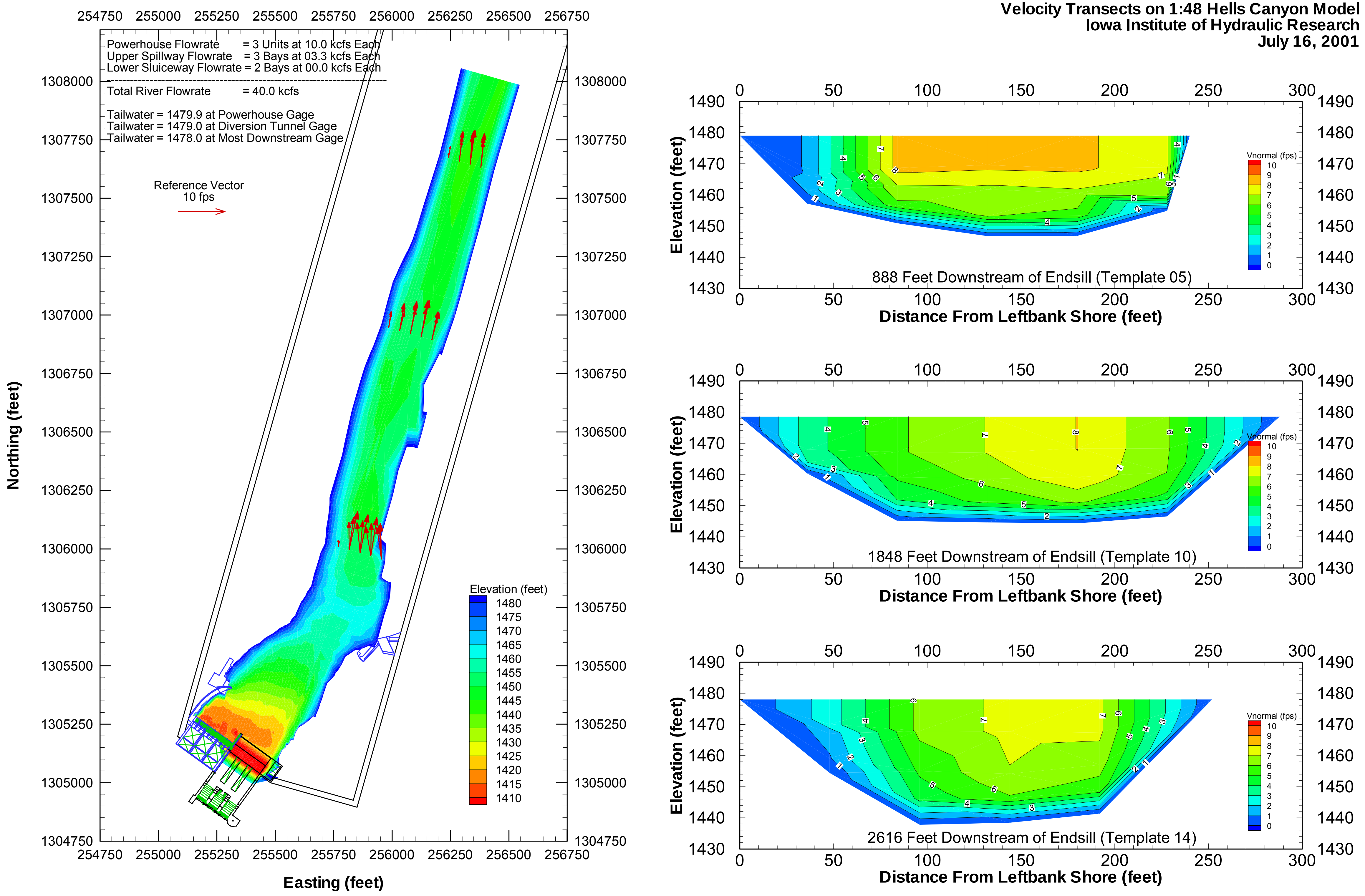


Figure 5.1. Velocity profiles at 3.3 kcfs per spillway bay

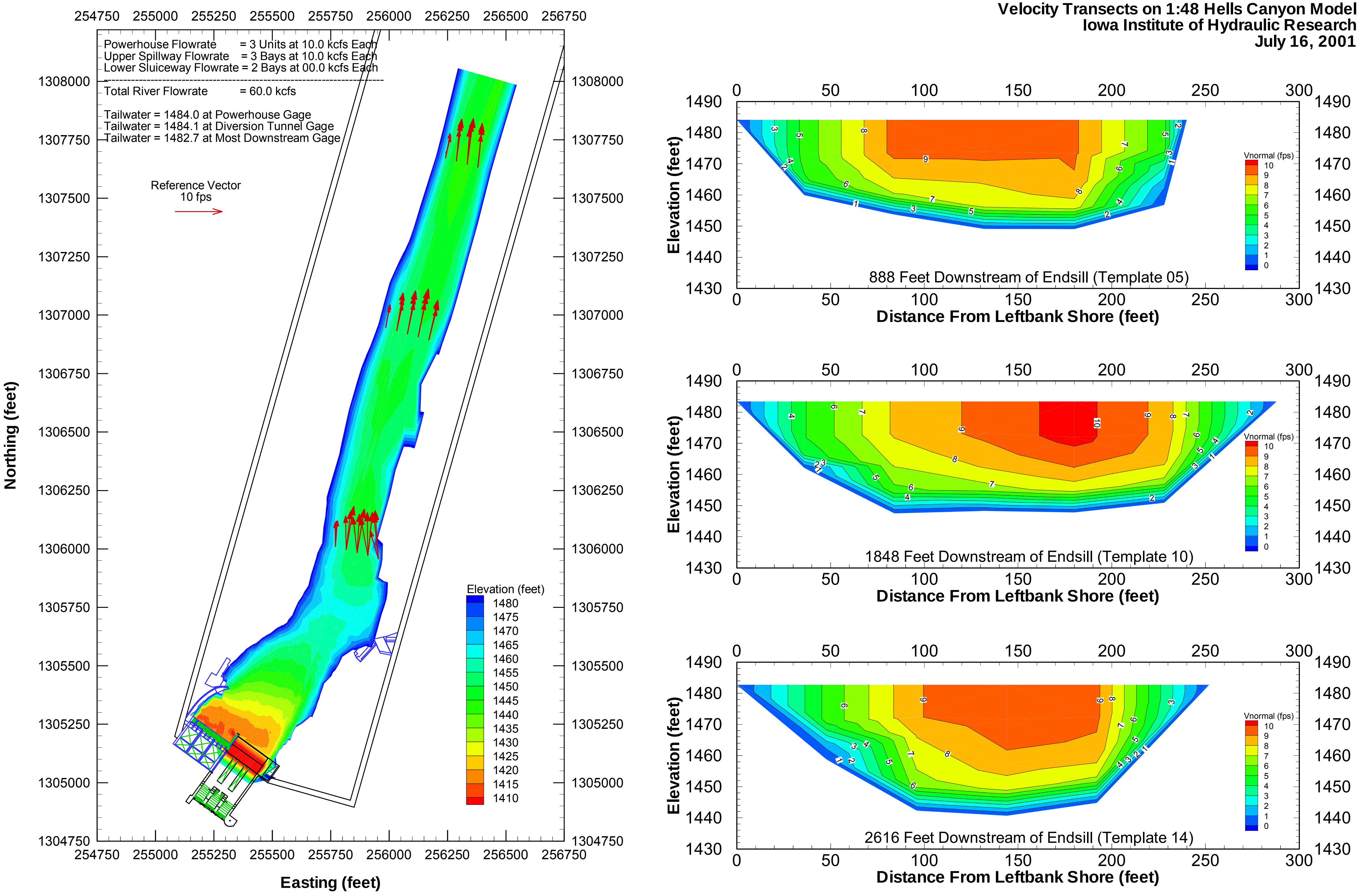


Figure 5.2. Velocity profiles at 10.0 kcfs per spillway bay

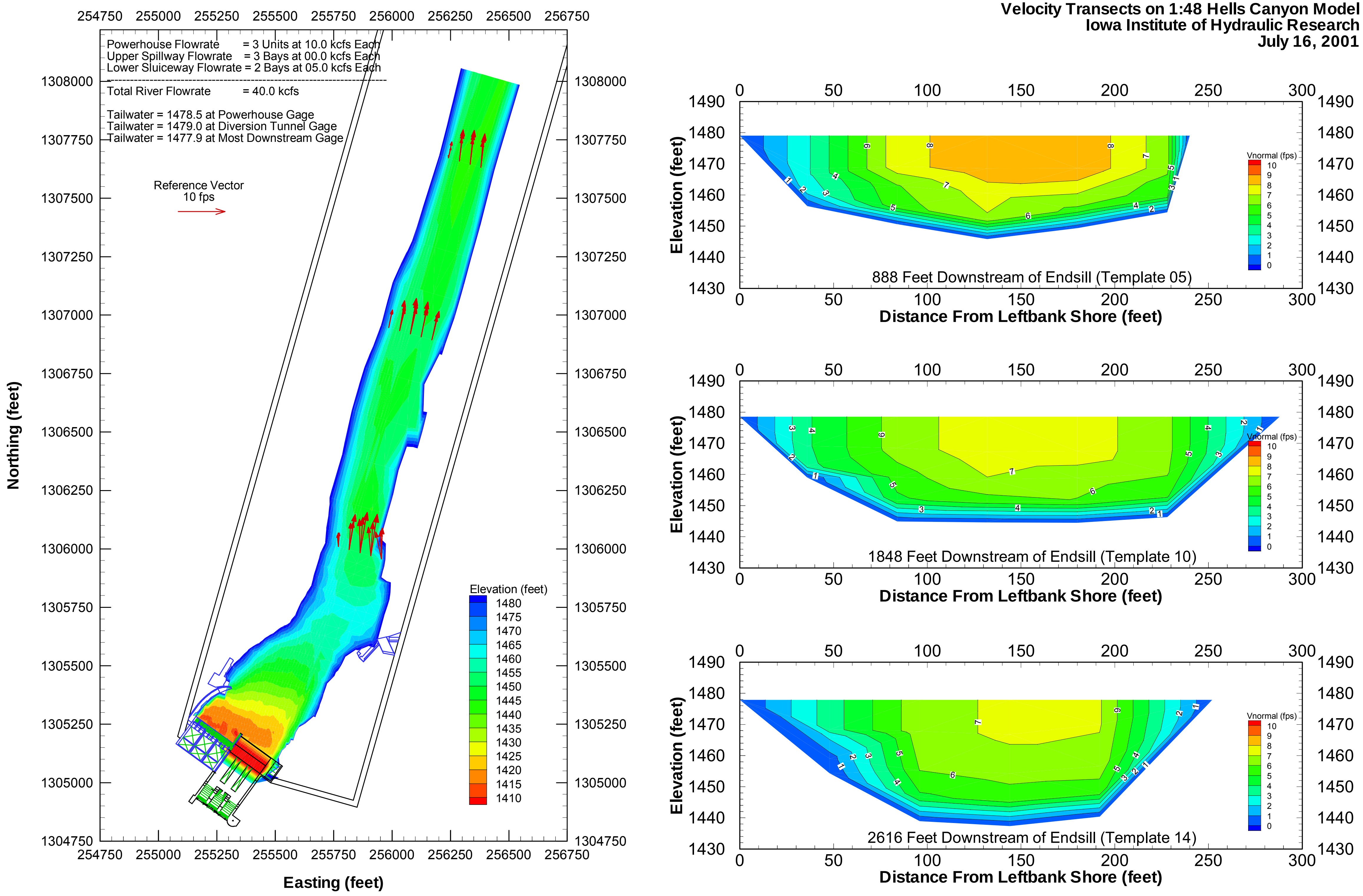


Figure 5.3. Velocity profiles at 5.0 kcfs per sluiceway bay

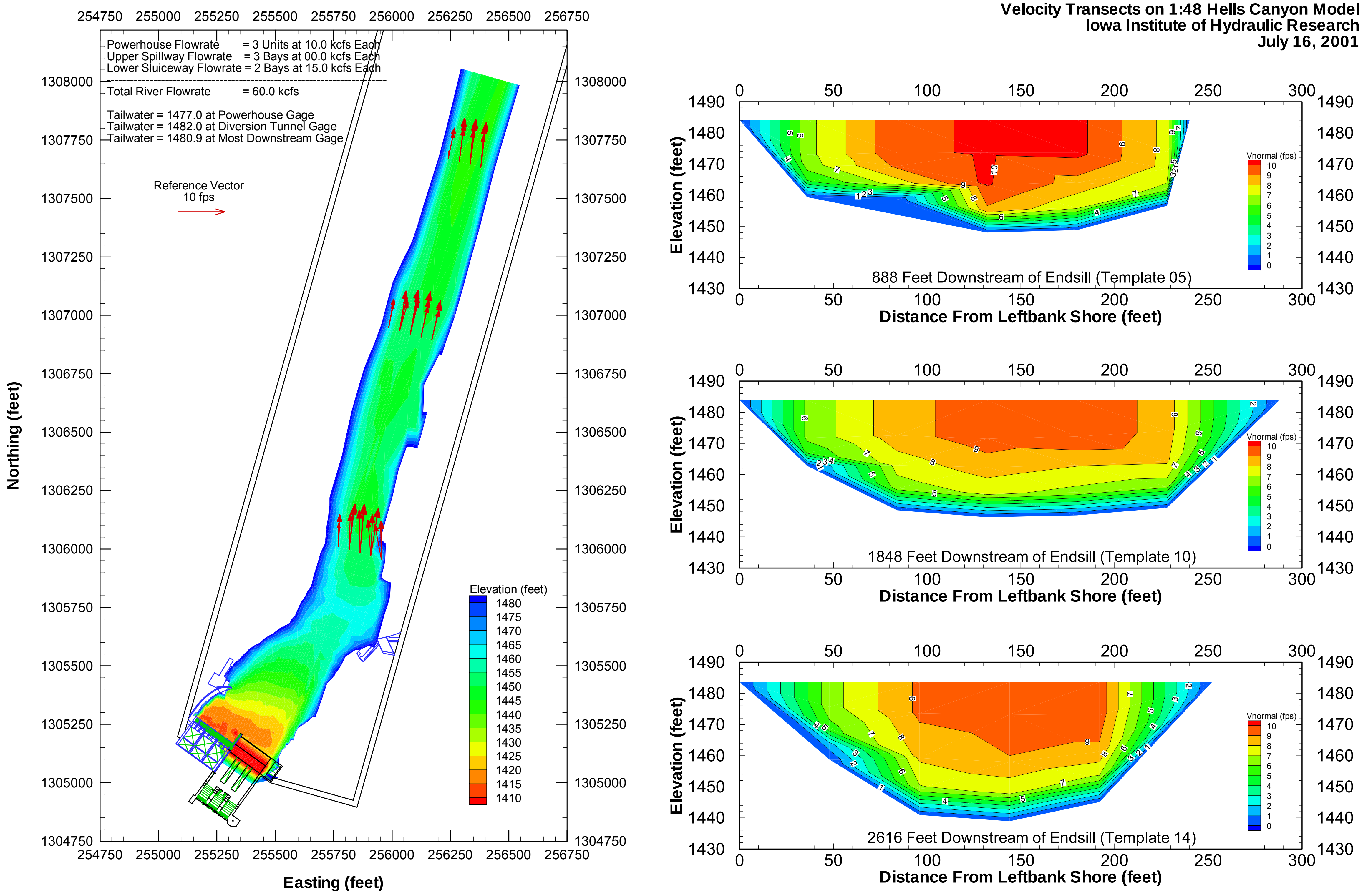


Figure 5.4. Velocity profiles at 15.0 kcfs per sluiceway bay

5.2 High Flow Velocity Profiles

In addition to the comparing sluiceway to crest gate operation at less than the 98% exceedence flowrate, a series of velocity profiles compared high discharge events through spillways and/or sluiceways. Figure 5.5 showed that velocity data for a 40.0 kcfs spill passed entirely through the upper crest gates (13.3 kcfs per crest gate). Figure 5.6 showed the same flowrate passed through sluiceway bays with deflectors (20.0 kcfs per bay). Passing a 40.0 kcfs spill through sluiceways increased the magnitude of the return flow along the leftbank powerhouse guide wall and forced much higher velocities along the rightbank bedrock layer and fish ladder entrance. Figures 5.5 and 5.6 illustrated that operators should not pass more than a 30 kcfs spill through sluiceways with deflectors until total river flowrates approach 300 kcfs.

Scour depths near the rightbank bedrock layer (350 feet downstream of the endsill) and diversion tunnel outlet (700 feet downstream) increased from 25 feet at 90 kcfs spill to more than 50 feet at 120 kcfs spill. Velocity profiles were collected for 40 kcfs per upper crest gate and plotted in Figure 5.7. Comparing Figures 5.5 (13 kcfs per crest gate) and 5.7 (20 kcfs per sluiceway bay), a dramatic shift in velocity resultants was seen in the left half of the tailrace. As flowrates approached 40 kcfs per crest gate, more flow was entrained into the spillway from the tailrace area near the fish ladder entrance. Higher velocities resulting from higher river discharge (and augmented from increasing entrainment flow) increased bed velocities to nearly six feet per second near the rightbank bedrock layer and diversion tunnel outlet.

Figures 5.8 and 5.9 compared velocity fields during the design discharge event without and with sluiceway deflectors. At 200 feet downstream of the endsill deflectors increased the downstream velocity component at the surface and decreased the upstream velocity component along the riverbed. At 400 and 600 feet downstream the deflectors increased surface velocity components in the downstream direction, and this was likely the cause for observing less scour potential near the diversion tunnel outlet.

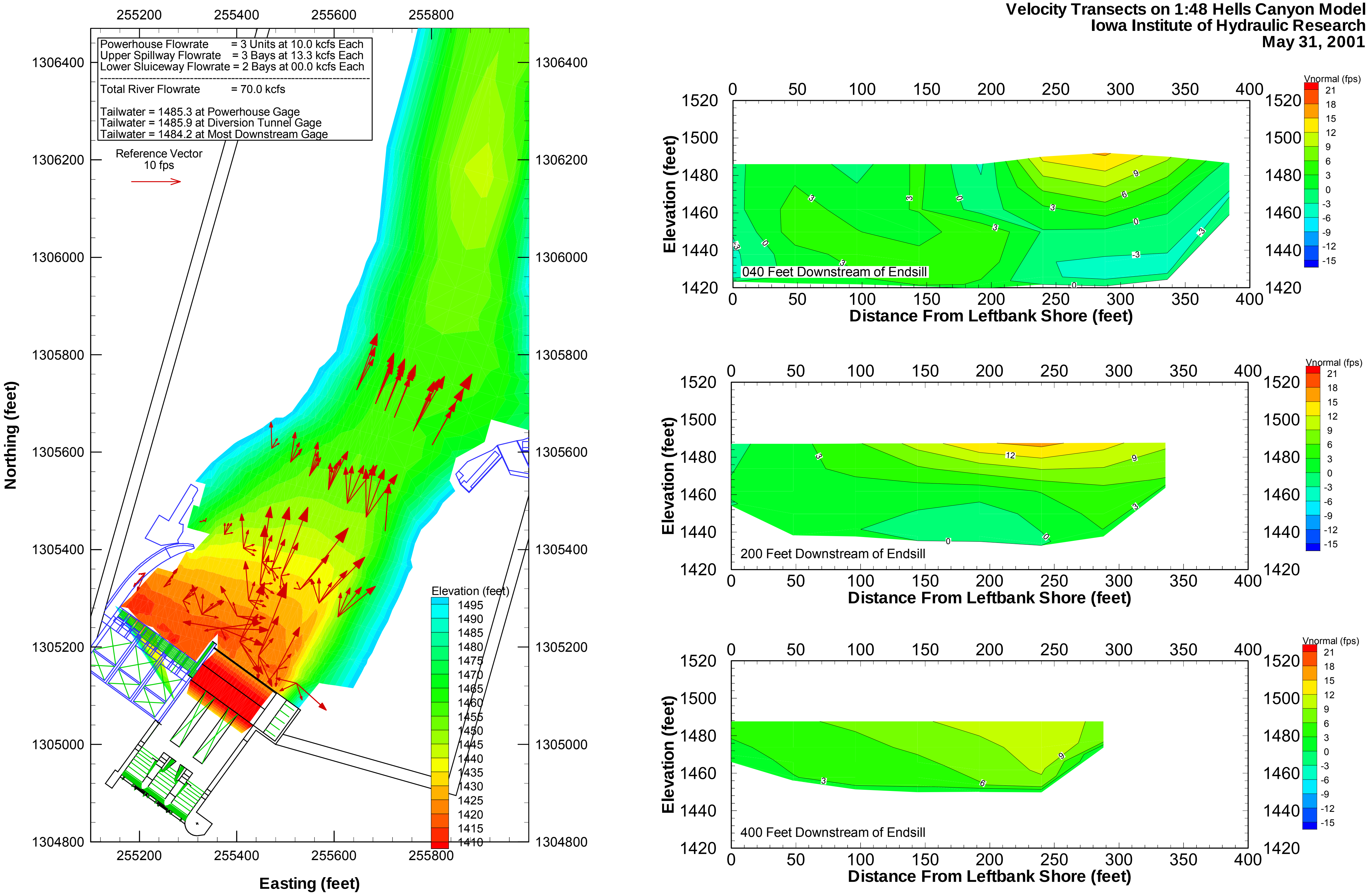


Figure 5.5. Velocity profiles at 13.3 kcfs per spillway bay

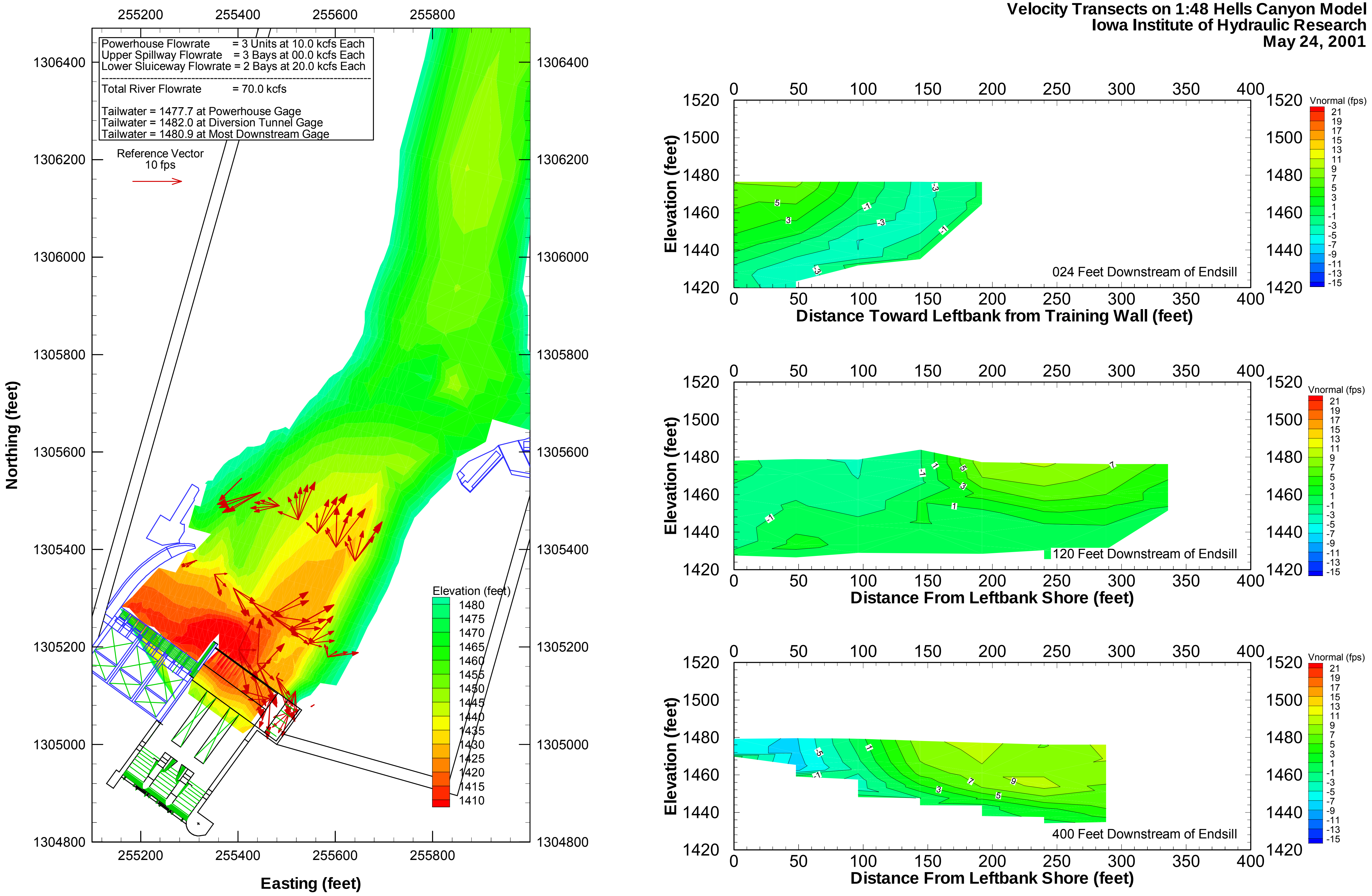


Figure 5.6. Velocity profiles at 20.0 kcfs per sluiceway bay

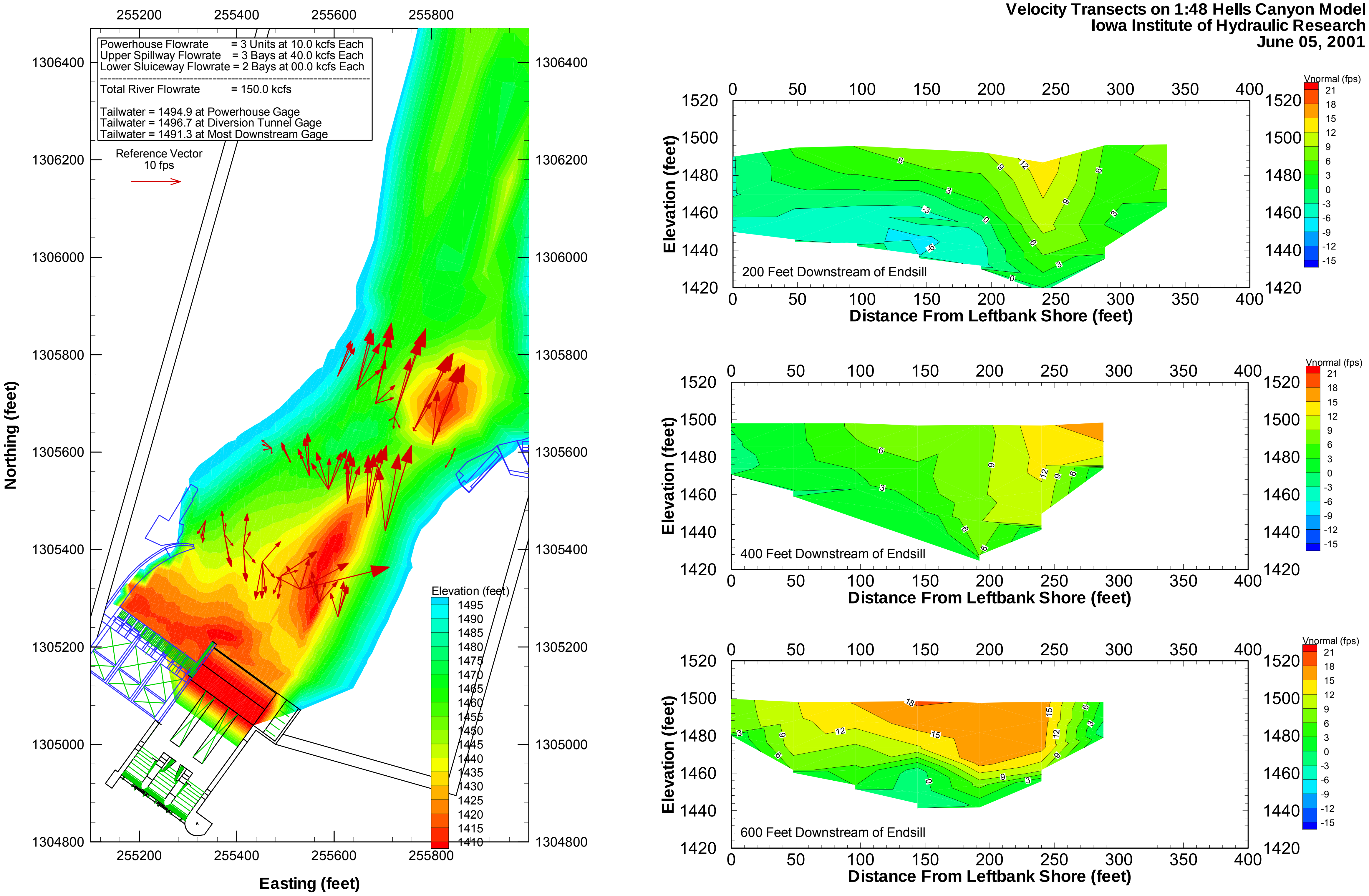


Figure 5.7. Velocity profiles at 40.0 kcfs per spillway bay

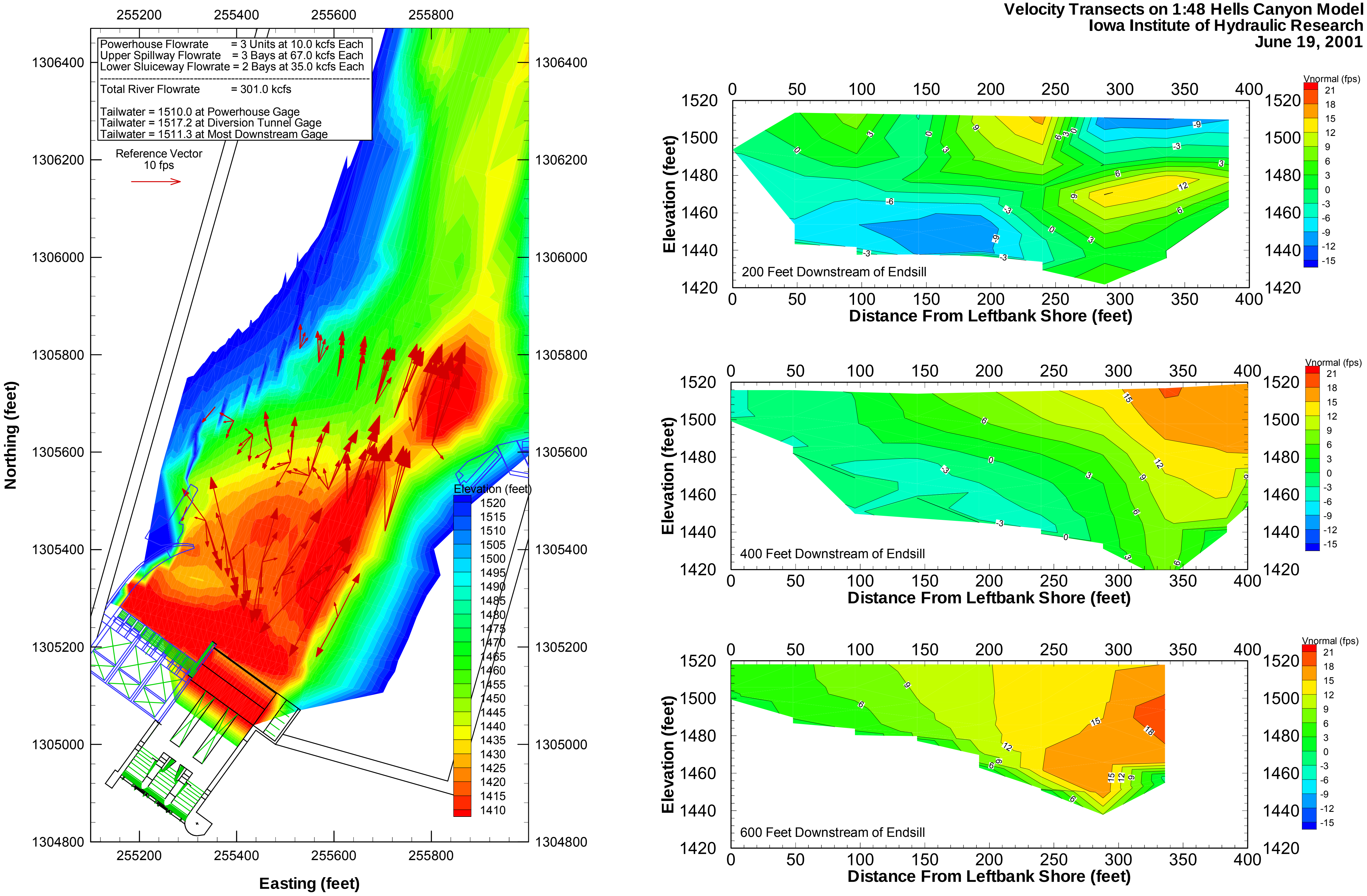


Figure 5.8. Velocity profiles at design discharge without deflectors installed

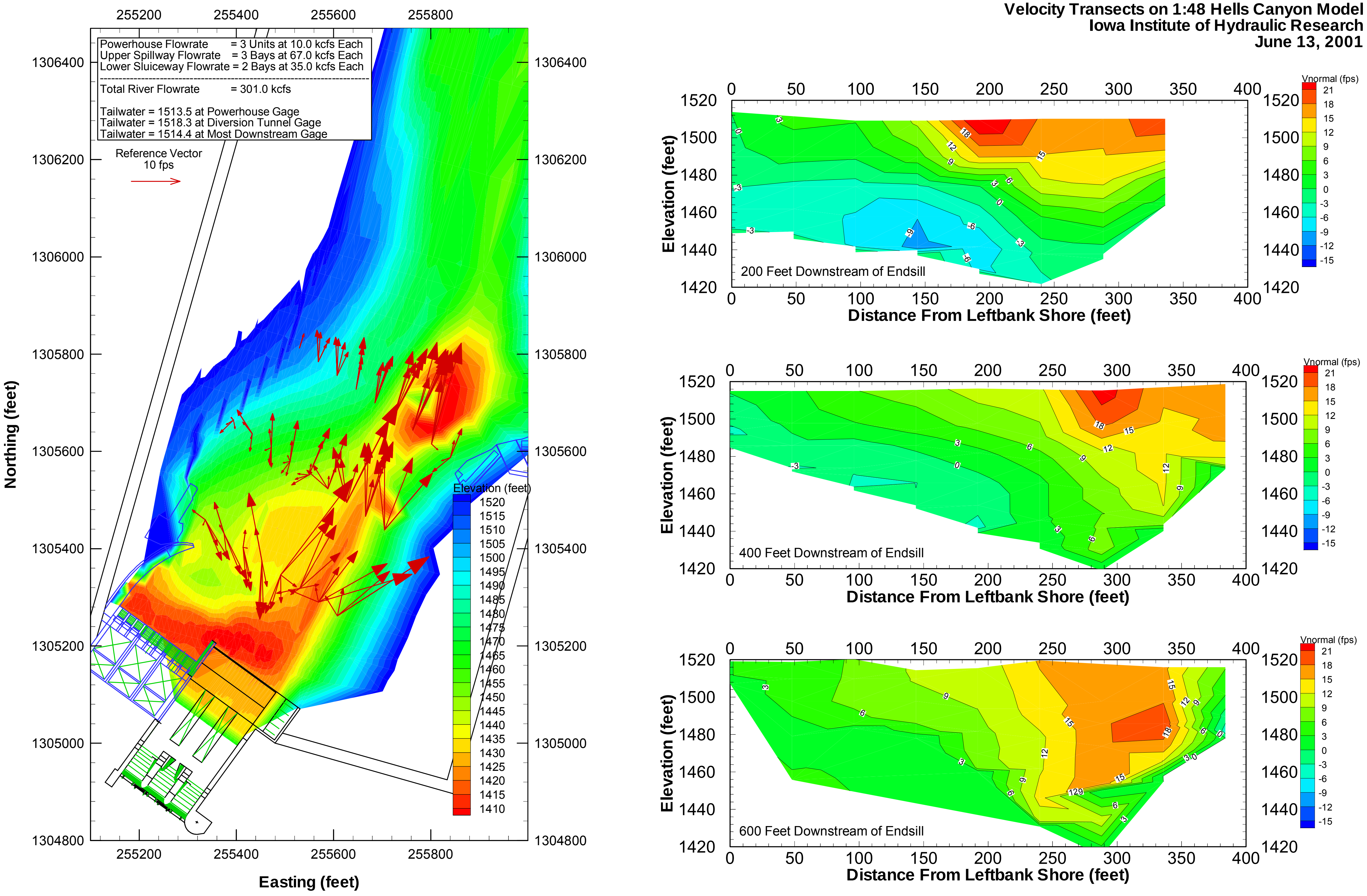


Figure 5.9. Velocity profiles at design discharge with deflectors installed

6. WAVE HEIGHT MEASUREMENTS

The deflector installation forced spillway jets to the water surface and increased potential for significant wave heights downstream. Wave height elevations were recorded for spillway and sluiceway flowrates with and without deflectors. Discharges at 10.0, 30.0, and 40.0 kcfs total spill flow were simulated in the model without deflectors to provide baseline measurements. The recommended deflectors were then installed and wave heights were obtained for sluiceway discharges of 10.0, 30.0, and 40.0 kcfs total spill flow. A full powerhouse discharge condition of 30 kcfs and a normal headwater elevation of 1686.0 feet were maintained during all test runs. Wave heights were recorded at three downstream cross-sections, corresponding to 920 feet (diversion tunnel water surface elevation gage), 1900 feet (midway down the length of the model), and 2900 feet (most downstream water surface elevation gage) downstream of the end sill. Wave height potentiometers provided high frequency digital recordings of water surface elevation every 1/100 second for twenty second measuring periods. From these digital recordings average, standard deviation, and maximum water surface elevations were calculated. One wave height gage was permanently mounted over the diversion tunnel water surface elevation gage, and another gage was moved back and forth to collect data at two downstream locations. At still pool condition with total river flowrate less than 6 kcfs, wave height data was recorded from 1466 to 1501 feet (-3 to 4 volts). Table 6.1 and Figure 6.1 provided calibration data for converting voltage to elevation. DT was the upstream gage and DS was the downstream (moveable) gage.

DT Gage CALIBRATION

Maximum elevation of calibration	1466.14	feet
Minimum elevation of calibration	1501.46	feet
Still pool elevation 2*standard deviation	0.16	feet

DT Gage Elevation = 6.00212 * Voltage + 1479.10 feet

DS Gage CALIBRATION

Maximum elevation of calibration	1492.78	feet
Minimum elevation of calibration	1466.14	feet
Still pool elevation 2*standard deviation	0.09	feet

DS Gage Elevation = 3.65292 * Voltage + 1476.90 feet

Table 6.1. Calibration data for wave height recorders

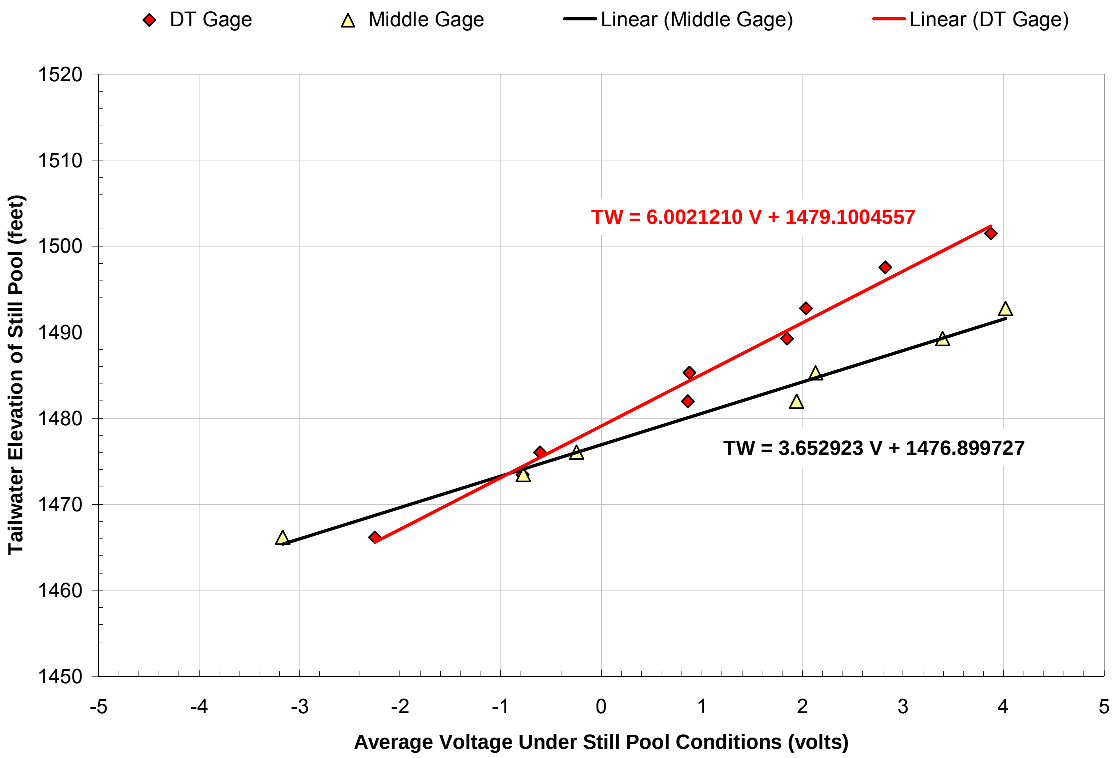


Figure 6.1. Calibration data for wave height recorders

From slope-intercept equations in Table 6.1 and Figure 6.1, voltages for each model run were converted into water surface elevations. Comparing raw elevation and time plots (Figures 5.3 and 5.4), large and small time scale variations in water surface elevation were observed. To convert water surface elevation changes to predicted wave heights, two statistical terms were used. Figure 6.describes these statistical terms.

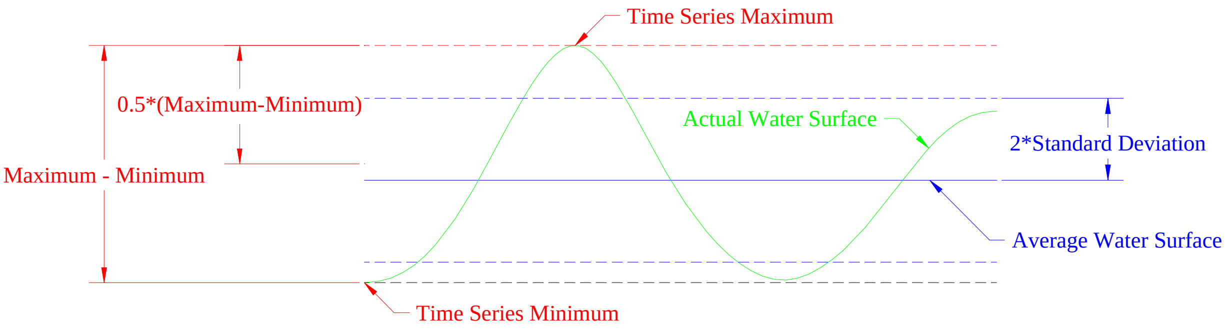


Figure 6.2. Statistical terms used to quantify expected wave heights

Twice the standard deviation of water surface elevation was used to predict the 95% confidence limits of wave height above average water surface elevation. One-half the maximum to minimum differential was the estimate of largest expected wave height.

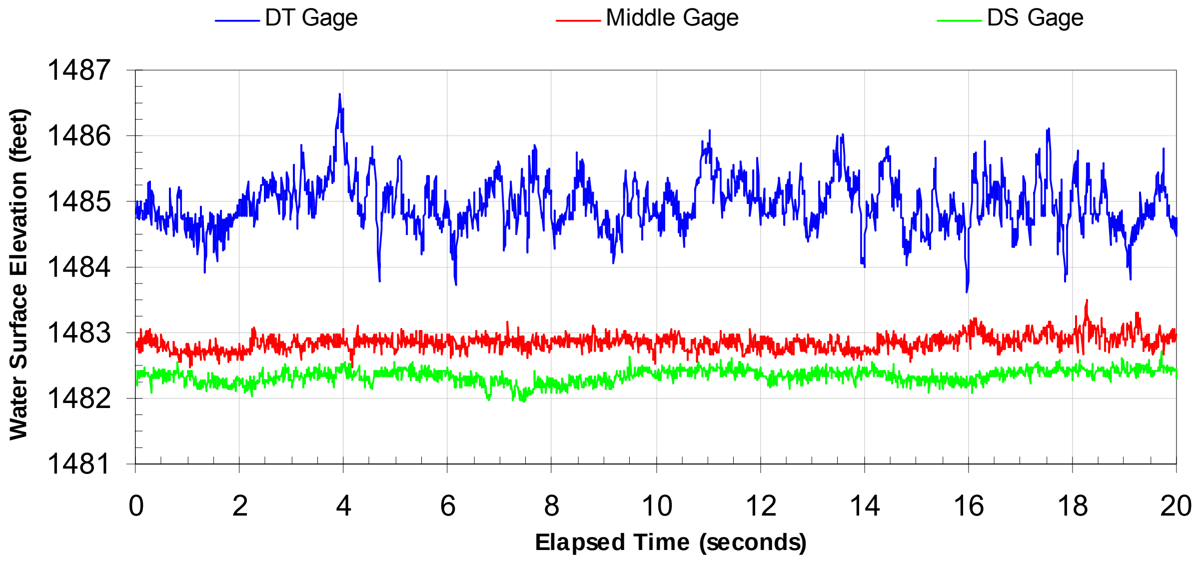


Figure 6.3. Large time scale fluctuations in water surface elevation

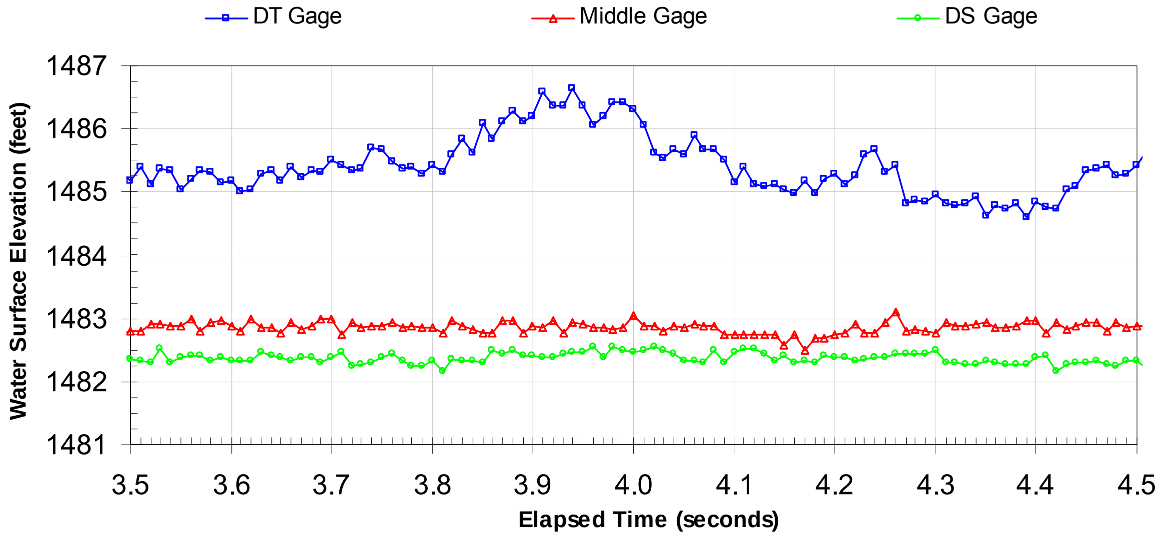


Figure 6.4. Small time scale fluctuations in water surface elevation

A summary of runs was included in Table 6.2 and plotted in Figures 5.5 and 5.6. Operating sluiceways instead of the crest gates only slightly increased wave heights downstream. Table 6.2 suggested that the increase in wave height due to sluiceway operations with deflectors was less than 0.2 feet beyond 2900 feet downstream of the dam. This indicated that the addition of deflectors to the sluiceway bays should not significantly increase wave heights at this far downstream.

USING (MAXIMUM-MINIMUM)/2 TO QUANTIFY WAVE HEIGHTS

Model Run Condition	(Maximum-Minimum)/2 Values			% Difference from Spillway Condition		
	920 ft (DT Gage)	1900 ft (Middle)	2900 ft (DS Gage)	920 ft (DT Gage)	1900 ft (Middle)	2900 ft (DS Gage)
Sluiceway 10 kcfs With Deflector	0.70	0.24	0.20	71%	8%	-21%
Sluiceway 30 kcfs With Deflector	1.61	0.51	0.38	129%	42%	54%
Sluiceway 40 kcfs With Deflector	1.49	0.55	0.36	46%	48%	25%
Sluiceway 10 kcfs Without Deflector	0.59	0.33	0.29	43%	48%	14%
Sluiceway 30 kcfs Without Deflector	1.10	0.40	0.45	56%	12%	79%
Sluiceway 40 kcfs Without Deflector	1.27	0.45	0.51	24%	19%	78%
Spillway 10 kcfs	0.41	0.22	0.25	0%	0%	0%
Spillway 30 kcfs	0.70	0.36	0.25	0%	0%	0%
Spillway 40 kcfs	1.03	0.37	0.29	0%	0%	0%

USING 2*STANDARD DEVIATION TO QUANTIFY WAVE HEIGHTS

Model Run Condition	2*Standard Deviation Values			% Difference from Spillway Condition		
	920 ft (DT Gage)	1900 ft (Middle)	2900 ft (DS Gage)	920 ft (DT Gage)	1900 ft (Middle)	2900 ft (DS Gage)
Sluiceway 10 kcfs With Deflector	0.41	0.14	0.13	89%	-14%	26%
Sluiceway 30 kcfs With Deflector	0.84	0.24	0.21	90%	11%	49%
Sluiceway 40 kcfs With Deflector	1.09	0.42	0.41	58%	100%	86%
Sluiceway 10 kcfs Without Deflector	0.33	0.20	0.20	55%	20%	91%
Sluiceway 30 kcfs Without Deflector	0.73	0.25	0.26	66%	14%	86%
Sluiceway 40 kcfs Without Deflector	0.85	0.27	0.23	23%	31%	4%
Spillway 10 kcfs	0.22	0.17	0.10	0%	0%	0%
Spillway 30 kcfs	0.44	0.22	0.14	0%	0%	0%
Spillway 40 kcfs	0.69	0.21	0.22	0%	0%	0%

Table 6.2. Results of wave height tests

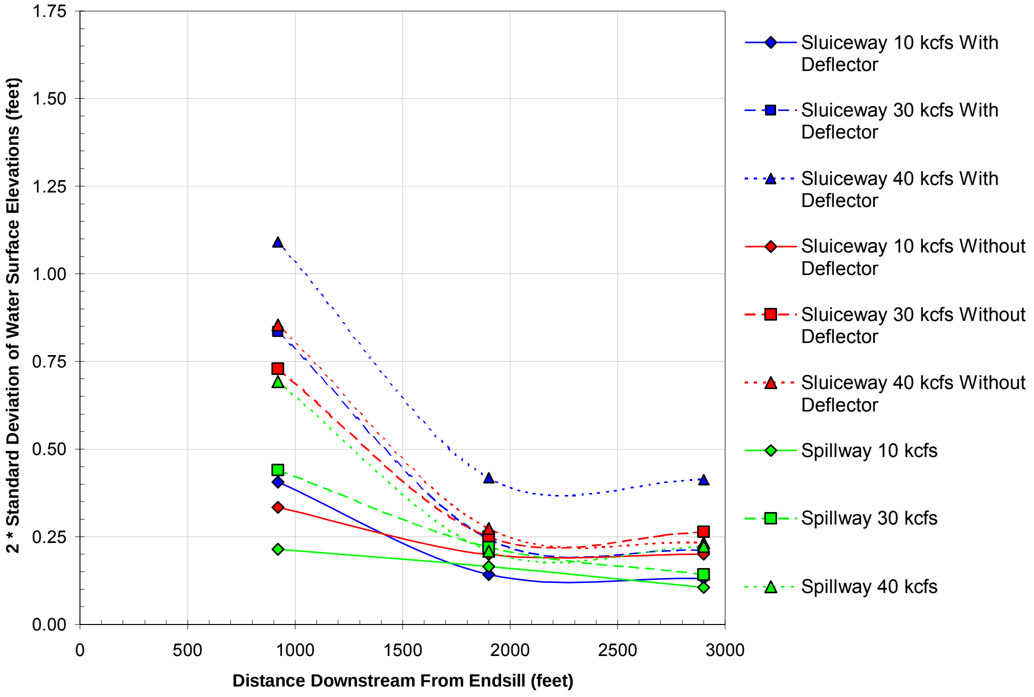


Figure 6.5. 95% confidence limits around average of water surface elevation

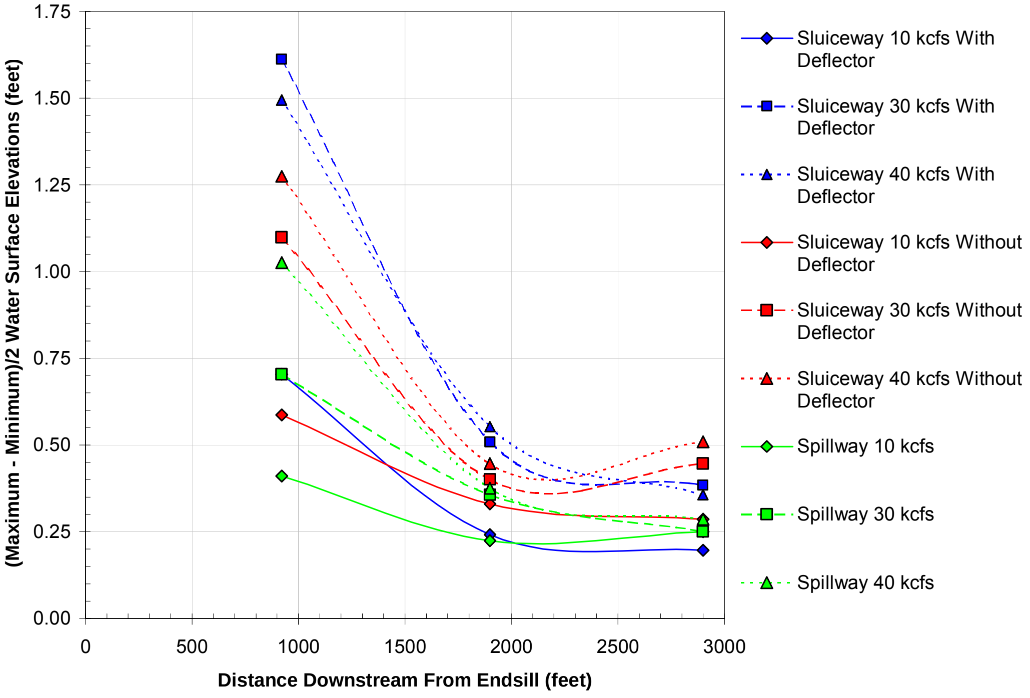


Figure 6.6. Half the maximum to minimum differential of water surface elevations

7. CONCLUSIONS

Tailwater elevations available for surface jet flow regime region were reduced when tailrace bathymetry was included in the model, but air entrainment performance for flowrates less than or equal to 15 kcfs per sluiceway bay was still acceptable. The deflectors did not increase erosion potential at the design flood level of 300 kcfs (total river). In fact, the model predicted a decrease in scour depths under the design discharge with deflectors installed. For total river flowrates less than 300 kcfs, sluiceways alone should not pass total spill flowrates more than 30 kcfs. In these cases, upper crest gates should be opened to pass total spill flowrates greater than 30 kcfs, and the sluiceway bays should only be fully opened when approaching the 300 kcfs total river design flood. Deflectors did not significantly increase wave heights beyond 2900 feet downstream of the endsill.

Please feel free to contact us at your convenience with any questions or comments.

Sincerely, Sincerely,

Larry Weber Pete Haug

Exhibit 7.3-3

Numerical modeling in the tailrace of Hells Canyon Dam Phase V: deflector optimization

NUMERICAL MODELING IN THE TAILRACE OF HELLS CANYON DAM

PHASE V: DEFLECTOR OPTIMIZATION

by

Marcela Politano and Michael Carbone

Submitted to
Idaho Power Company

Limited Distribution Report No. 378

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September 2012

Executive Summary

The purpose of this study was to perform a comprehensive evaluation of the performance of sluiceway deflectors in Hells Canyon Dam. The Computational Fluid Dynamics (CFD) model developed and validated by Politano et al. (2010) was used.

The deflector recommended in a 1:48 IIHR reduced scale laboratory model by Haug and Weber (2002) provided a baseline and was numerically evaluated for flowrates of 25 kcfs and 45 kcfs. Three additional geometries, with modified elevation, length and transition radius, were analyzed. Two tailwater elevations were simulated to evaluate the possibility of surface jumps or vented surface jets. TDG production and distribution, spillway jet regime, and tailrace flow pattern were predicted and analyzed for all geometries. According to the model, decreasing the deflector length or increasing the transition radius results in more TDG production. At 45 kcfs, the deflector elevation does not appreciably affect either spillway regime or the TDG distribution in the tailrace. However, increasing the deflector elevation slightly increases powerhouse entrainment inducing a recirculation in the western region of the tailrace. Since the deflector tested in the laboratory model performs better to reduce TDG and has less impact on the tailrace flow pattern; this deflector was selected for future studies.

The performance of the selected deflector was evaluated for 37 kcfs, 45 kcfs and a 7Q10 flow. The deflector prevents bubbles from traveling to depth, thereby minimizing gas dissolution and TDG production. The 7Q10 flow substantially increases TDG concentration. With deflectors, TDG levels return to forebay TDG after approximately 1 mile and 3.5 miles, for 37 kcfs and 45 kcfs flows, respectively. For a 7Q10 flow, water plunges downstream of the stilling basin with appreciable TDG production. However, deflectors can still reduce TDG levels by about 10%.

For all river flows, attraction of powerhouse flows by sluice jets is observed. Powerhouse entrainment increases with spill flowrate and decreases with an increase in powerhouse flowrate. Stronger sluice surface jets promote surface currents that attract more water towards the spillway region. On the other hand, larger powerhouse flows increase the streamwise velocity in the powerhouse region reducing lateral flows. Velocities near the fish trap decrease as the powerhouse entrainment increases. An important recirculation is observed near the western region for the 7Q10 simulation. This recirculation causes reverse flows near the fish trap and water moving back to the aerated region in the spillway. For a 7Q10 flow, the water entrained into the spillway region increases approximately 2.5 times more due to the inclusion of deflectors.

Possible injury of fish traveling over the spillway and through the sluiceway was estimated. Particles were released from sluice and spillway gates and their acceleration and strain rates were calculated. Numerical results were compared against literature values for fish injury from Deng (2005). The inclusion of deflectors increases the probability of fish injury. The most critical flow conditions for possible fish injury are 37 kcfs and 7Q10 flows. For these flows, about 10% and 3% of fish can suffer minor and major injuries, respectively. The inclusion of deflectors in a 7Q10 flow increases the percent of fish with minor injuries from approximately 5% to 10%. The percent of major injury increases from 1% to 3%. It is important to note that the above estimated percentages could be overestimated since fish injury reported by Deng et al. (2005) are based on fish aggressively introduced to a high shear jet, which is a condition much more severe than analyzed in this study.

The residence time of particles traveling 650 ft of the Hells Canyon tailrace was calculated releasing particles from spillway/sluice bays and powerhouse units for 37 kcfs, 45 kcfs and a 7Q10 flow. The latest flow was evaluated with and without deflectors. Residence time of particles released from the spillway decreases with spillway flowrate. The residence time of particles from the powerhouse is affected by powerhouse entrainment. A small level of entrainment increases the residence time since particles move to a deep low velocity region in the stilling basin. As the lateral flow increases, some particles from the powerhouse join the high velocity surface jets decreasing their residence time. According to the model, deflectors decrease the residence time and therefore they are not expected to delay fish migration time.

Water surface elevation was extracted near the fish entrances. For 25 kcfs, 37 kcfs and 45 kcfs flows, surface waves are minor when deflectors are installed. The amplitude of the predicted surface waves for a 7Q10 simulation is approximately 1 ft. The model predicts that deflectors reduce wave generation near the fish trap.

Acknowledgements

This numerical model study was conducted for, and sponsored by Idaho Power Company. The authors are grateful to Mr. Kelvin Anderson, Mr. Brian Hoelscher and Mr. Ralph Myers for their support and cooperation.

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1. INTRODUCTION AND BACKGROUND

IIHR – Hydroscience & Engineering (IIHR) conducted a comprehensive numerical study to evaluate the effect of sluiceway deflectors on the tailrace hydrodynamics and total dissolved gas (TDG) field in Hells Canyon Dam (HCD).

In the phases I and II of this study, a fully 3D computational fluid dynamics model (CFD) was developed to predict the hydrodynamics and TDG distribution within the HCD tailrace and the river downstream (Politano et al., 2010). Two models, a volume of fluid (VOF) model and a two-phase rigid-lid model, were used. The VOF model computes free surface characteristics and spillway jet regimes near the dam. The VOF solution is used to construct a grid conformed to the free surface for the rigid-lid model. Since computation of the free surface is computationally expensive, about 0.2 miles of the tailrace are simulated with this method. Downstream of the VOF model, free surface characteristics are determined with the 1D Mike-11 model. The rigid-lid model extends approximately 7 miles downstream of the dam. The rigid-lid model takes into account the effect of the bubbles on the flow field and calculates TDG concentration downstream of the dam considering bubble dissolution, convection and diffusion. TDG production is a function of bubble size, pressure and gas volume fraction. The model was calibrated and validated using TDG data collected during field studies on May 21, 1998 and May 4, 2006. The model captured the main observed features of the flow field and TDG distribution in the HCD tailrace.

In the phase III of the study, grids were refined to predict shear stress at the river bed and a discrete phase model was used to evaluate possible sediment mobilization in the river downstream of the dam.

In the phase IV of the study, sluiceway deflectors were incorporated in the model. Five operational conditions, with and without deflectors were simulated with the VOF model. The model was compared against deflector performance curve. The model was able to predict spillway jet regimes and the general flow pattern observed in the laboratory. Changes in water surface elevation near the fish trap due to the inclusion of the deflectors were analyzed. A particle tracking technique was used to simulate conditions experienced by fish as they travel through the spillway. Accelerations experienced by the particles were calculated for two flow conditions, with and without deflectors, and predictions were compared against probability of injury found in the literature (Deng et al., 2005 and Guensch et al., 2002).

This phase of the study used the CFD model developed in the previous phases to evaluate various configurations of the flow deflectors in the sluiceways of Hells Canyon Dam. Multiple simulations were performed to evaluate how changes in deflector elevation, length, and transition radius affect tailrace flow pattern and TDG production. Based on these evaluation runs, final deflector specifications are provided. After deflector selection, the deflector performance is evaluated at 37 kcfs, 45 kcfs and 7Q10 flows. Parameters used to evaluate the deflectors were TDG production and distribution in the tailrace and river downstream, powerhouse entrainment, possible fish injury, tailrace residence time and generation of surface waves.

2. GOALS AND OBJECTIVES

This phase of the project includes the optimization of the sluiceway deflectors. The purpose of this study is to assist in the understanding of the effect of different deflector designs on the flow pattern in the tailrace of Hells Canyon and production and distribution of TDG. Different deflector designs were numerically evaluated for two tailwater elevations. The following tasks were involved in this study:

1) Free surface simulations to evaluate:
   a) Spillway jet regimes
   b) Back-rolls that might cause fish to be caught in this portion of the flow

2) Rigid-lid simulations near the dam to assess:
   a) TDG production and distribution in the tailrace
   b) Induced lateral flows (powerhouse entrainment)
   c) Recirculations near the fish trap

After deflector selection, three flowrates of 37 kcfs, 45 kcfs and a 7Q10 condition were simulated to assess deflector performance under different operational conditions. The 7Q10 condition was simulated also without deflector to analyze differences in tailrace flow pattern and TDG production due to the inclusion of the deflector. In addition to points 1) and 2), the following tasks were completed:

3) Rigid-lid simulations to assess TDG distribution in the river 7 miles downstream of HCD

4) Computation of stilling basin retention time using a particle tracking technique

5) Evaluation of surface waves that might affect fish trap operation

6) Estimation of possible fish injury taking into account the history of acceleration and strain rate down the sluiceway or spillway using a particle tracking technique

3. STUDY AREA

Hells Canyon Dam is located at river mile (RM) 247.7 in a deep canyon in the Snake River. Figure 3-1 shows the area modeled of the Hells Canyon tailrace. The study area for the TDG simulation extends approximately 7 miles downstream of the dam, including both banks. The VOF model included the upper 0.2 miles of the TDG model. The detail at the bottom of Figure 3-1 shows the VOF model domain. Bathymetric data, colored in Figure 3-1, was supplied by IPC to generate the river bed downstream of the dam. In this study, all elevations are in NAVD88 ellipsoid heights. A value of 46.43 ft needs to be added to the elevations for conversion to the NGVD29 coordinate system.

The numerical model uses a different coordinate system to allow small tolerance values and convenient post-processing. The model was converted from IPC projection to local model coordinates using the following transformation $\left(X_m, Y_m\right) = \left(X_{IPC} - 1.33141\ 10^6, Y_{IPC} - 1.51213\ 10^6\right)$ and 2D rotation of -54° about $\left(0.55472, 3.76919\right)$ for alignment with the x-y axis.

Figures 3-2 shows details of some of the structures included in the CFD model. The model includes the main features of the Hells Canyon Dam: 3 spillway bays, 2 sluiceway bays, 2 sluiceway deflectors, 3 powerhouse units including the draft tube outlets of the generating units, fish trap and diversion tunnel.

Deflector designs evaluated in this study are shown in Figure 3-3.

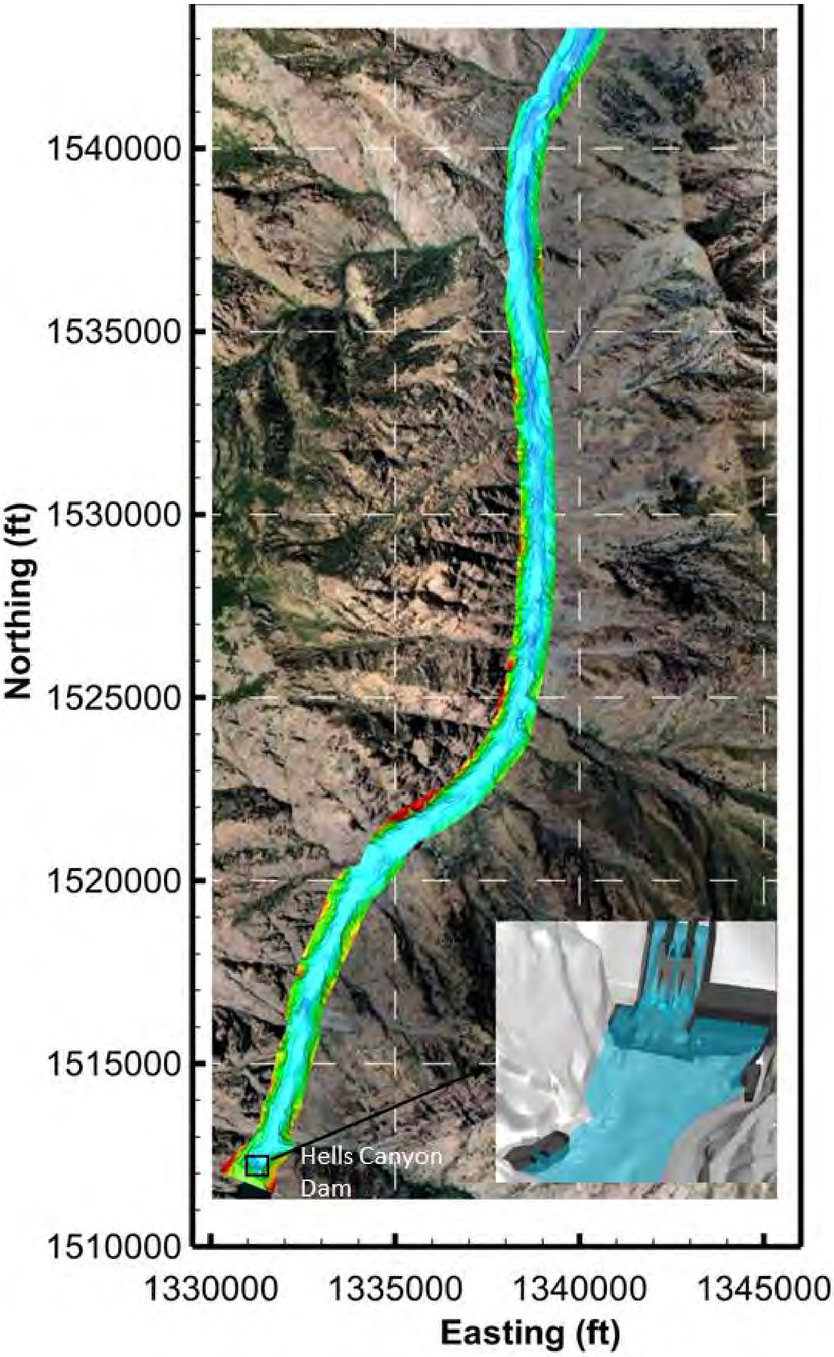


Figure 3-1.Study Area for the Hells Canyon tailrace model

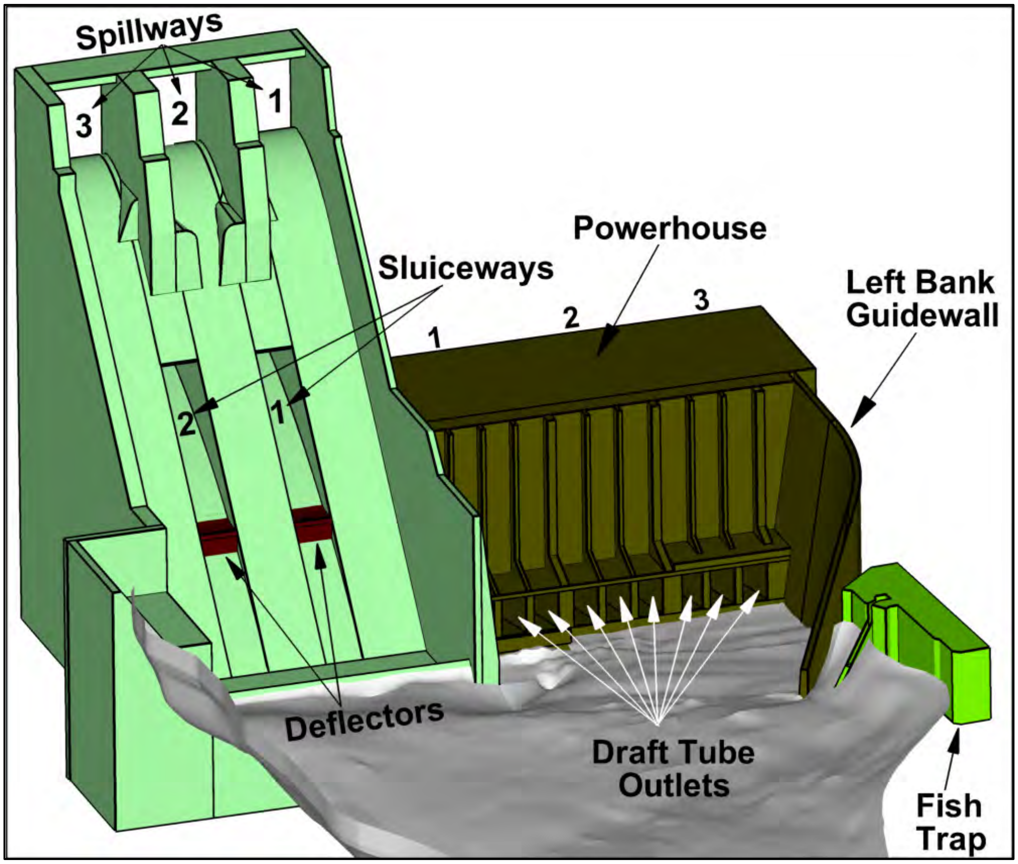


Figure 3-2.Structures included in the Hells Canyon model

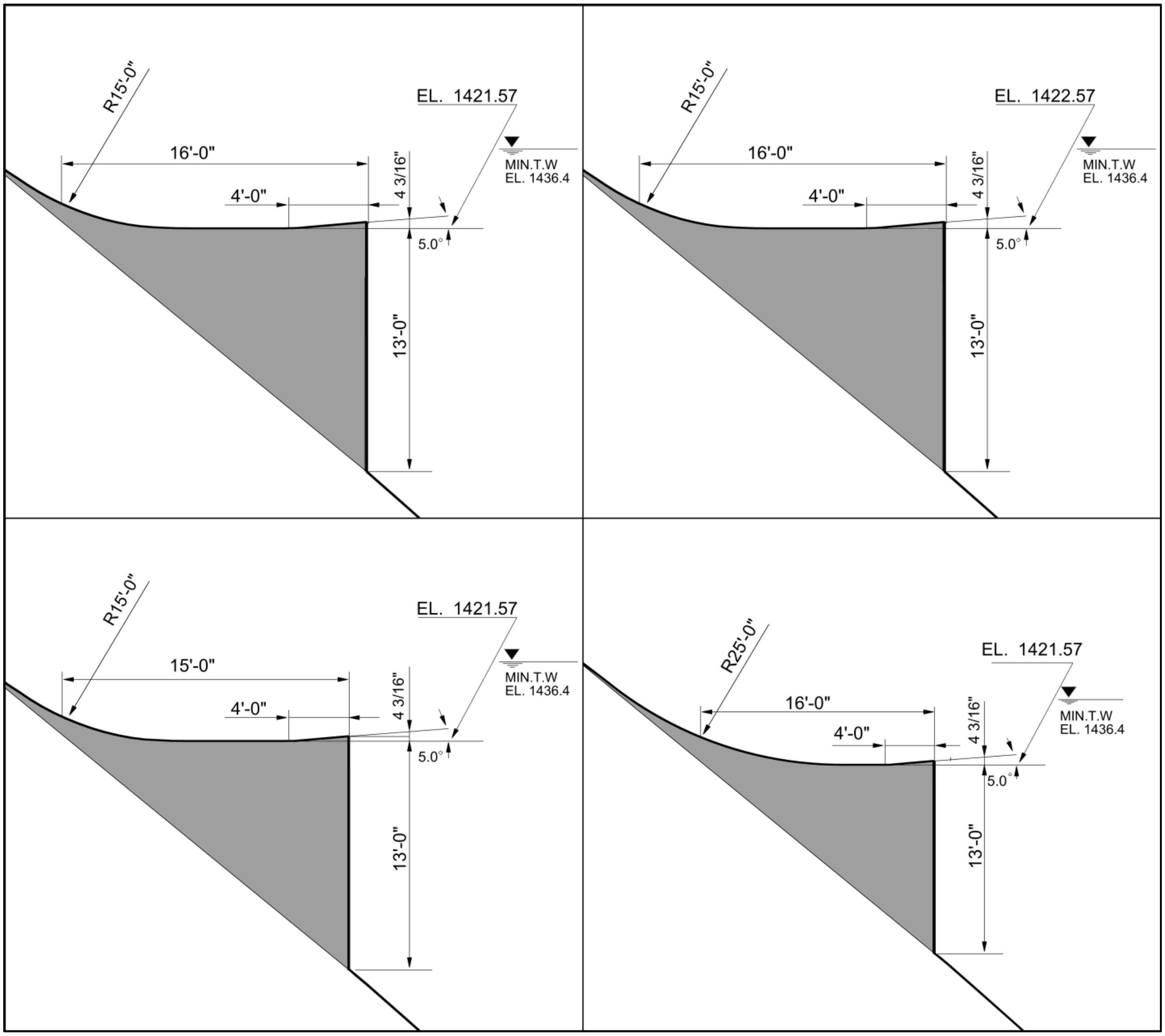


Figure 3-3.Dimensions of simulated deflectors

4. METHODOLOGY

Model Overview

The models used in this study are based on the commercial code Fluent, Ansys. The discrete Reynolds-averaged Navier-Stokes (RANS) equations are solved using a cell-centered finite volume scheme. Three models were used in this study: a) a VOF model, b) a rigid-lid mixture model and c) a Lagrangian model.

The VOF model predicts the free-surface shape. Due to the small time-step required to obtain convergence, the VOF model extends approximately 0.2 miles downstream of the dam. After the statistically steady-state solution is reached, the free-surface shape is extracted and used to generate a grid, conformed to this geometry.

The grid with fixed free surface fixed (rigid-lid approach) extends about 7 miles and includes the tailrace and river downstream. The mixture model takes into account the effect of the bubbles on the flow field allowing a proper prediction of the tailrace flow pattern and TDG concentration. The mixture model includes the region in the tailrace where a two-phase bubble-liquid flow is found. It considers the volume occupied by the bubbles as well as the density and viscosity of the gas/water mixture. In addition, the suppression and production of turbulence by the bubbles is included into the model for appropriate assessment of water entrainment from the powerhouse into the spillway region. Note that proper prediction of the flow pattern in the tailrace is indispensable for adequate computation of TDG production and subsequent distribution in the tailrace and river downstream. Bubble velocities are calculated considering buoyancy, pressure and drag forces. Specific two phase flow models and boundary conditions were implemented into FLUENT through User Defined Functions (UDFs). Two-phase User Defined Scalar (UDSs) transport equations were used to calculate the distribution of TDG concentration and bubble number density. The air entrainment (gas volume fraction and bubble size) is a model parameter imposed as a boundary condition at the spillway bays. In this study, the bubble diameter and volume fraction used at the spillway gates were selected during the model calibration to match the experimental TDG data measured on May 21, 1998 and May 4, 2006, and the same values are used for all computations. Model parameters for the Hells Canyon model were gas volume fraction $\alpha = 0.03$, bubble diameter $D_b = 0.8\,mm$ and mass transfer coefficient at the free surface $k_l = 0.001\ 1/s^2$. Please refer to Politano et al. (2009a) for details of the mathematical model, implementation in Fluent and calibration. For the region downstream of the bubbly flow, a single phase model is used. This region is determined such as an isosurface of gas volume fraction of 10^{-4} is completely within the upstream region or in other words 99.67% of the bubbles have risen out of the domain. In this region, TDG production by bubble dissolution can be neglected. However, TDG concentration and distribution can still change due to mixing and degasification at the free surface.

The Lagrangian model calculates the trajectories of neutrally buoyant spherical particles released from the sluice gates. Trajectories are computed using velocity field obtained with the VOF model. The model computes the statistics of accelerations and strain rate to estimate fish mechanical injury.

All simulations were run at Linux clusters available at IIHR.

Numerical Method and Initial Conditions

The pressure at the faces was obtained using a body force weighted scheme. The continuity equation was enforced using a Semi-Implicit Method for Pressure-Linked (SIMPLE) algorithm. A first order upwind scheme was used for the turbulent quantities.

Unsteady free surface simulations were performed using time-steps between 0.002 to 0.004 seconds. Rigid-lid simulations used a time steps ranging from 0.5 seconds to 1 second. Typically, two to three nonlinear iterations were needed within each time step to converge all variables to a L_2 norm of the error $< 10^{-3}$.

For the VOF simulations two initial conditions were used: 1) a constant water surface elevation with zero velocities and turbulence or 2) volume fraction, velocities and turbulence interpolated from earlier VOF solutions with similar river flowrates.

In the mixture model, first a single phase model was run and then, after convergence was obtained, bubbles were injected in the domain neglecting dissolution. Finally, bubble dissolution and TDG production is included and the model was run until a constant average TDG at the exit was obtained.

Simulation Conditions

The performance of four deflector geometries was evaluated using two flowrates: 25 kcfs and 45 kcfs. Table 4-1 summarizes deflector geometry, project operations, river flowrate, and tailwater elevation used in the simulations. Simulations SI, SIII, SV and SVII used a flowrate of 25 kcfs and SII, SIV, SVI and SVIII a flowrate of 45 kcfs. These simulations assumed a constant flow of 7.5 kcfs passing through each of the sluiceways and no flow through the upper spillway gates.

Simulations SI and SII used the deflector selected in the IIHR 1:48 scale laboratory model (Dierking and Weber, 2002). In simulations SIII and SIV, the elevation of the deflector is one foot higher. Simulations SV and SVI has a one foot shorter deflector. Finally, in simulations SVII and SVIII the curvature radius changed from 15 ft to 25 ft.

For a flowrate of 25 kcfs, the effect of operating with eastern (#1) or western (#3) powerhouse units was evaluated. For these simulations, the SV deflector geometry was used. Simulation SV_1 operates with powerhouse unit #1 and SV_3 with powerhouse unit #3. Results of these simulations are presented in Chapter 5. Numerical results indicate that in the first 50 ft from the dividing wall, powerhouse entrainment is larger when operating with unit #1. However, this entrainment loses strength quickly as it moves away from the dividing wall (see Figure 5-32). Water entrainment and the western recirculation are overall more significant when operating with unit #3. In this case, more bubbles are attracted back to the spillway region. On the other hand, operation with unit #1 promotes mixing downstream of the powerhouse and lower TDG concentration near the fish trap. In this study, all simulations with a river flowrate of 25 kcfs, assumed that powerhouse unit #3 is operating.

TDG at the forebay is assumed to be 1.15 based on the forebay TDG criterion issued by the Washington and Oregon State Departments of Ecology (Washington State Department of Ecology and State of Oregon Department of Environmental Quality 2009). This criterion had been used in Wells Dam for evaluation of compliance with TDG standards (Politano et al. 2009b, Politano et al. 2011, Politano et al. 2012).

Table 4-1. Conditions used for deflector geometry evaluation

	Deflector Optimization								
	SI	SII	SIII	SIV	SV_1	SV_3	SVI	SVII	SVIII
Forebay Elevation (ft)	1640.4	1640.4	1640.4	1640.4	1640.4	1640.4	1640.4	1640.4	1640.4
Tailwater Elevation (ft)	1430.5	1436.4	1430.5	1436.4	1430.5	1430.5	1436.4	1430.5	1436.4
River flow (kcfs)	25	45	25	45	25	25	45	25	45
Powerhouse Discharge (kcfs)									
Unit #1	0	10	0	10	10	0	10	0	10
Unit #2	0	10	0	10	0	0	10	0	10
Unit #3	10	10	10	10	0	10	10	10	10
	Sluice Structure								
Deflector Elevation (ft)	1421.6	1421.6	**1422.6**	**1422.6**	1421.6	1421.6	1421.6	1421.6	1421.6
Deflector Transition Radius (ft)	15	15	15	15	15	15	15	**25**	**25**
Deflector Length (ft)	16	16	16	16	**15**	**15**	**15**	16	16

After the deflector was selected, the performance of the deflector was evaluated for three flowrates: 37 kcfs, 45 kcfs and 71.5 kcfs. These flowrates were selected by IPC. Table 4-2 describes the conditions for these simulations. The 45 kcfs flow is the highest flow for current fish trap operation, and the 71.5 kcfs flow is the 7Q10 maximum flow defined in the 401 report for meeting TDG targets.

For the 7Q10 flow, an additional simulation without deflector was performed to use as a baseline condition. This simulation use spillway gates following the recommendation of the reduced-scale model study of using spillway gates for high spill discharges when energy dissipation is important (Haug and Weber, 2002).

Table 4-2. Conditions used for deflector performance evaluation

	Performance Simulations			
	37kcfs	45kcfs	7Q10-D	7Q10-ND
Forebay Elevation (ft)	1640.4	1640.4	1640.4	1640.4
Tailwater Elevation (ft)	1433.9	1436.4	1441.6	1441.6
Sluiceway Discharge per bay (kcfs)	3.5	7.5	20.75	0
Spillway Discharge per bay (kcfs)	0	0	0	13.84
River flow (kcfs)	37	45	71.5	71.5
Powerhouse Discharge (kcfs)				
Unit #1	10	10	10	10
Unit #2	10	10	10	10
Unit #3	10	10	10	10
	Sluice Structure			
Deflector Elevation (ft)	1421.57	1421.57	1421.57	1421.57
Deflector Transition Radius (ft)	15	15	15	15
Deflector Length (ft)	16	16	16	16

Grid Generation

The grids were generated using Gridgen and ANSYS ICEM. Gridgen was used to generate most of the volumes. The domain was divided into a number of blocks and a structured mesh was generated in each block. Each individual block consists of hexahedral cells. An extra block at the top of the VOF grids was included to accommodate the air volume. ANSYS ICEM was used to mesh the deflectors and wedges at the bottom of the spillway. All quad elements were used to mesh the surfaces. Volumes were generated by sweeping surface meshes.

For the VOF simulations, grids with approximately 2.0 10^6 nodes, were constructed nearly orthogonal in the vicinity of the free surface to improve convergence. Grid points were concentrated near the tailwater elevation to resolve the free surface and minimize numerical diffusion. Figure 4-1 shows some views of the grid used for the VOF simulations. Frames in the top show overviews of the grids in the tailrace and details in the bottom show the grid for different deflector geometries.

Grid size for the mixture model near the dam ranges from 1.0×10^6 to 2.7×10^6 nodes. For simulations with 25 kcfs and 37 kcfs, the grids include 900 ft of the tailrace. For 45 kcfs, bubbles travel farther and the domain was extended to 1200 ft. For the 7Q10 simulations with the highest flowrate, the grid included 4500 ft of the tailrace. Figure 4-2 shows grid details near the deflector and at the free surface for 45 kcfs.

The river downstream is modeled with structured grids containing about 2.0×10^6 nodes. Grids near the inflow, RM 246.5, RM 241.6 and outflow are shown in Figure 4-3.

Table 4-3 shows typical grid sizes in the longitudinal, lateral and vertical directions for the different models.

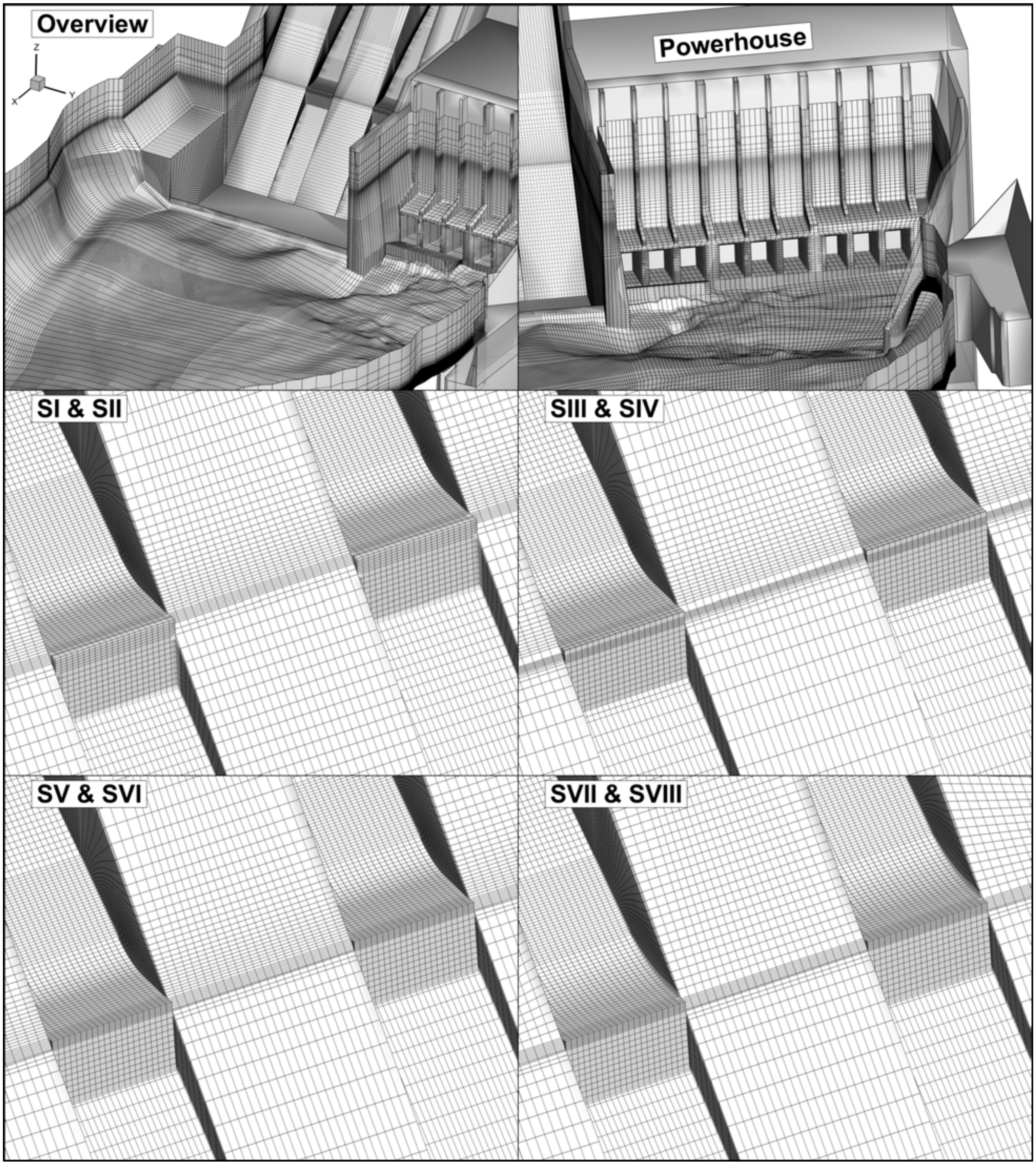


Figure 4-1. Grid for the VOF model. Top: tailrace mesh, central and bottom: details near the deflectors

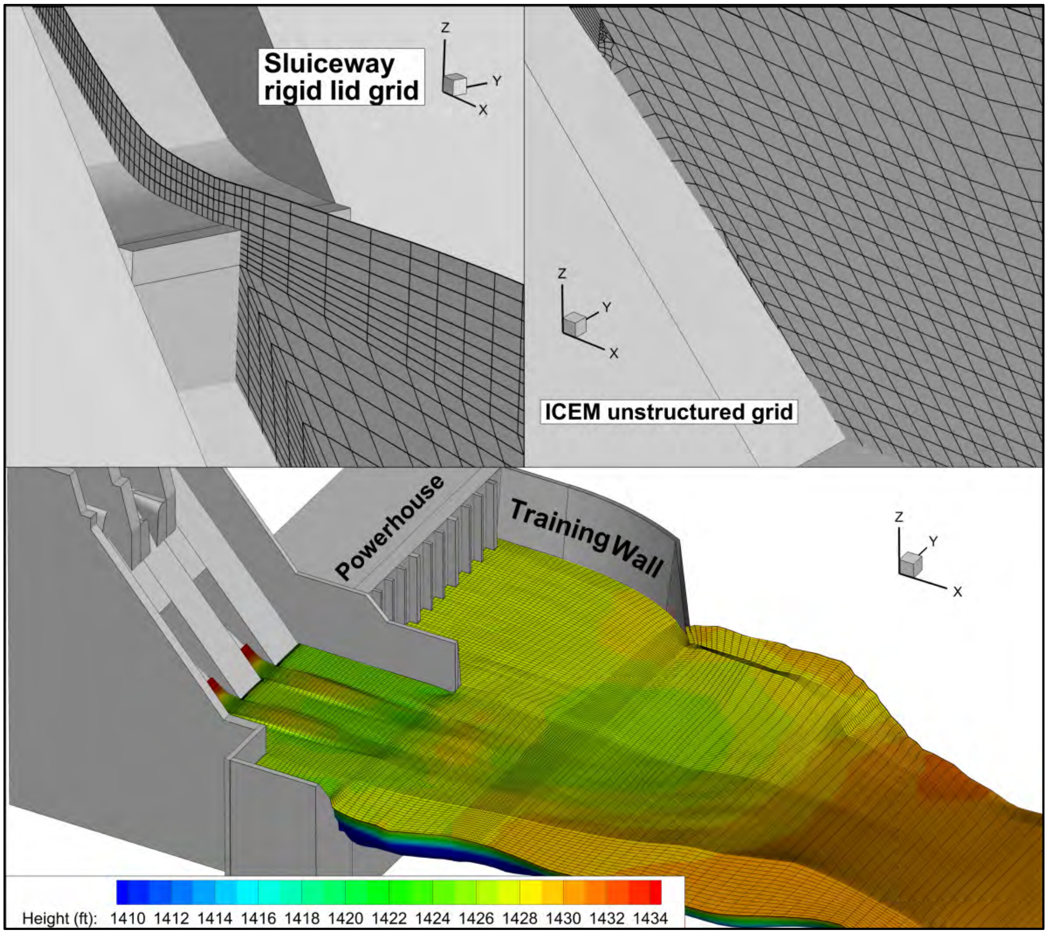


Figure 4-2.Grid details for the mixture model. Top left: slice through a deflector, top right: unstructured grid at a wedge created between spillway and sluice, and bottom: grid at the fixed free surface

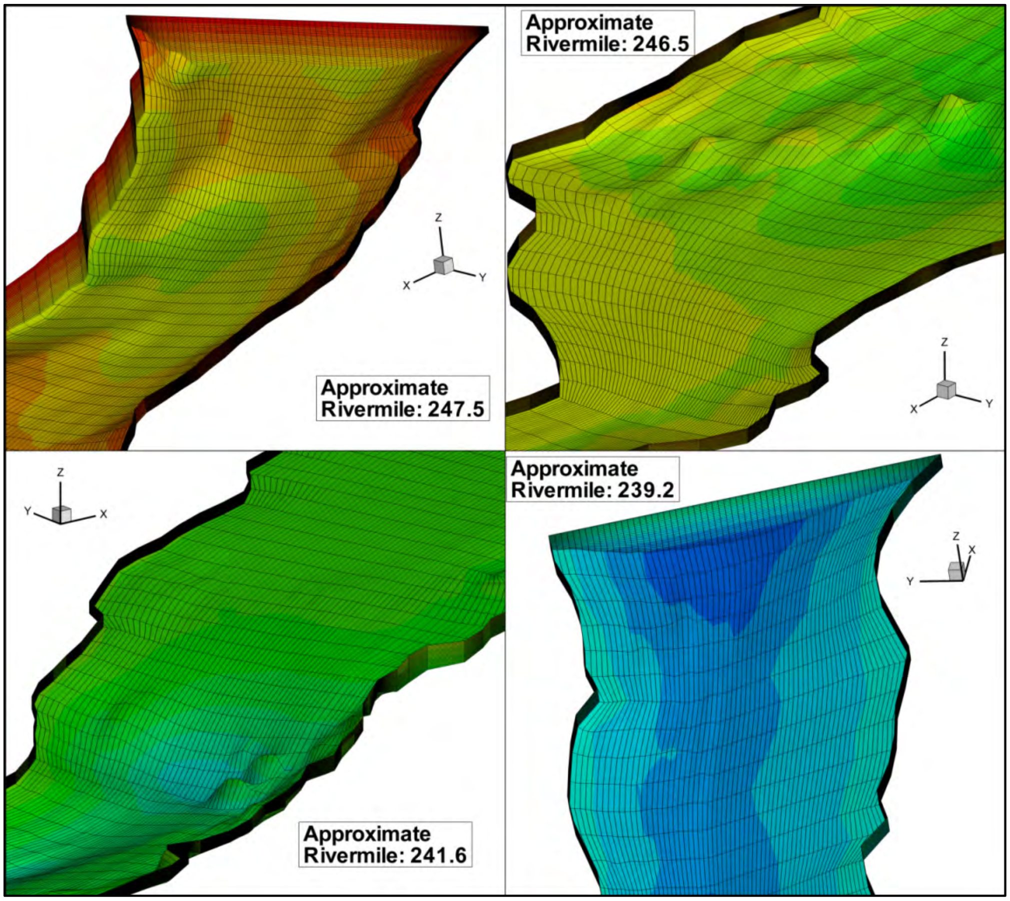
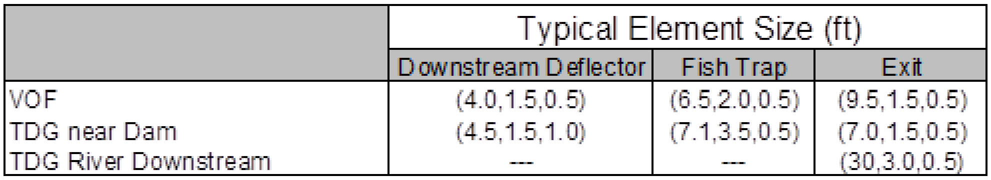


Figure 4-3.Grid details for the TDG model downstream.

Table 4-3. Typical element size in the longitudinal, lateral and vertical directions of Hells Canyon grids



	Typical Element Size (ft)		
	Downstream Deflector	Fish Trap	Exit
VOF	(4.0,1.5,0.5)	(6.5,2.0,0.5)	(9.5,1.5,0.5)
TDG near Dam	(4.5,1.5,1.0)	(7.1,3.5,0.5)	(7.0,1.5,0.5)
TDG River Downstream	---	---	(30,3.0,0.5)

Boundary Conditions

Please refer to Politano et al. (2010) for details of boundary conditions. In this study, boundary conditions at the spillway inlets were modified to take into account the water contraction and resulting velocity increase after spillway gates.

Velocity and water depth at the contraction are used as boundary conditions in the VOF model. Assuming zero energy loss in the gate, the velocity and water depth *h* at the inflow can be calculated from:

$$g\ \Delta H = \frac{|V|^2}{2} \qquad (1)$$

$$q = U\,hW \qquad (2)$$

where $|V|$ is the velocity magnitude, U the velocity in longitudinal direction, q the gate flowrate, ΔH is the difference between forebay and gate elevations, and W is the spillway width. For a forebay elevation of 1640.4 ft, $\Delta H = 138\ ft$ and $|V| = 94.2\ ft/s$.

In the rigid-lid model, an inflow boundary condition is imposed at about 33 ft upstream of the deflector. Water surface elevation and velocity profiles at that location are extracted from the VOF model results.

5. DEFLECTOR OPTIMIZATION

VOF Simulations

The criteria for convergence of the VOF simulations was a steady flow rate at the exit.

Simulations with 25 kcfs

The flowrate evolution of the simulations for 25 kcfs is illustrated in Figure 5-1. The horizontal black line shows the target flowrate. Statistically steady solutions were obtained at approximately 15 minutes of flow time, which required about 10 days of computation time for an initial condition with zero velocity and constant water surface elevation. Simulation SV_3 started from an interpolated solution from SV_1 and converged in less than 3 minutes of flow time.

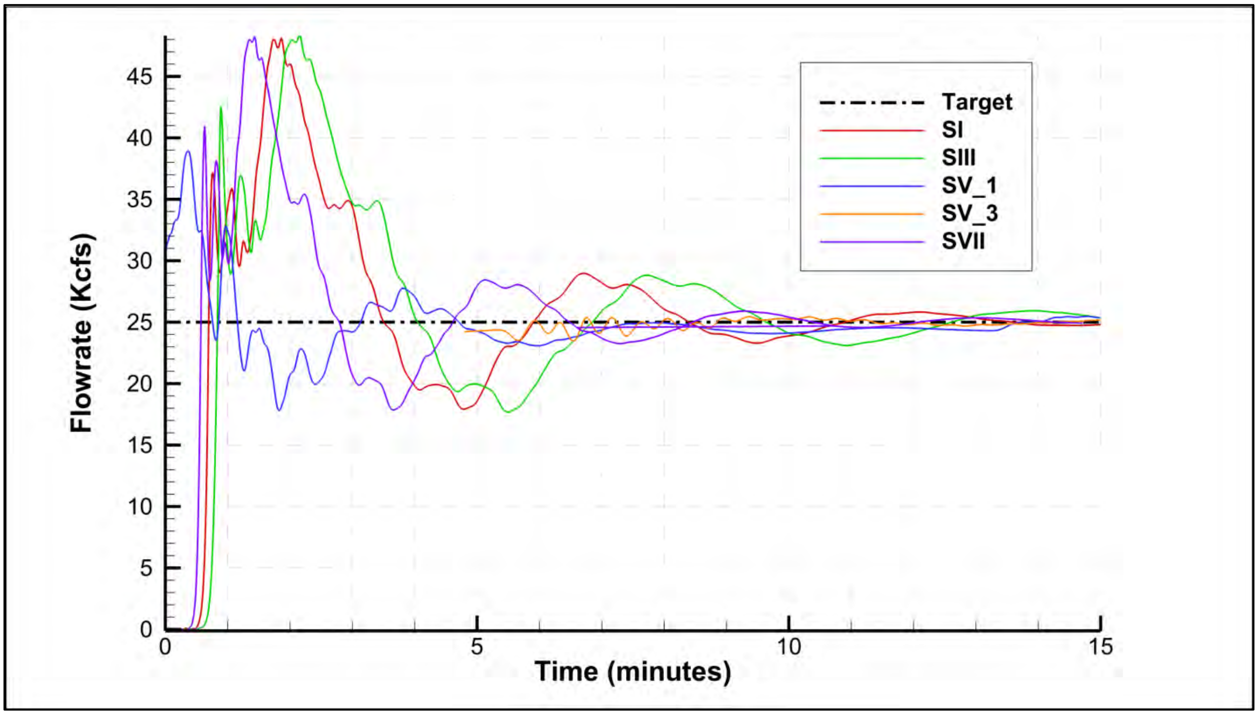


Figure 5-1.Evolution of the flowrate for simulations with 25 kcfs

Minor differences are found in the free surface shape and jet regimes due to changes in deflector geometry. Figure 5-2 shows isosurfaces of gas volume fraction $\alpha_w = 0.5$ representing the free-surface location used to create the top of the rigid-lid grid. The free surface near the dam is about 3 ft lower than the water elevation at the exit due to the effect of sluice jets on the tailrace.

In Figure 5-3 a horizontal slice at 1430.4 ft show the predicted flow field at 0.1 ft from the free surface with the VOF method. For clarity, predicted velocity vectors were interpolated in a coarser structured uniform grid. In all simulations, a big recirculation is predicted in the tailrace. Near the fish trap, water flows towards the powerhouse and then entrains into the spillway region.

Figure 5-4 shows spillway jet regimes predicted with the VOF method. All deflectors produce surface jets in sluice #2. In sluice #1, lateral currents create some plunging downstream of the stilling basin with potential of entraining bubbles to depth. Back rolls are predicted in the stilling basin, mainly downstream of sluice #1.

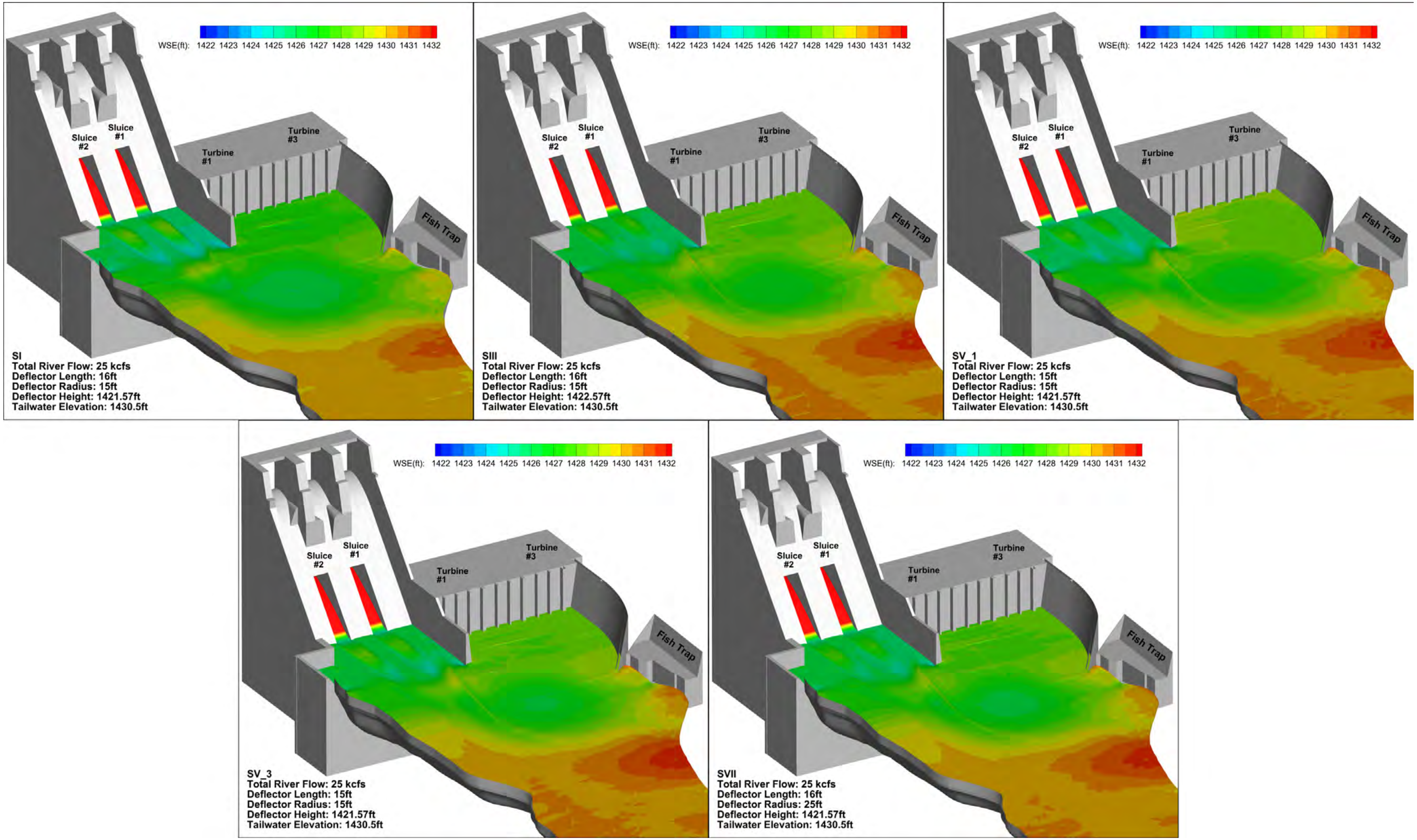


Figure 5-2.Free surface colored by elevation for 25 kcfs

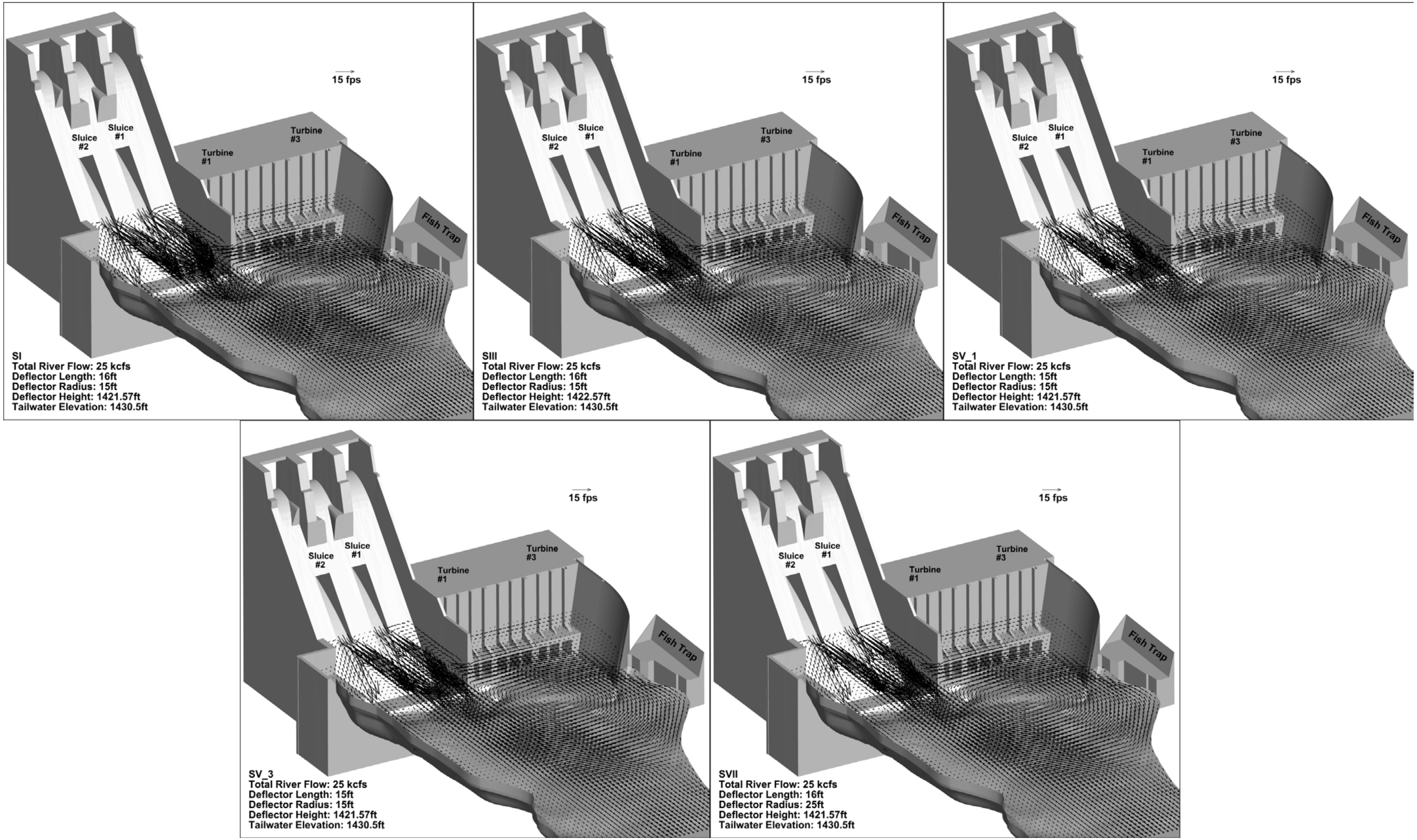


Figure 5-3. Velocity vectors at 1430.4 ft for 25 kcfs

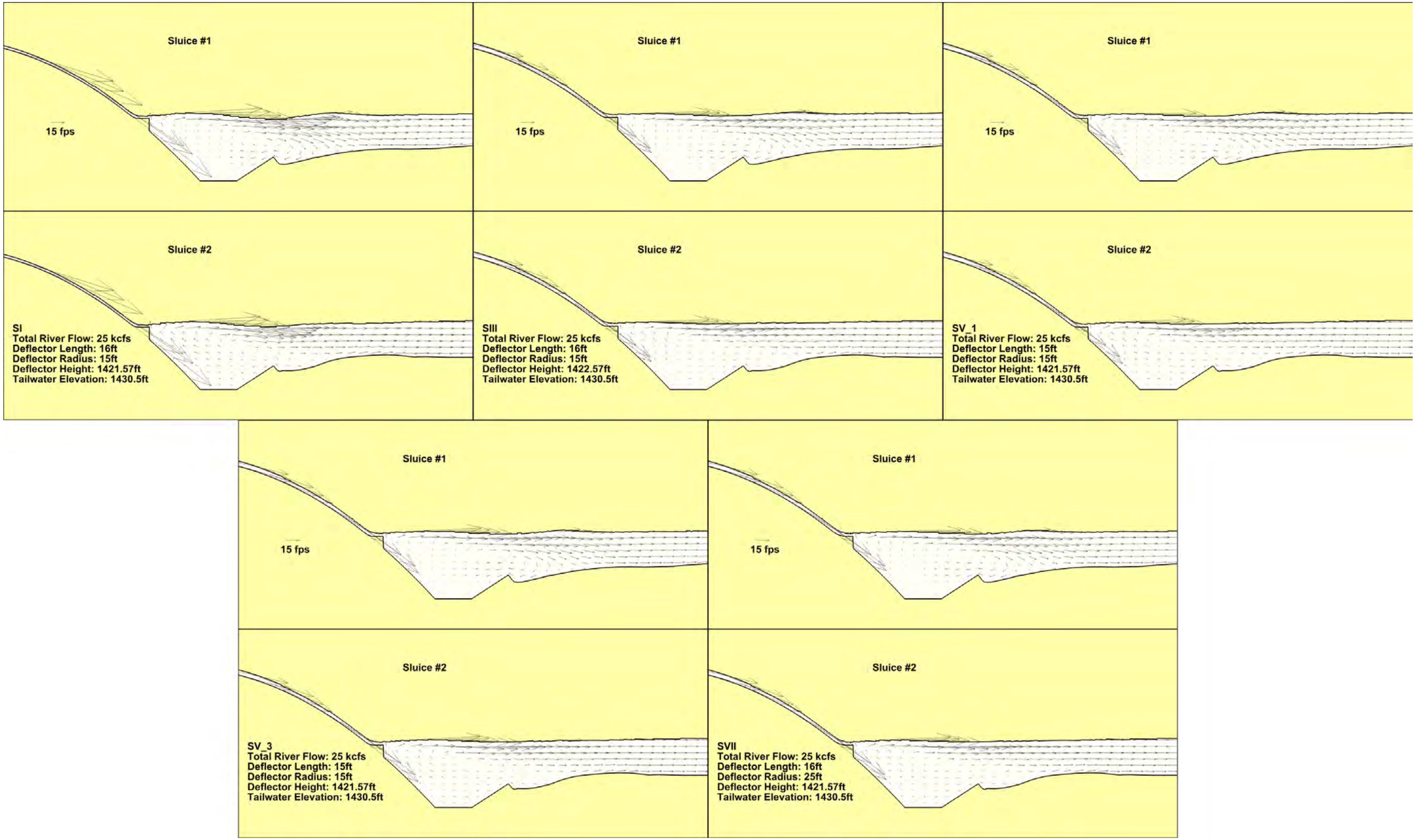


Figure 5-4. Velocity vectors at slices passing through the sluiceways for 25 kcfs

Simulations with 45 kcfs

The flowrate evolution for 45 kcfs is shown in Figure 5-5. The horizontal black line shows the target flowrate. Statistically steady solutions were obtained at approximately 20 minutes of flow time. Simulation SIV used the interpolated solution of SII as initial condition and converged in about 3 minutes of flow time.

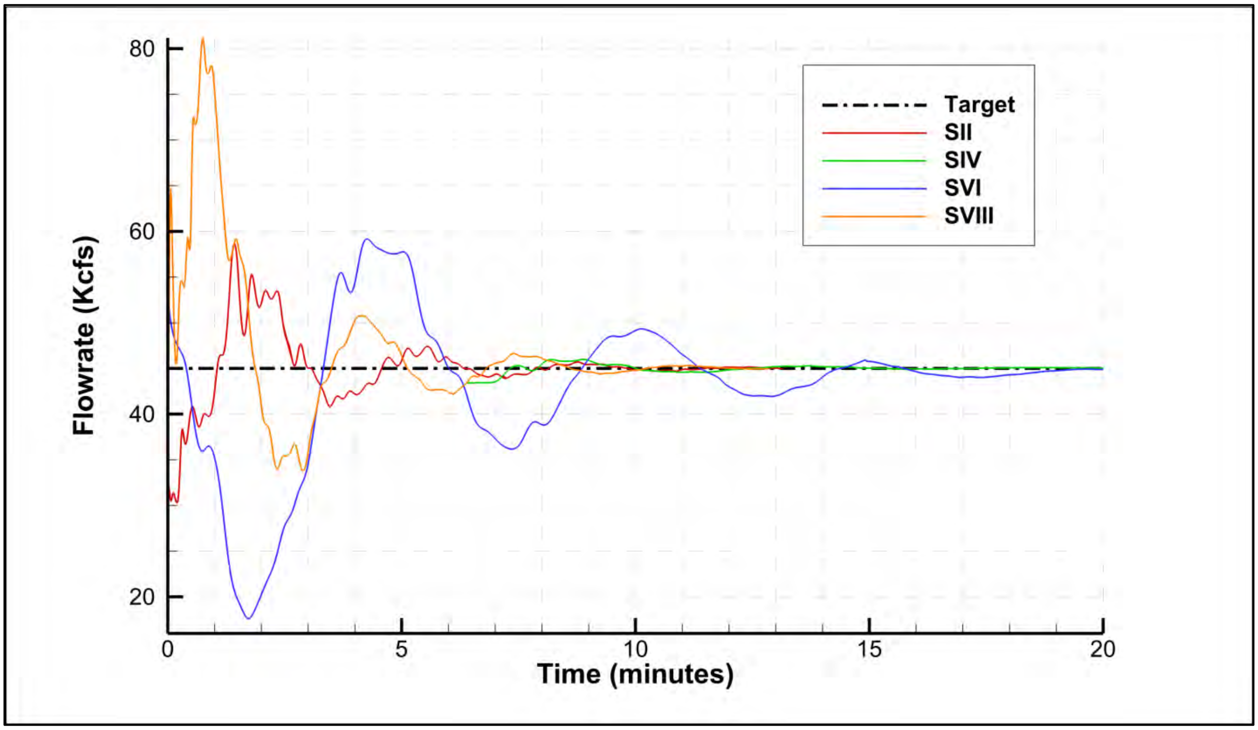


Figure 5-5.Evolution of the flowrate for simulations with 45 kcfs

Similar to predicted with a river flow of 25 kcfs, differences in free surface and jet regimes due to different deflector geometries are minimal. Figure 5-6 shows the free-surface colored by elevation obtained with the VOF method. Similar free surface characteristics are predicted for all deflector geometries. The free surface downstream of the spillway is deflected about 4 ft. Surface waves created in the spillway propagates downstream as the flowrate increases.

Figure 5-7 shows horizontal slices at 1430.4 ft (approximately 6 ft from the free surface). A tailrace recirculation is predicted near the fish trap; however this recirculation is weaker than that predicted for 25 kcfs. Note that, in this region, the streamwise velocity is stronger due of higher powerhouse flows.

Figure 5-8 shows spillway jet regimes predicted with the VOF method. Transition from surface jet to surface jump regime is predicted in sluice #1. In a surface jump, a hydraulic roller forms above the jet, aerating the downstream water surface with potential of higher TDG production that possible with a surface jet. As observed with 25 kcfs lateral flows entrained in the spillway region induce some water from sluice #1 to plunge downstream in the stilling basin.

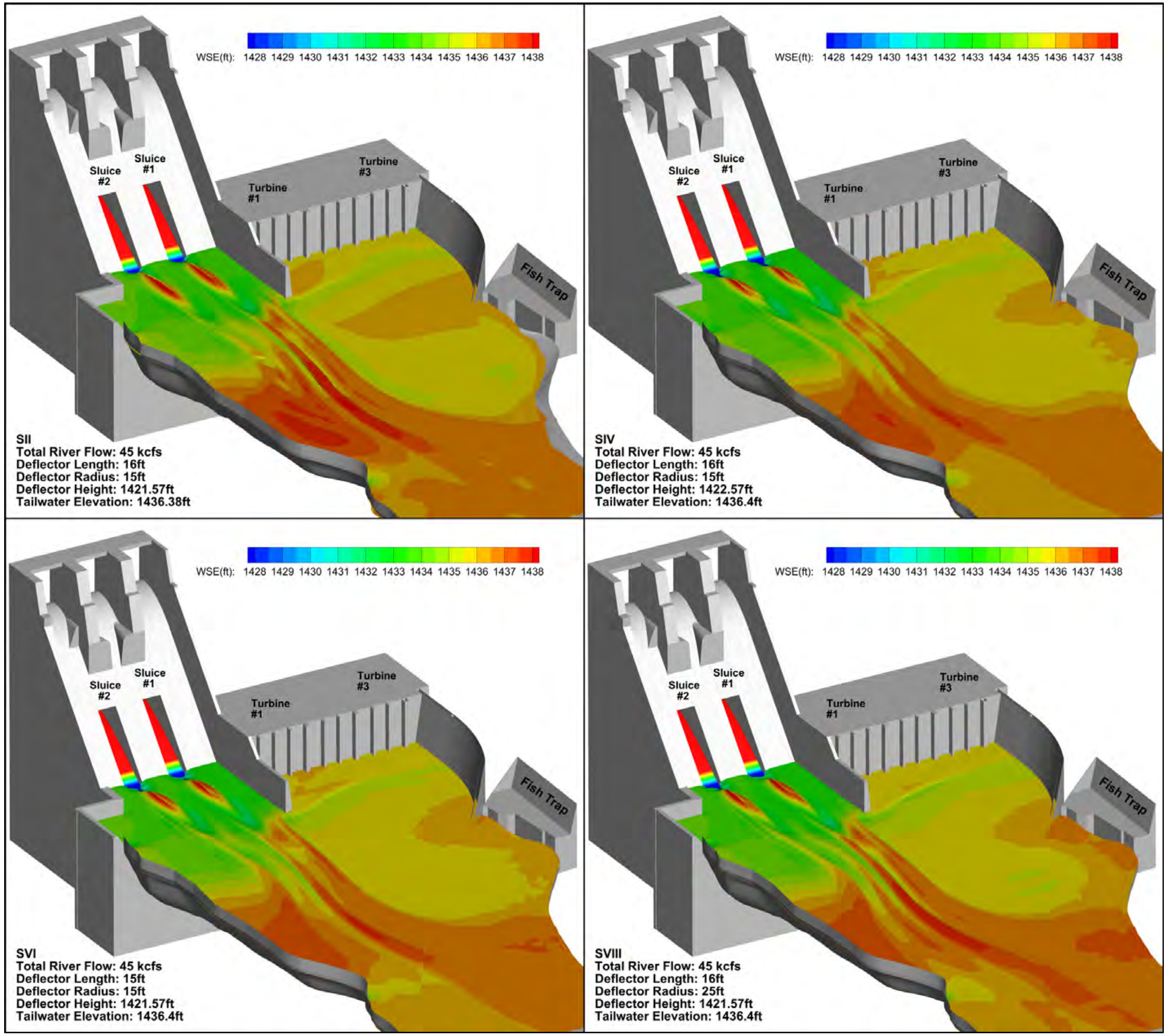


Figure 5-6. Free surface colored by elevation for 45 kcfs

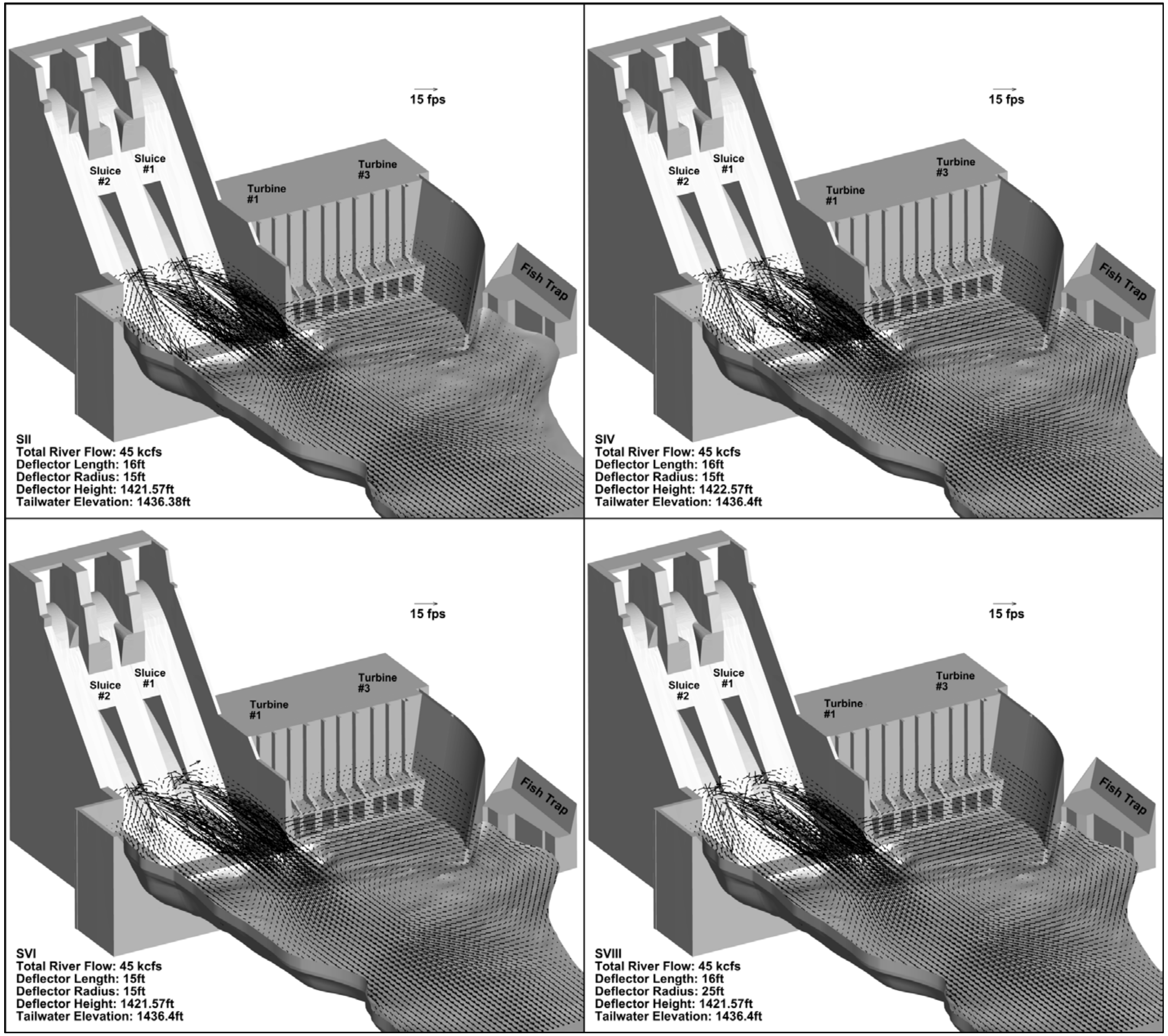


Figure 5-7. Velocity vectors at slices passing through the sluiceways for 45 kcfs

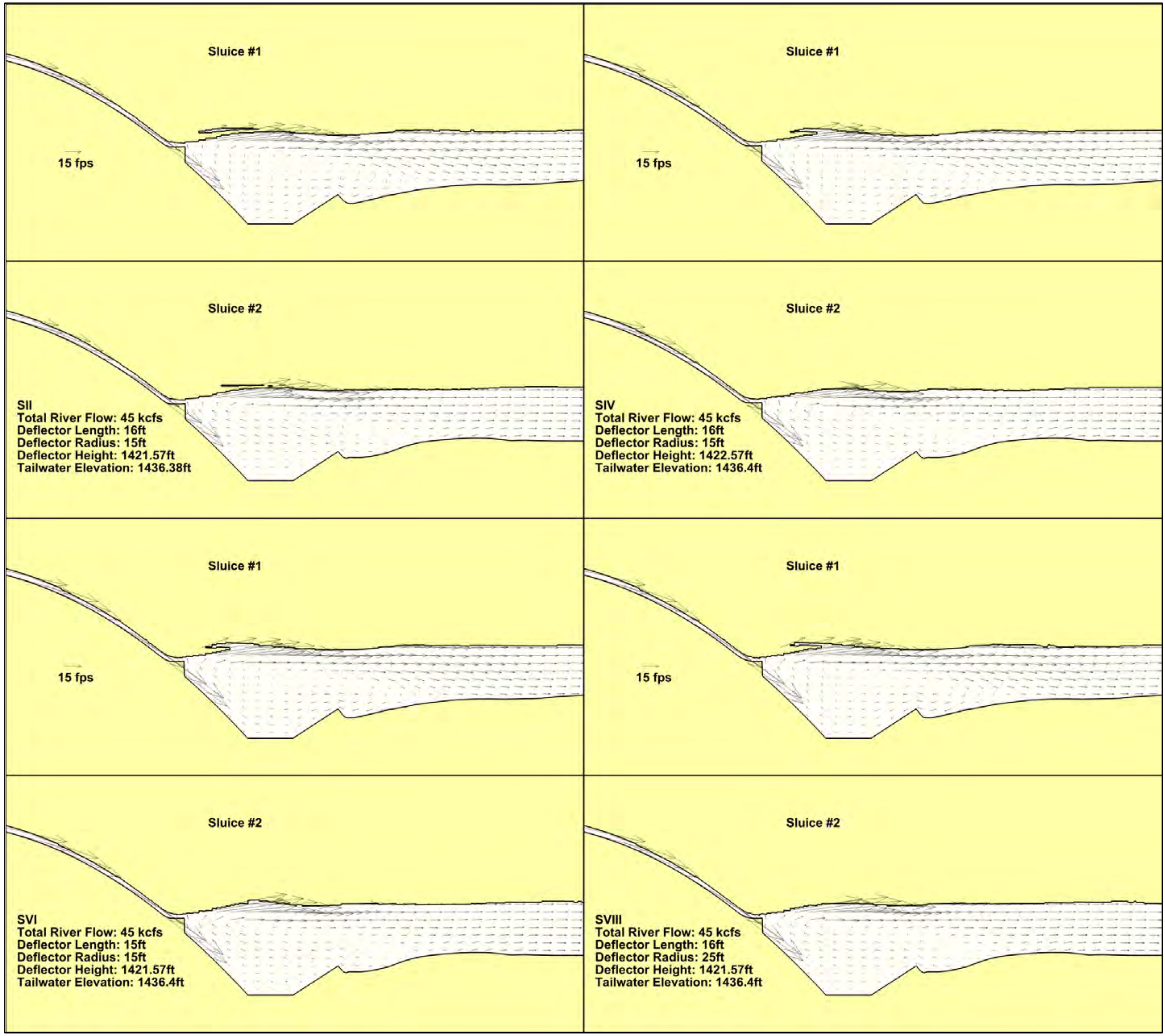


Figure 5-8. Velocity vectors at slices passing through the sluiceways for 45 kcfs

Rigid-lid Model

Simulations with 25 kcfs

Similar flow pattern and TDG distribution are predicted for all simulations with 25 kcfs. Slices illustrating the flow pattern, gas distribution and TDG are shown at 1410 ft and 1418 ft (approximately 20 ft and 12 ft from the free surface). The slice at 1410 ft is located approximately 2 ft beneath the lower end of the deflector.

Figures 5-9 and 5-10 show velocity vectors at 1410 ft and 1418 ft, respectively. Velocity vectors are interpolated in a coarser grid to improve visualization. Deflectors create strong jets near the free surface. High velocity surface jets attract water toward the jet region creating two recirculations; one big eddy in the western region near the fish trap and a smaller eddy in the eastern side of the tailrace. Velocity contours in the streamwise direction are shown in Figures 5-11 and 5-12, respectively. Operating with turbine unit #1 slightly reduce the strength of the sluice jets. This phenomenon is more evident at the deepest slice where the powerhouse entrainment is more important.

Figures 5-13 and 5-14 show gas volume fraction contours at 1410 ft and 1418 ft, respectively. High values of gas volume fraction indicate regions with elevated concentration of bubbles or “white water”. Bubble distribution in the tailrace is similar for all tested deflector geometries. Bubbles are transported by the western tailrace eddy moving towards the fish trap, powerhouse region and then entrained back into the spillway region. Figures 5-15 shows the vertical distribution of gas volume fraction at slices passing through sluiceways #1 and #2. Most of the bubbles concentrate near the free surface due to the effect of the deflectors. However, water plunging downstream of the stilling basin transports some bubbles to middle-depth downstream of sluiceway #1. A small amount of these bubbles are transported back to the stilling basin by back rolls. This effect, which reduces the efficiency of the deflector, was also observed in the 3D reduced scale model (Haug and Weber, 2002).

TDG source is similar for all tested deflectors as shown in Figure 5-16. TDG source increases with gas volume fraction and pressure. Near the free surface, gas volume fraction is high but pressure is smaller than that at equilibrium at local conditions and therefore degasification occurs (blue regions in the picture). At deep high pressure regions, bubbles are not present due to the presence of the deflectors. Therefore, the highest source values (red values) are found at mid-depth downstream of the tailrace.

TDG distribution at 1410 ft and 1418 ft is shown in Figures 5-17 and 5-18, respectively. For a forebay TDG of 1.15, TDG concentration downstream of the dam is smaller than 1.2 for all simulated deflectors. Figure 5-19 shows streamlines colored by TDG released from the powerhouse and sluiceways. Note that most of powerhouse flows are entrained in the spillway region. This entrainment can increase TDG since more water is exposed to bubbles. This is true as long as water is under-saturated at local conditions and bubbles are available for dissolution. Lateral flows can also increase TDG since water available for dilution downstream is reduced.

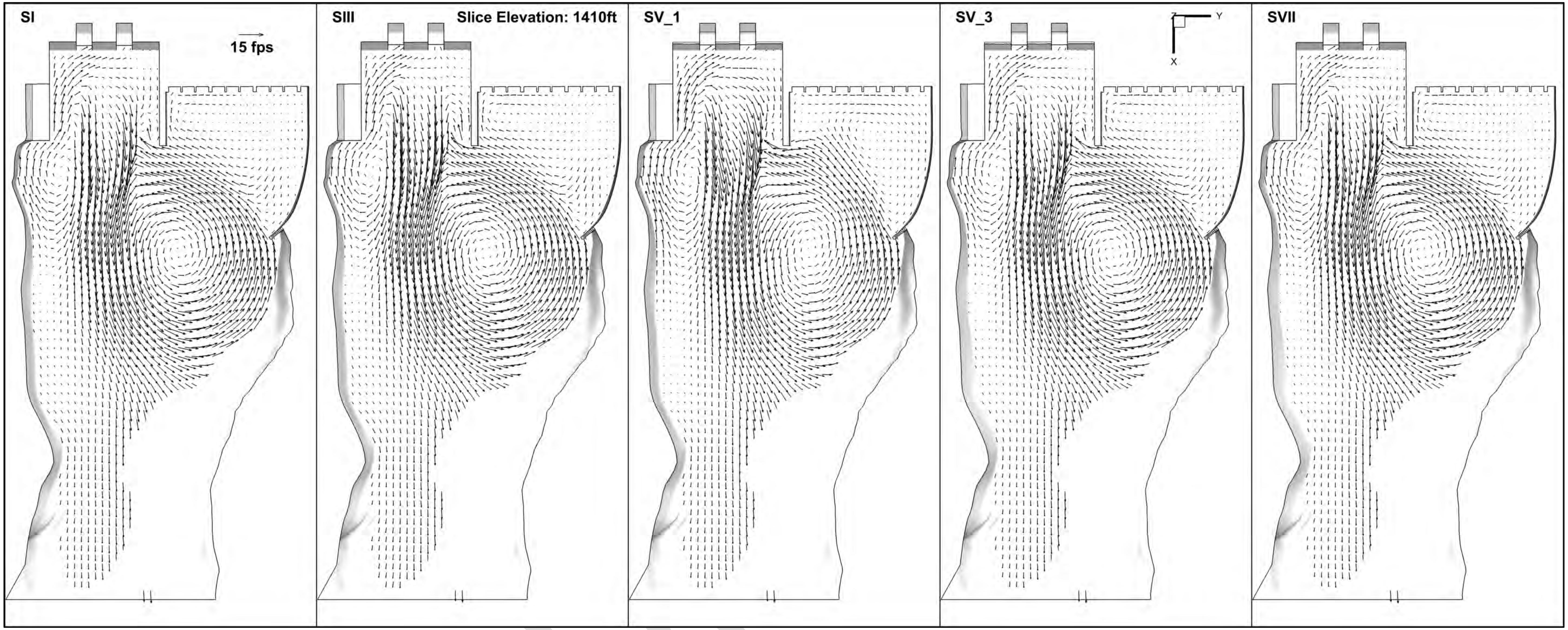


Figure 5-9. Velocity vectors at 1410 ft for 25 kcfs

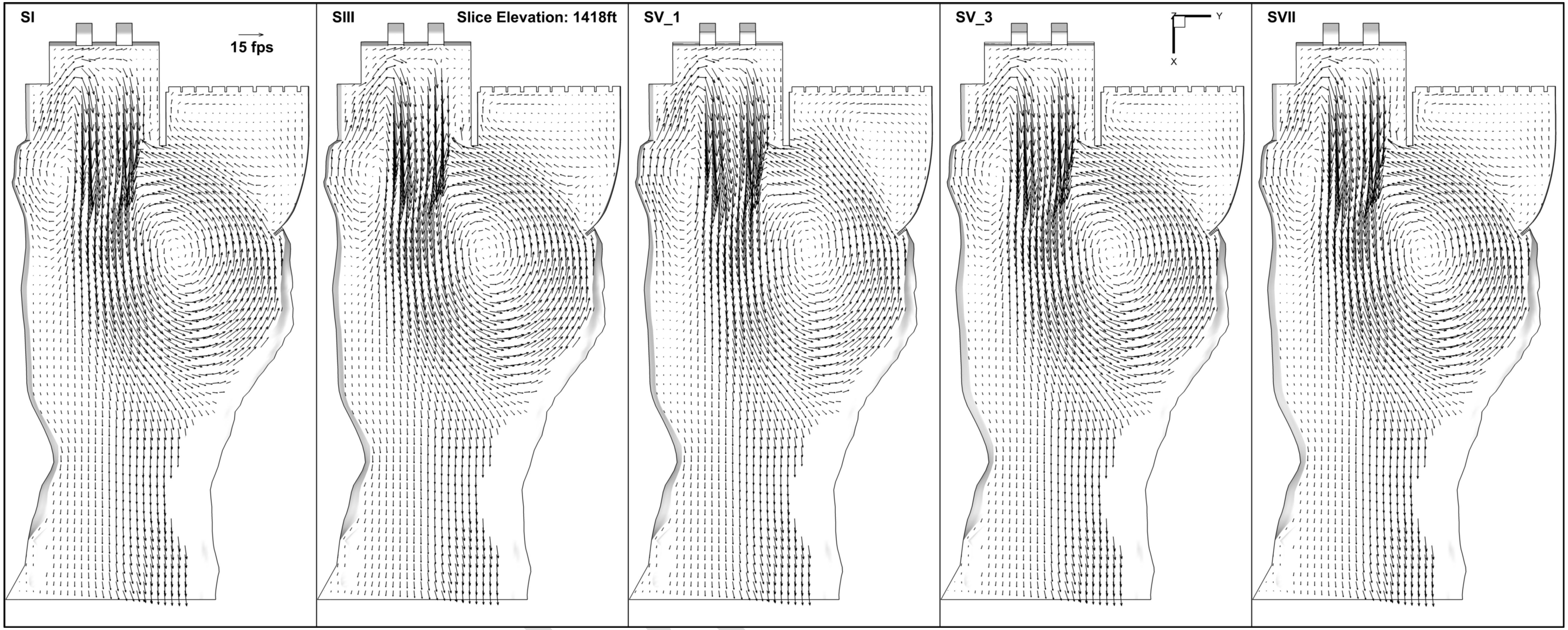


Figure 5-10. Velocity vectors at 1418 ft for 25 kcfs

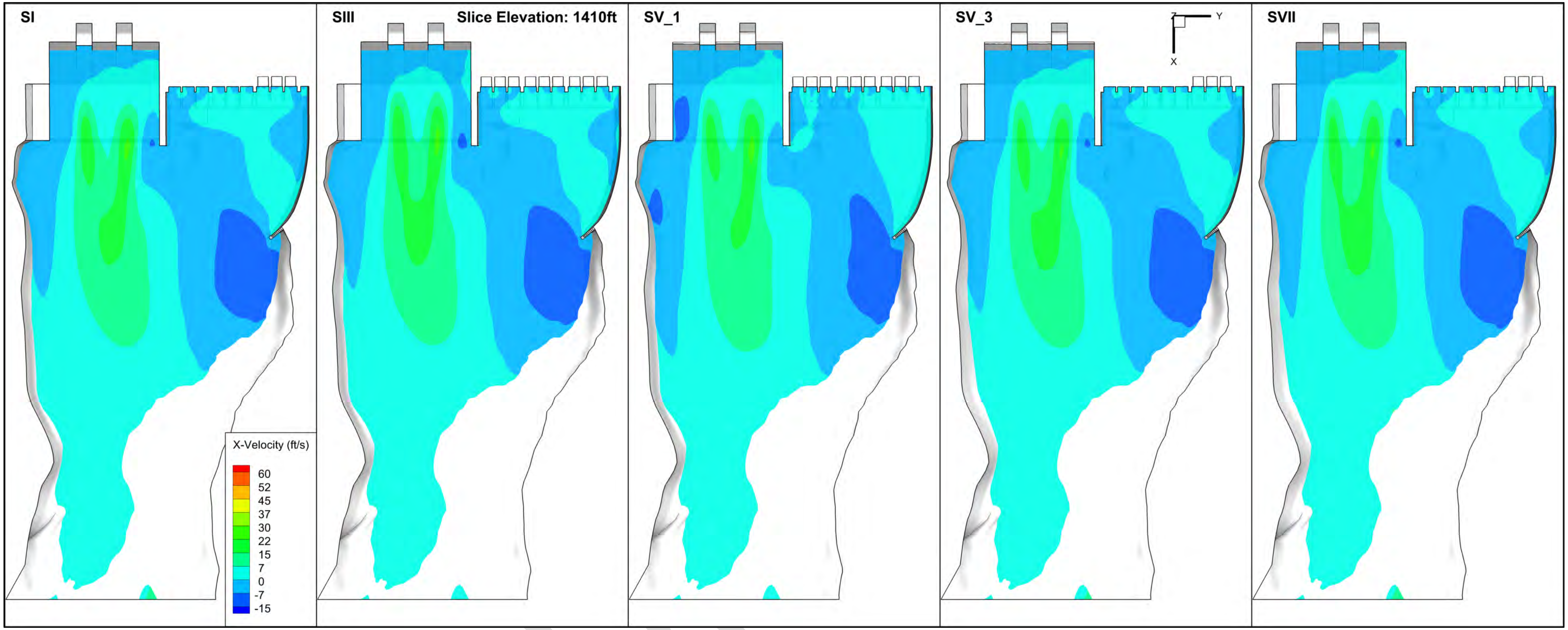


Figure 5-11. Velocity in the streamwise direction at 1410 ft for 25 kcfs

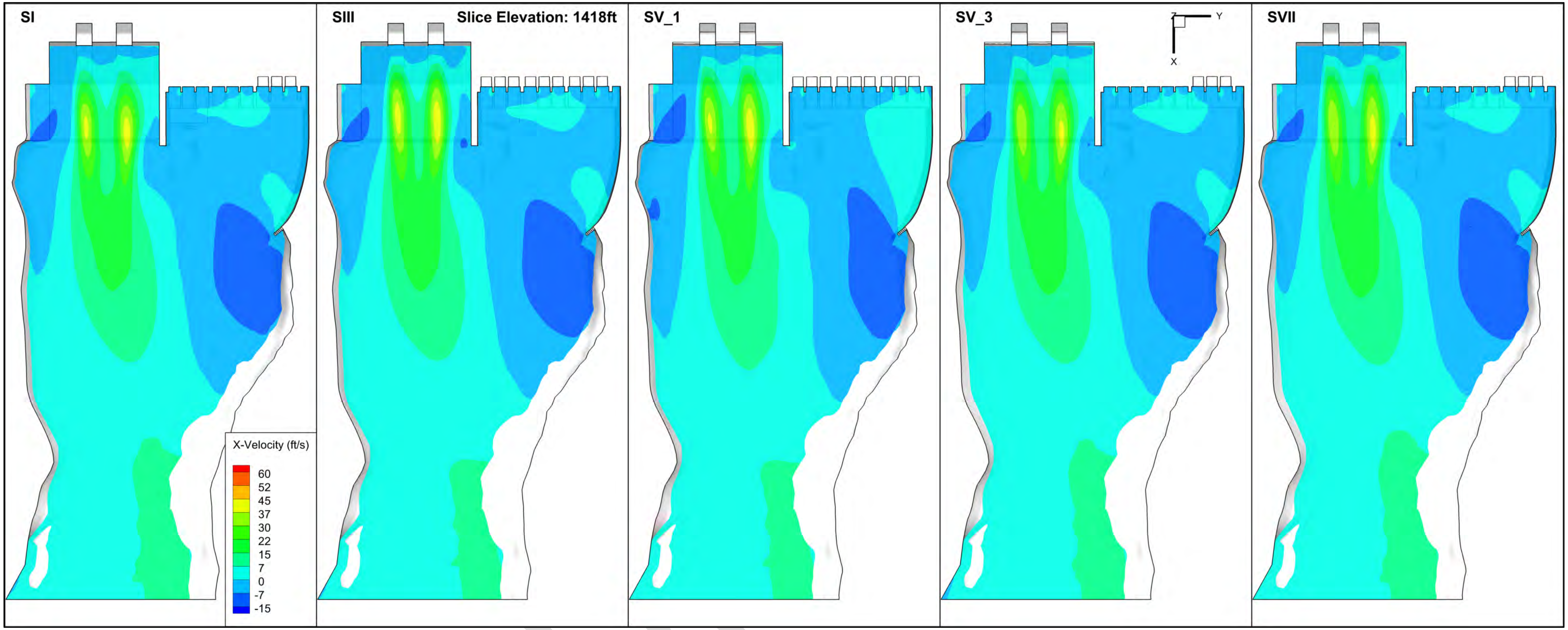


Figure 5-12. Velocity in the streamwise direction at 1418 ft for 25 kcfs

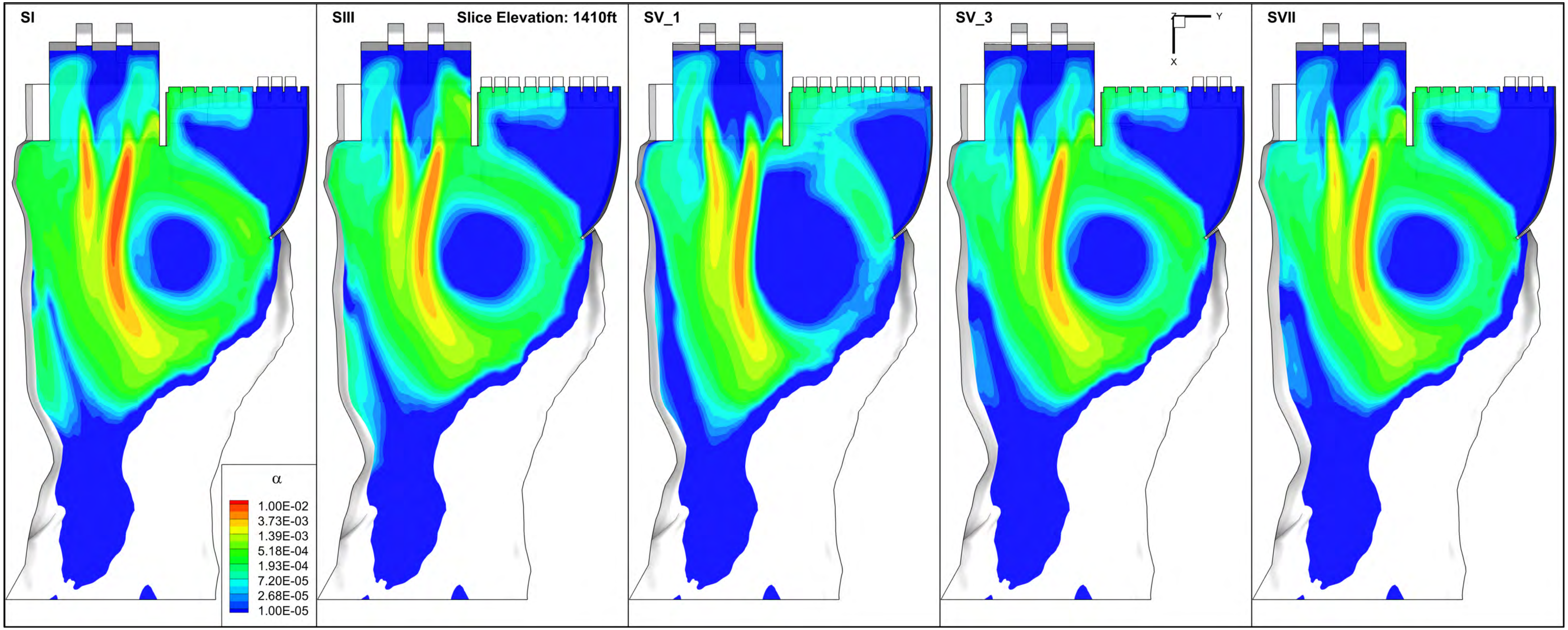


Figure 5-13. Gas volume fraction at 1410 ft for 25 kcfs

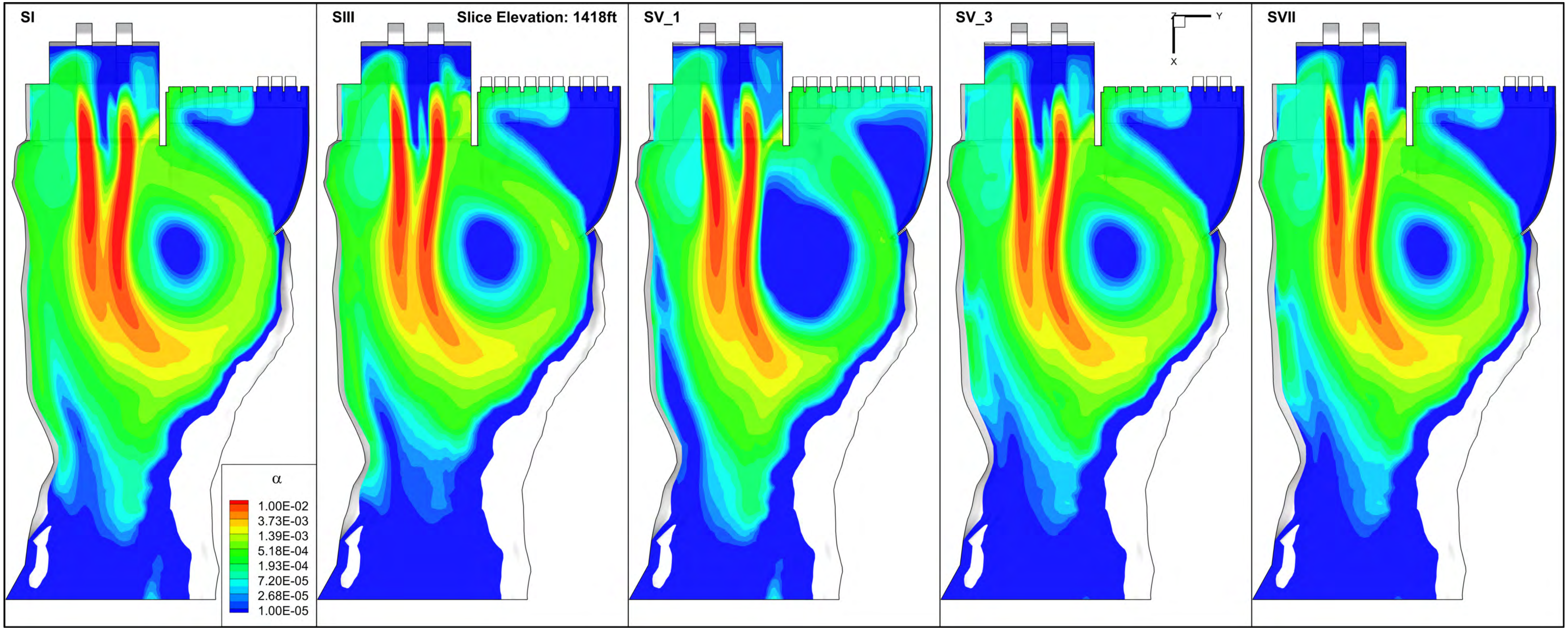


Figure 5-14. Gas volume fraction at 1418 ft for 25 kcfs.

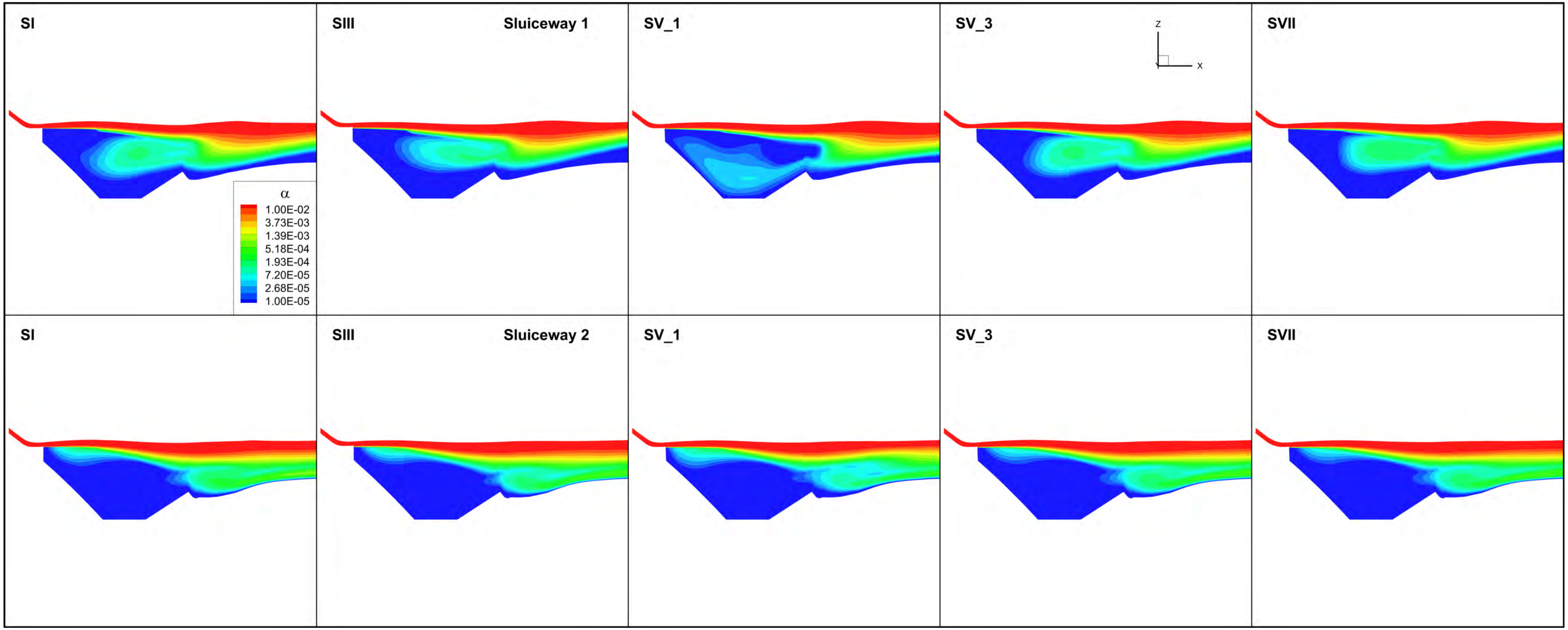


Figure 5-15. Gas volume fraction at vertical slices passing through sluiceway #1 and #2 for 25 kcfs.

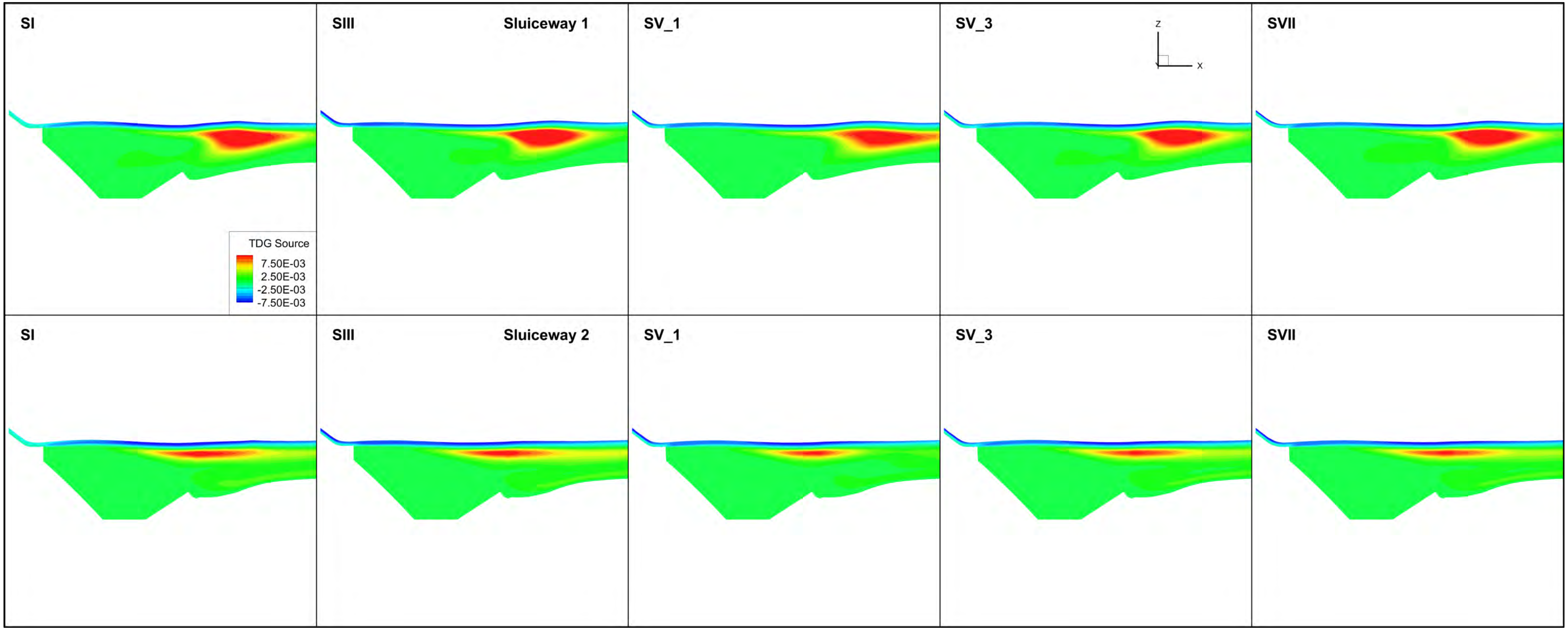


Figure 5-16. TDG source at vertical slices passing through sluiceway #1 and #2 for 25 kcfs

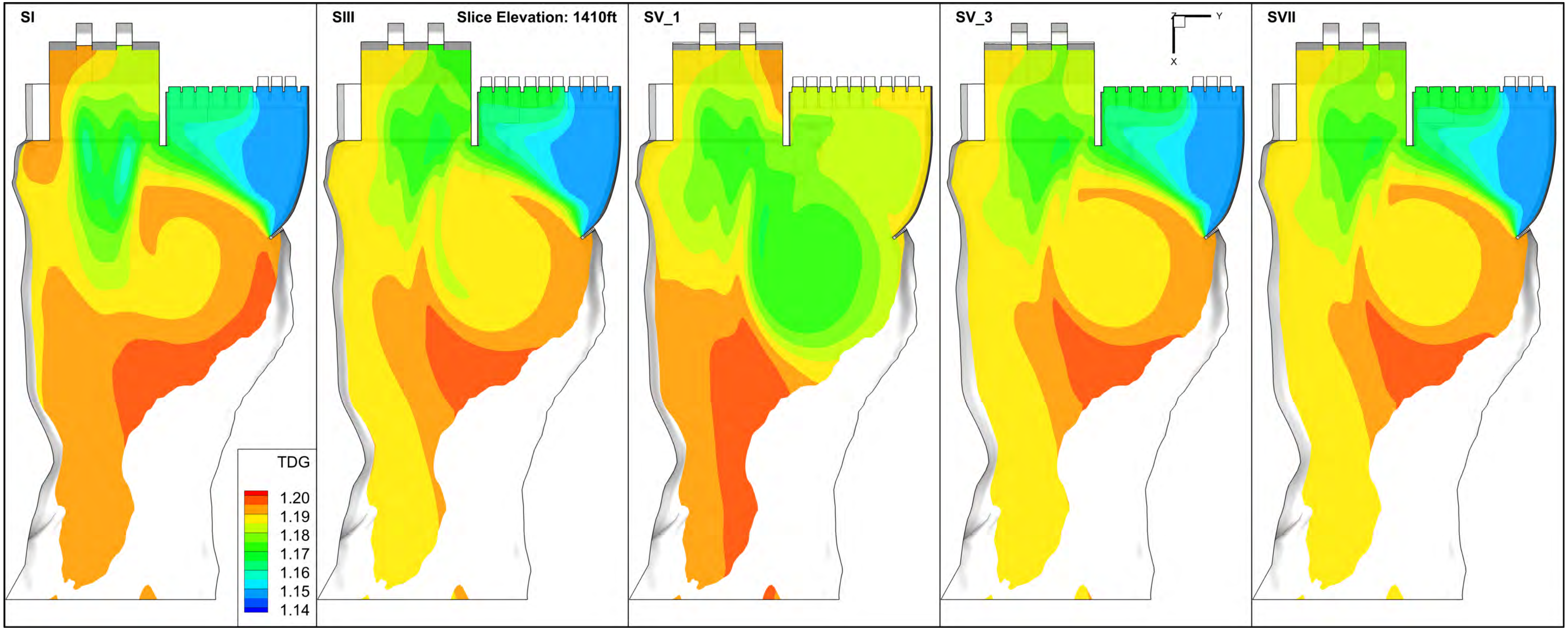


Figure 5-17. TDG distribution at 1410 ft for 25 kcfs

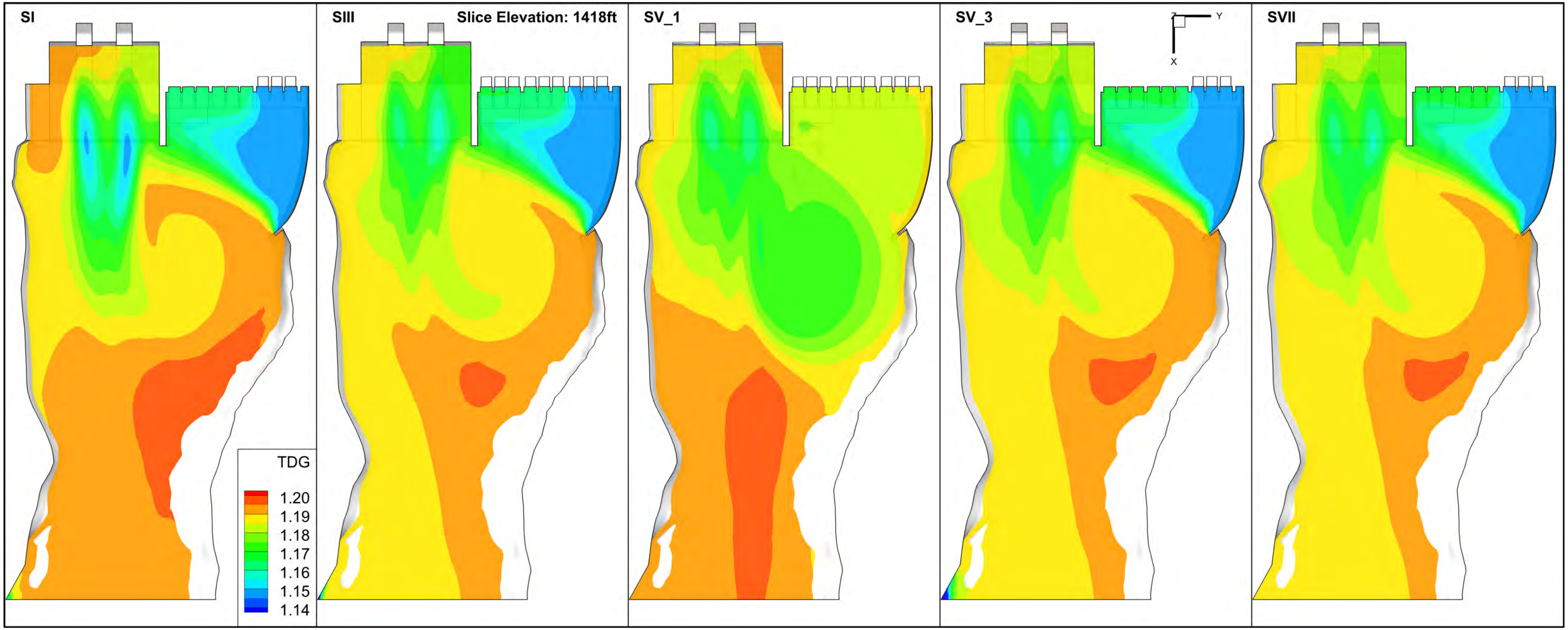


Figure 5-18. TDG distribution at 1418 ft for 25 kcfs

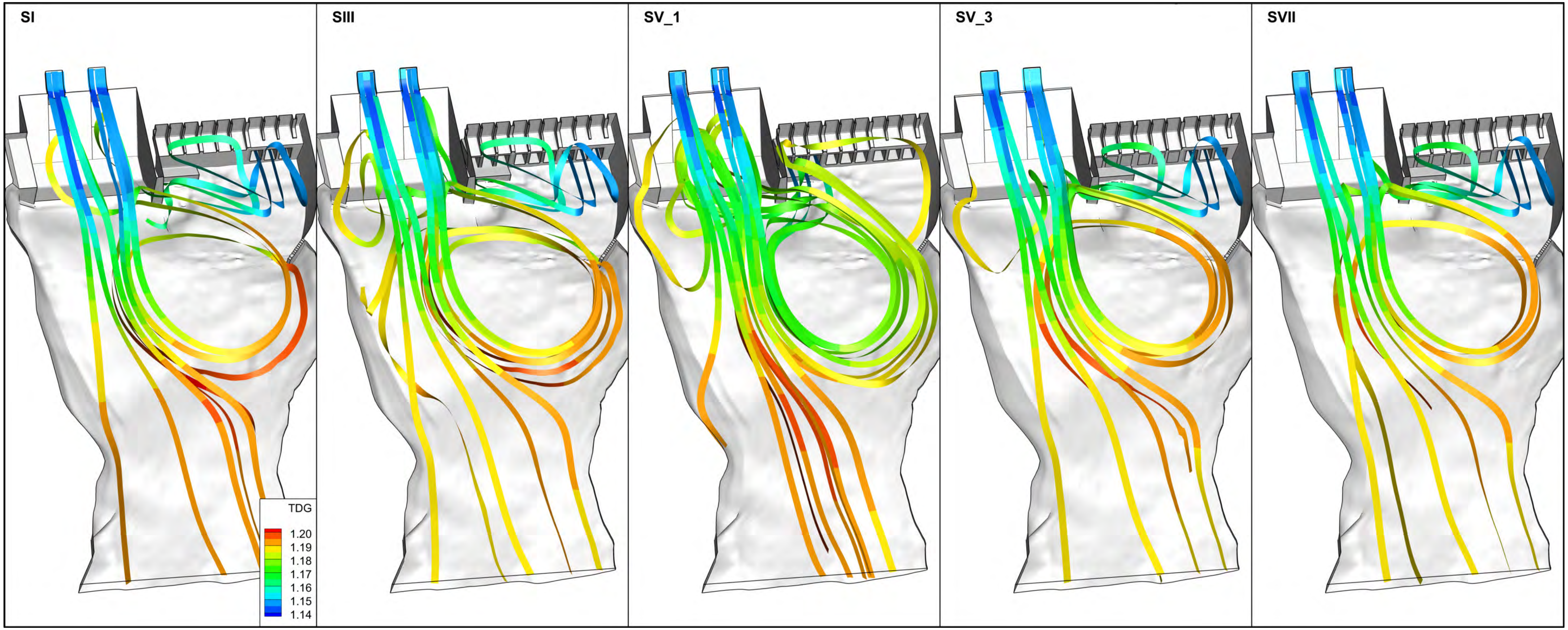


Figure 5-19. Streamlines colored by TDG distribution

Simulations with 45 kcfs

Figures 5-20 and 5-21 show velocity vectors at 1410 ft and 1424 ft (26.5 ft and 12.5 ft from the free surface), respectively. Surface jets are noticeable at 1424 ft. Water attraction by surface jets are clear for all simulated deflectors. A recirculation in the western region, downstream of the fish trap, is only predicted for the deflector with higher elevation. All deflectors produce an eddy in the western region. Contours of velocity in the streamwise direction are shown in Figures 5-22 and 5-23. Slightly weaker surface jets are predicted with the shorter deflector.

Figures 5-24 and 5-25 show gas volume fraction at elevations 1410 ft and 1424 ft. Some bubbles are entrained back into the spillway region by the eastern eddy, particularly for the shorter deflector and the one with larger curvature radius. Vertical slices in Figure 5-26 shows that more bubbles are entrained at depth downstream of sluice #1 in the tailrace with a shorter deflector. Model results indicate that the original deflector performs better to prevent bubbles traveling deep into the tailrace.

Figure 5-27 shows vertical distribution of TDG source. At 45 kcfs, TDG production is observed closer to the spillway (in the stilling basin) than predicted for 25 kcfs. This is consistent with elevated bubble concentration near the spillway for a higher tailwater elevation. A big curvature radius results in elevated TDG production downstream of the stilling basin. Figures 5-28 and 5-29 show TDG distribution at 1410 ft and 1424 ft, respectively. Consistent with higher TDG production, TDG concentration is higher for a shorter deflector and a deflector with larger curvature radius. TDG distribution is similar for the original and elevated deflectors. However, the deflector at higher elevation creates a recirculation zone near the western zone that might affect fish trap operation (Figure 5-30). Streamlines released from turbine units and spillways indicate that all water from powerhouse #1 is entrained in the spillway region while water from powerhouse units #2 and #3 flows along the main channel and west shore. This water, with low TDG concentration, increases the lateral gradient in the tailrace.

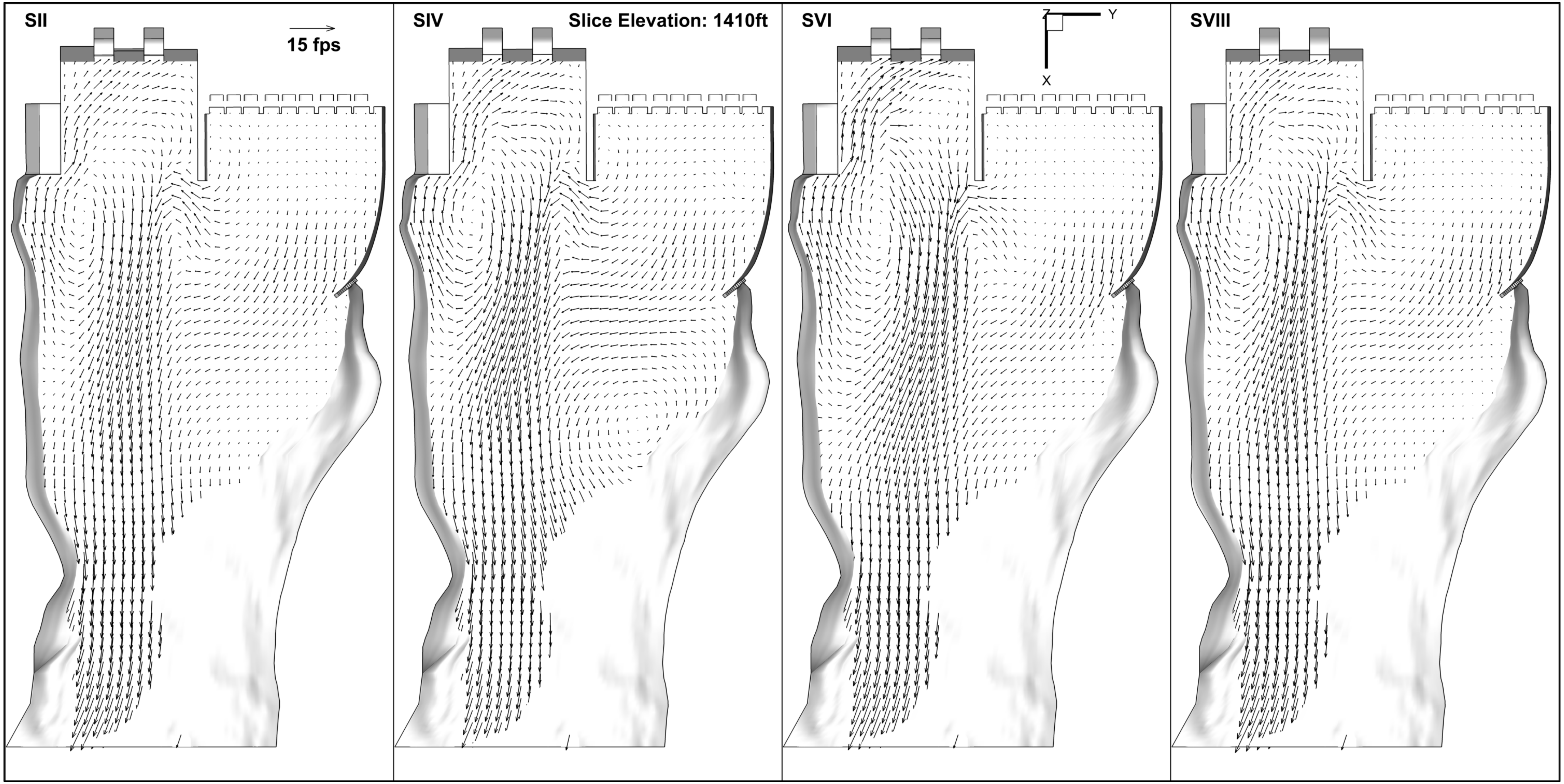


Figure 5-20. Velocity vectors at 1410 ft for 45 kcfs

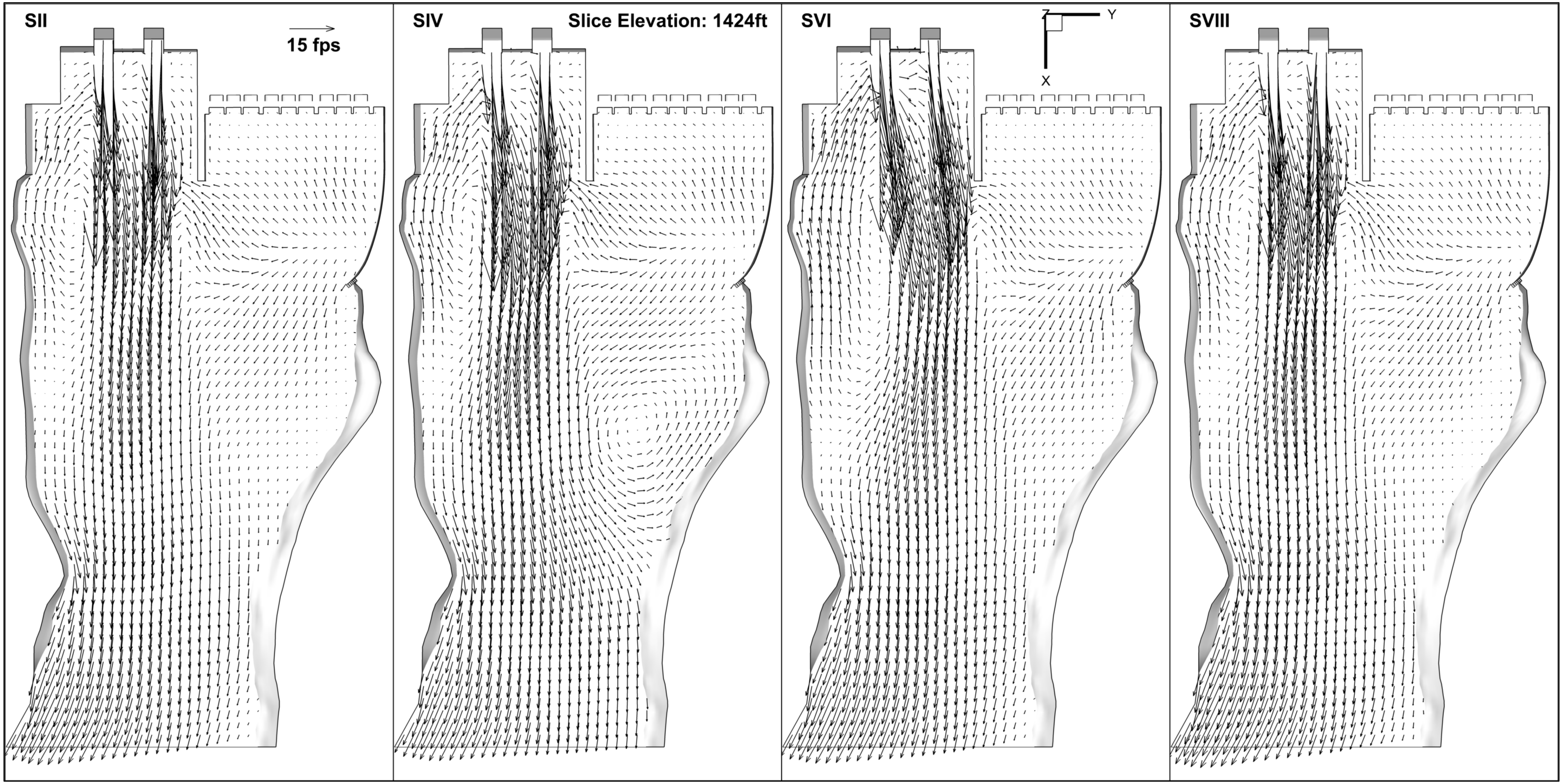


Figure 5-21. Velocity vectors at 1424 ft for 45 kcfs

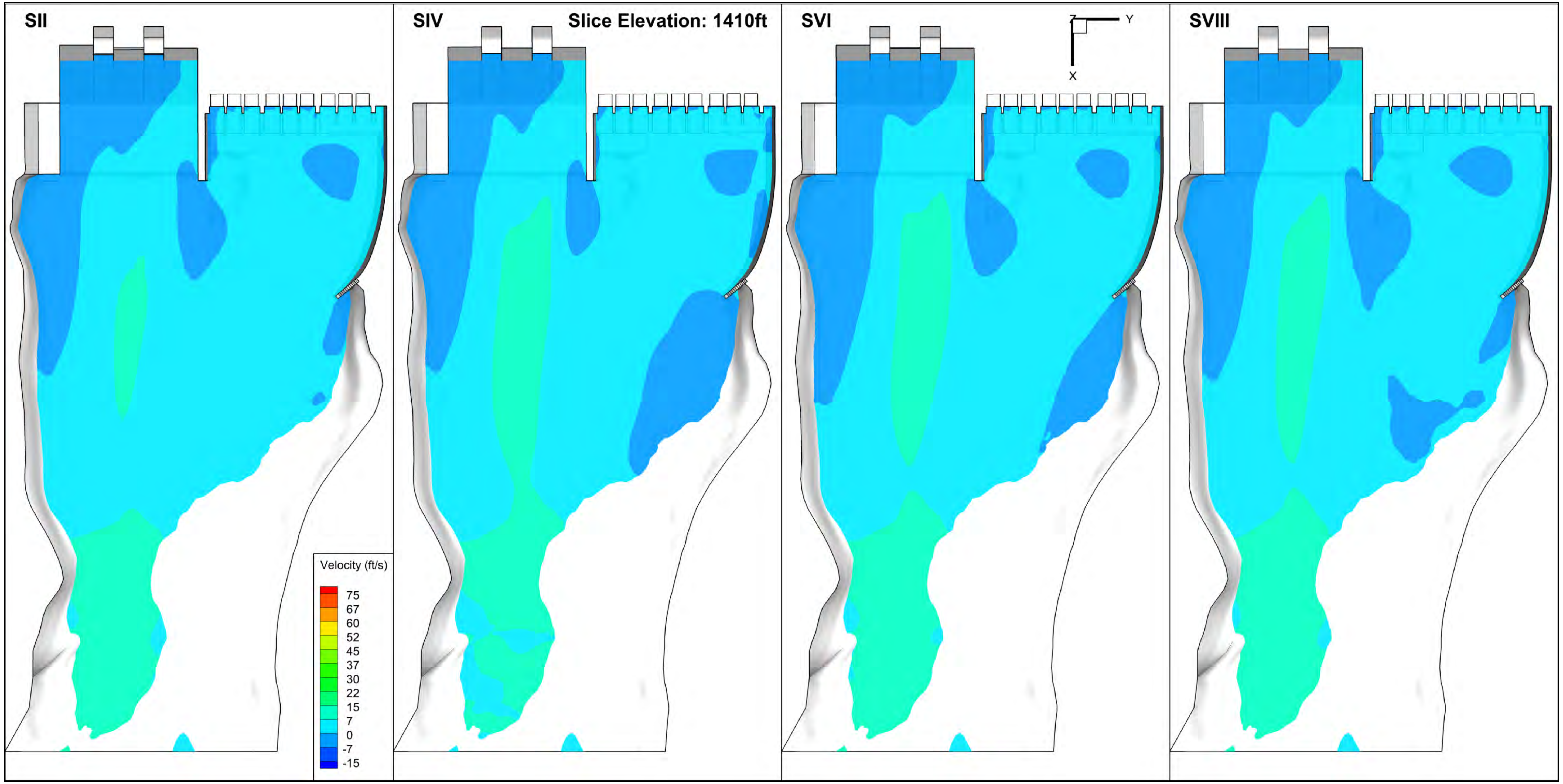


Figure 5-22. Velocity contours at 1410 ft for 45 kcfs

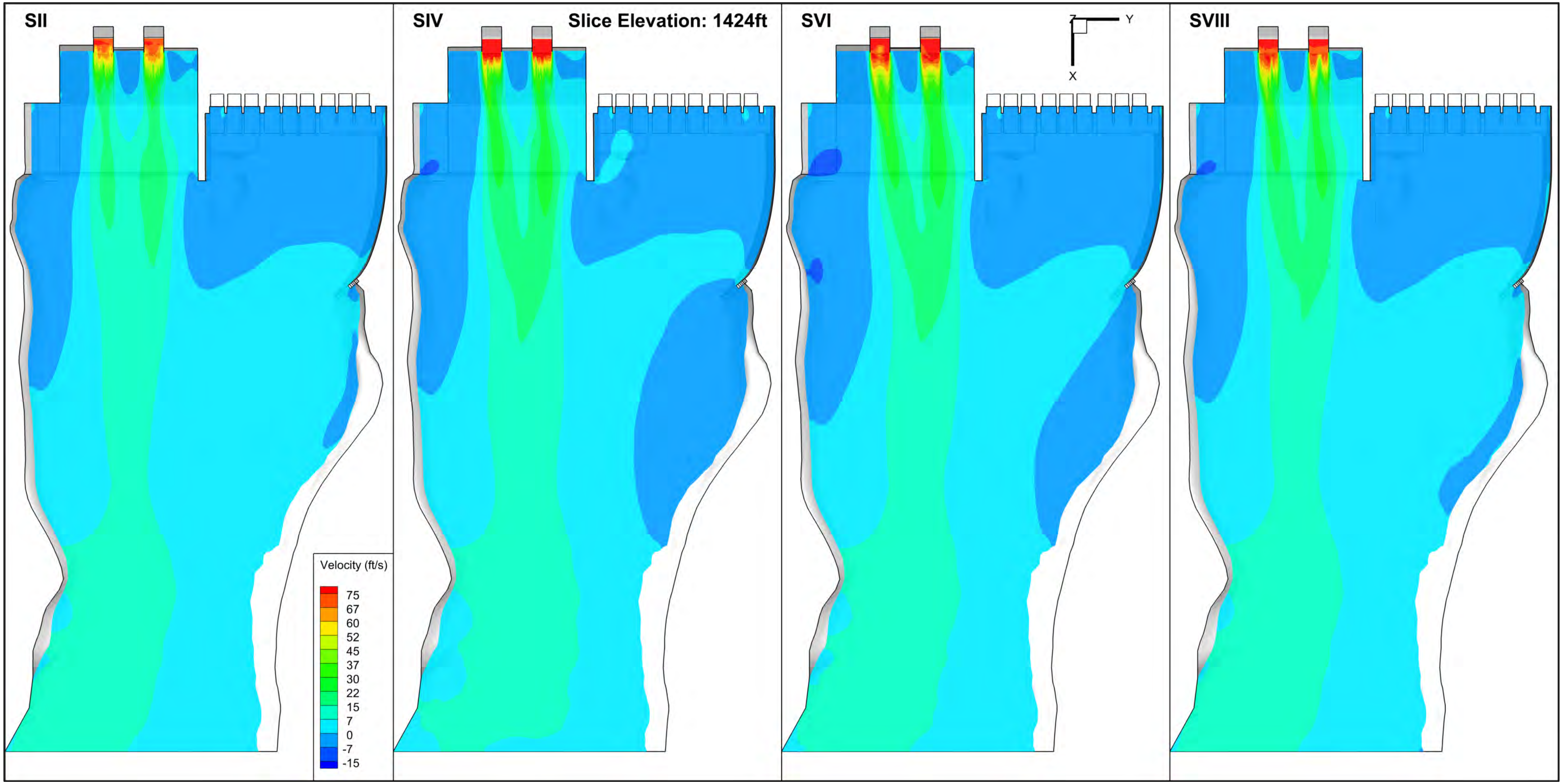


Figure 5-23. Velocity contours at 1424 ft for 45 kcfs

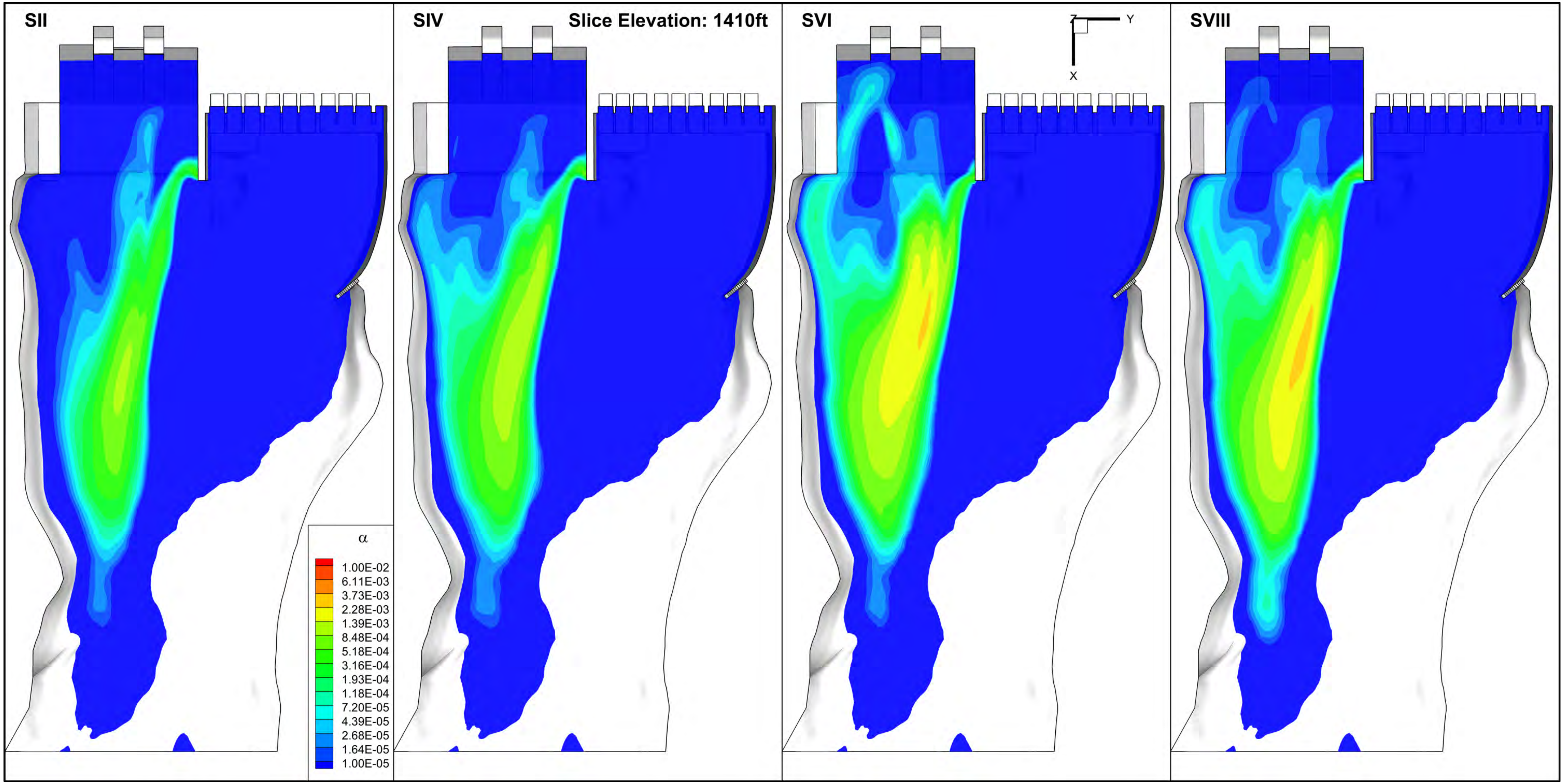


Figure 5-24. Gas volume fraction contours at 1410 ft for 45 kcfs

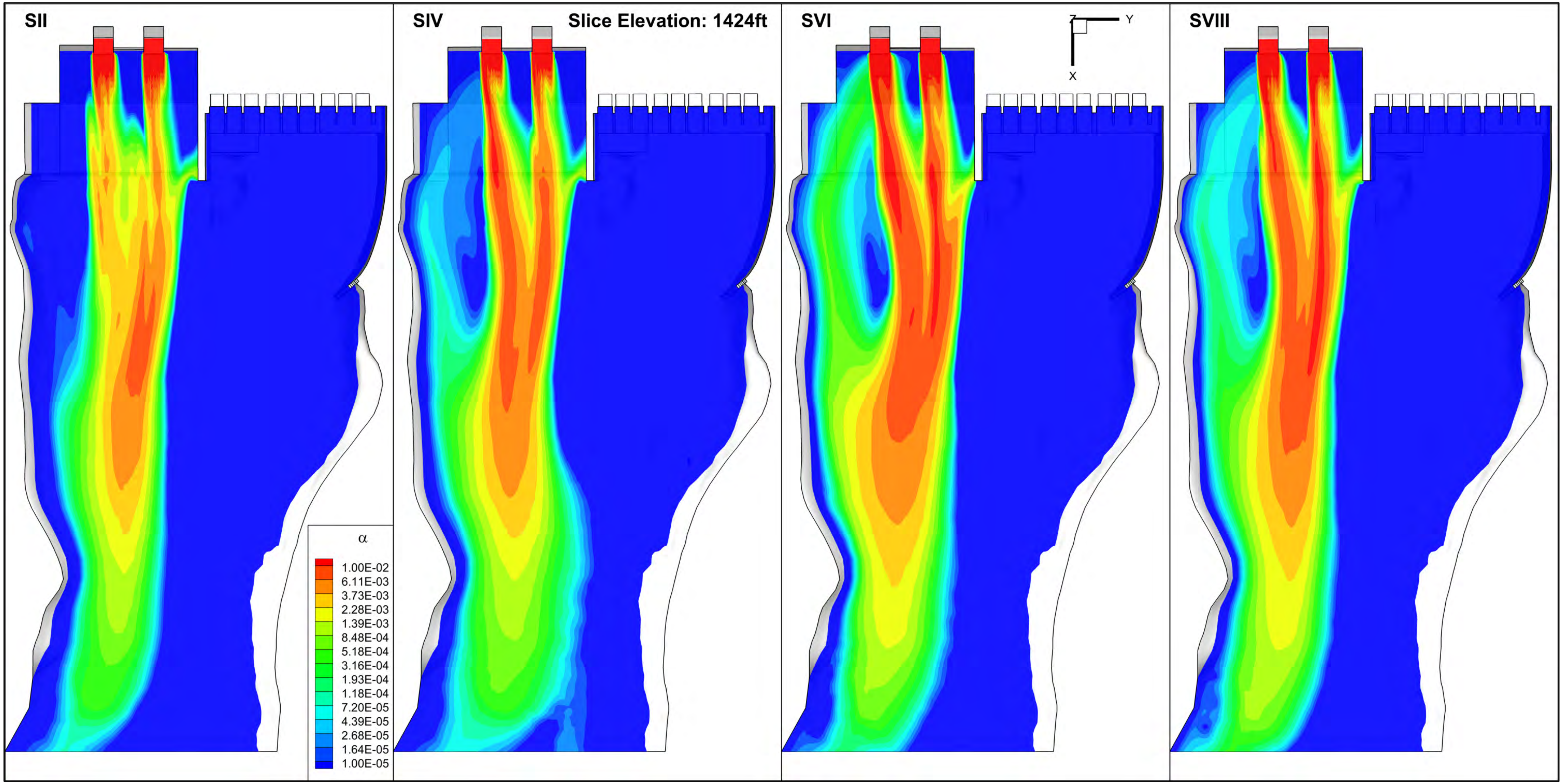


Figure 5-25. Gas volume fraction contours at 1424 ft for 45 kcfs

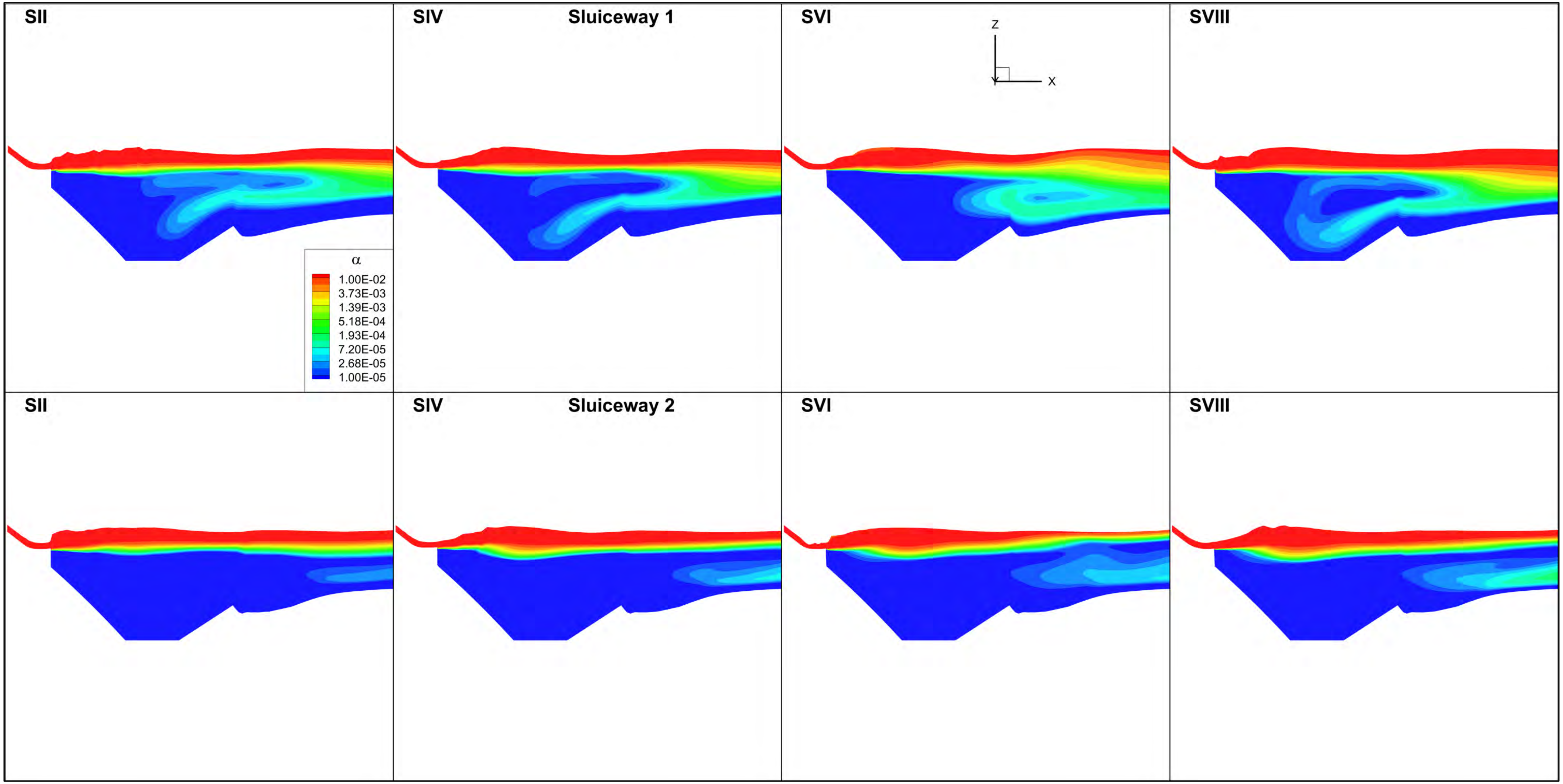


Figure 5-26. Gas volume fraction contours at vertical slices passing through sluiceway #1 and #2 for 45 kcfs

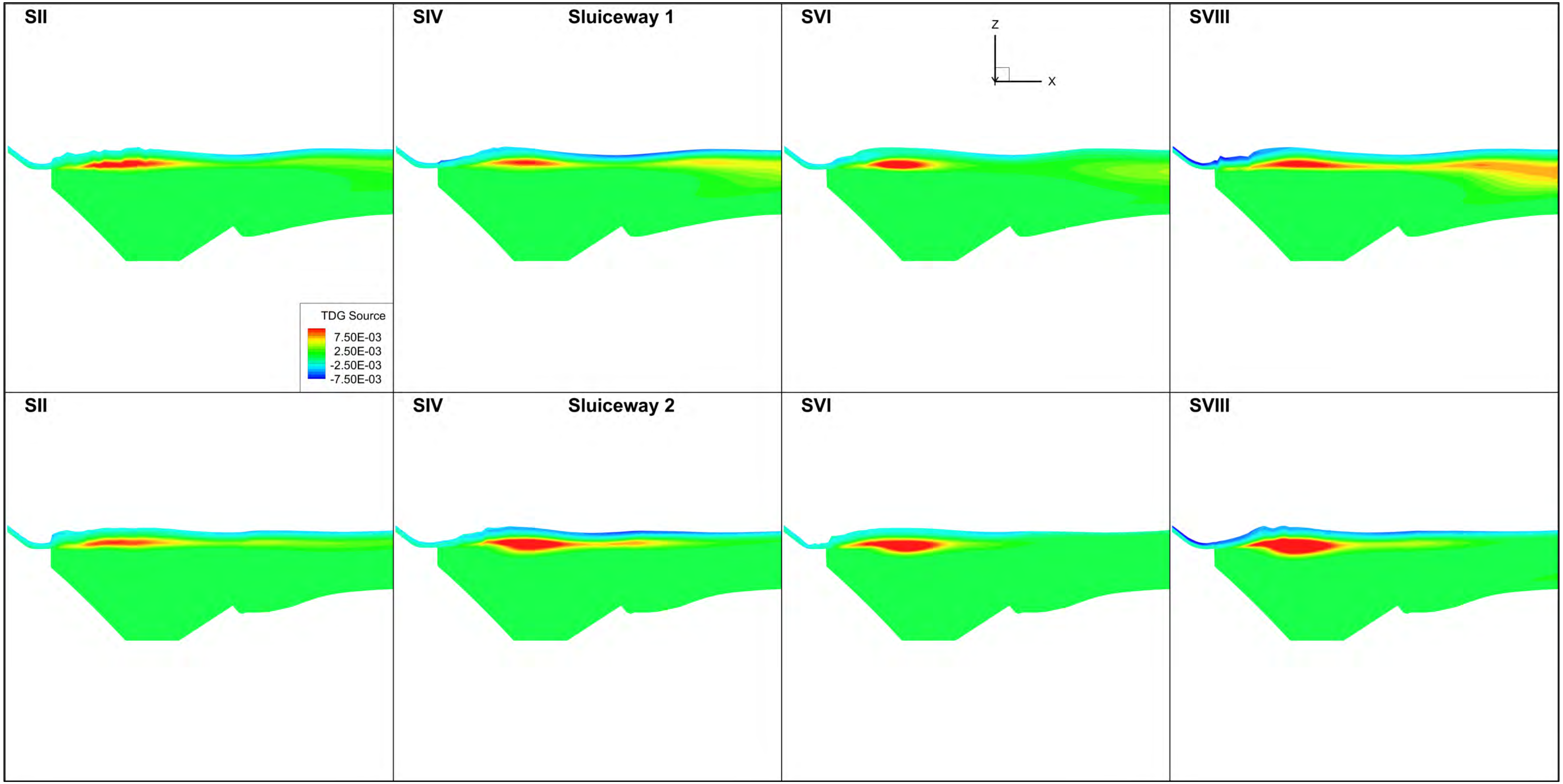


Figure 5-27. TDG production at vertical slices passing through sluiceway #1 and #2 for 45 kcfs

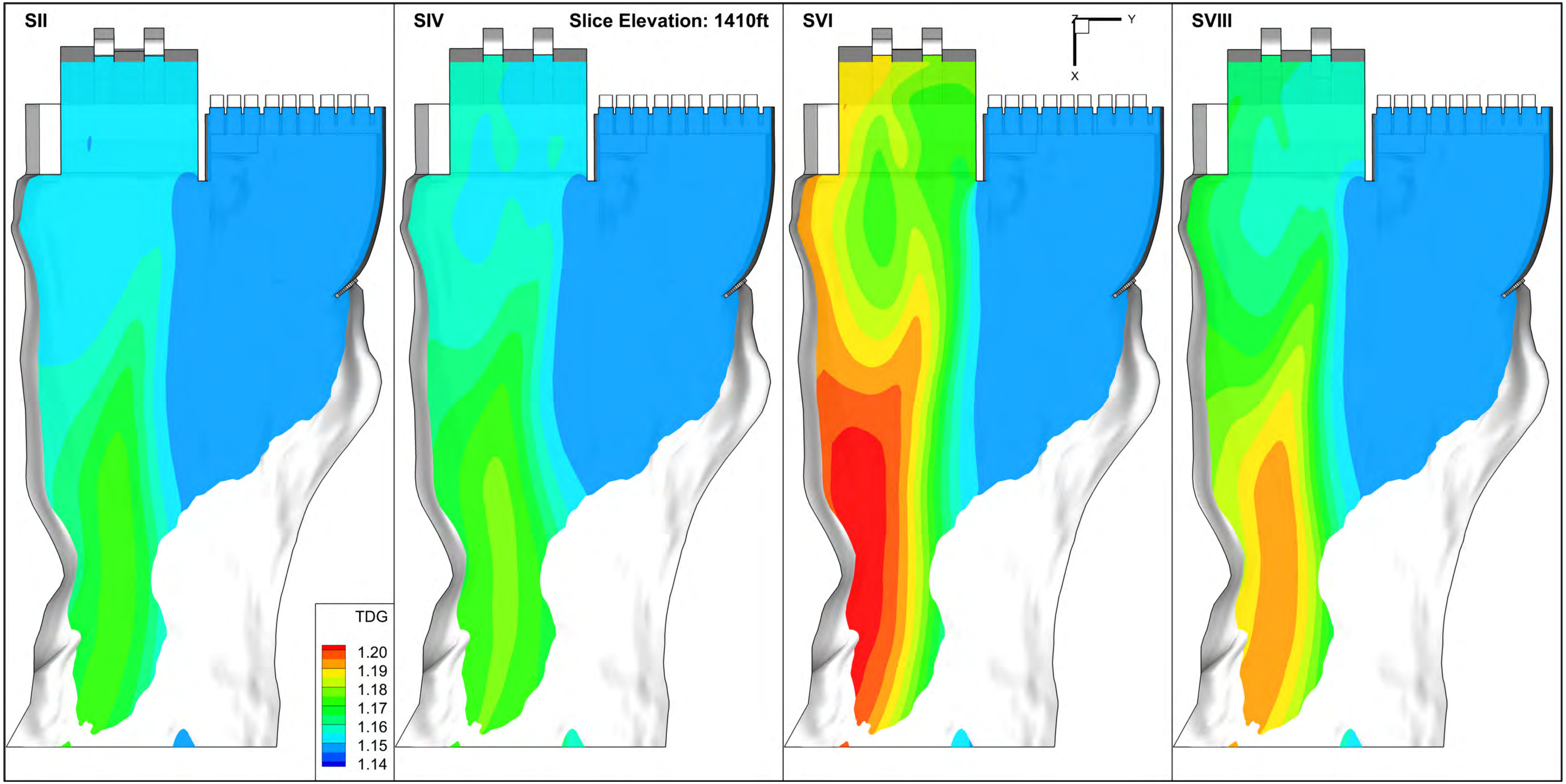


Figure 5-28. TDG contours at 1410 ft for 45 kcfs

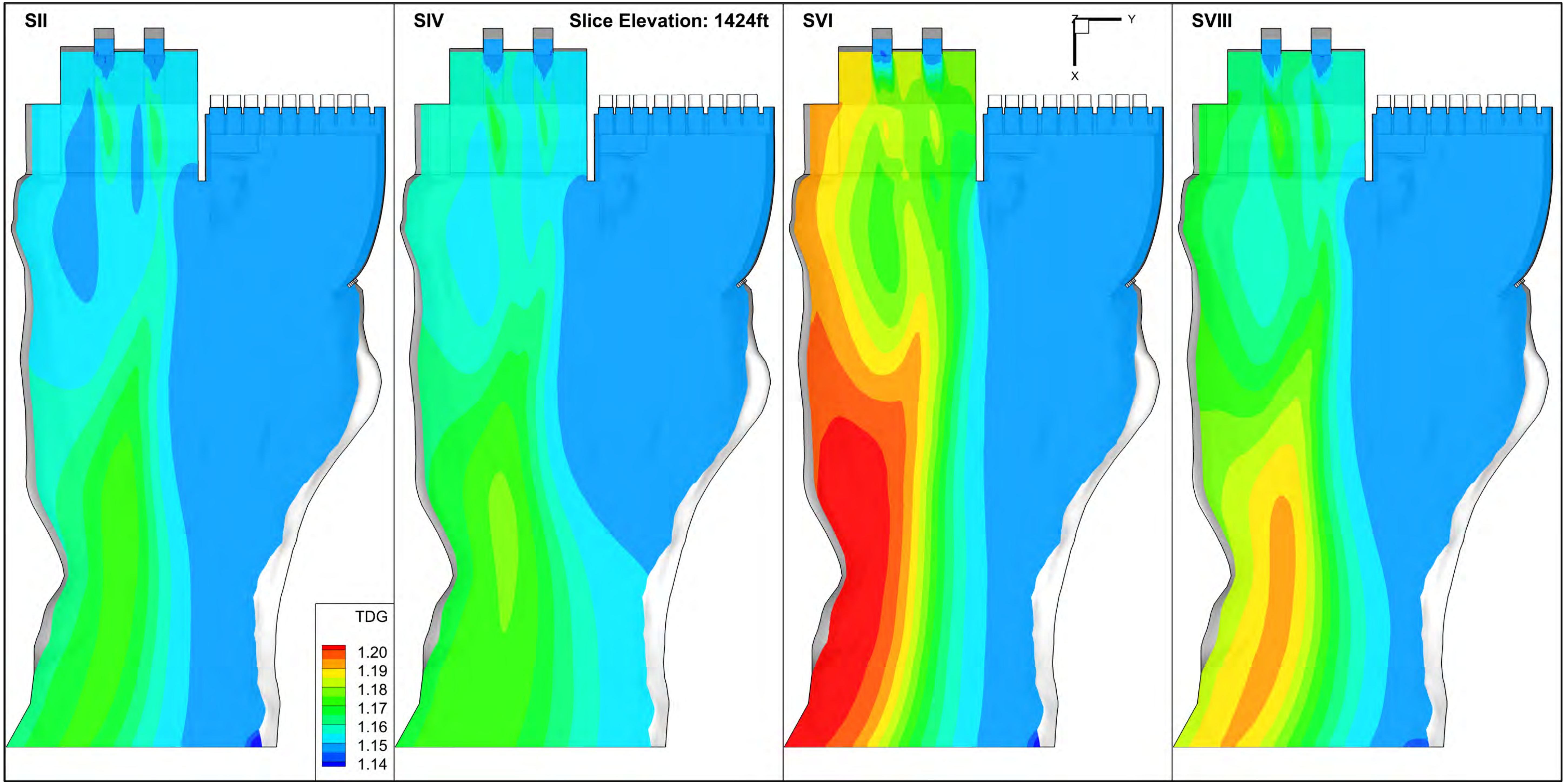


Figure 5-29. TDG contours at 1424 ft for 45 kcfs

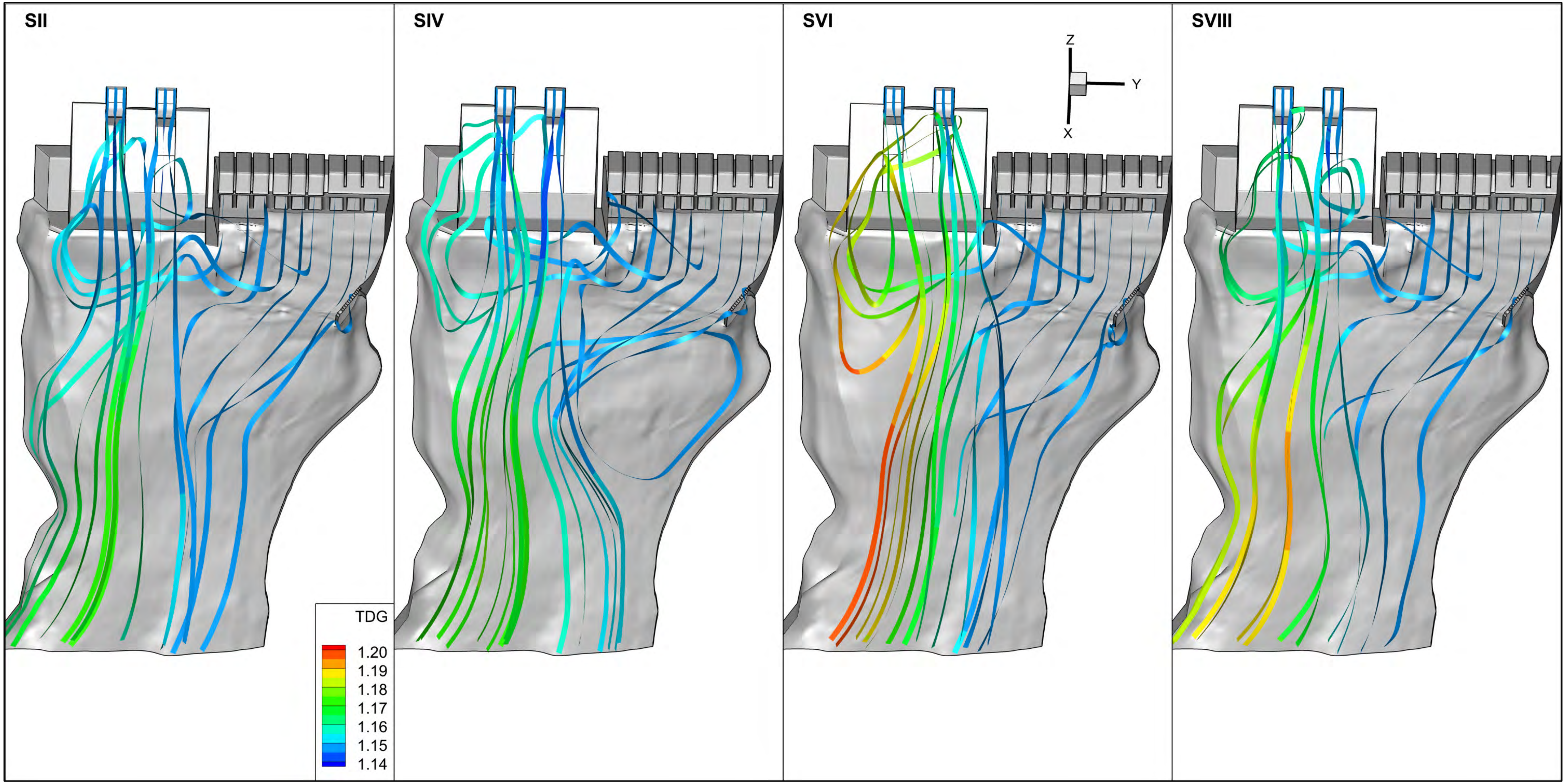


Figure 5-30. Streamlines colored by TDG for 45 kcfs

Powerhouse Entrainment

The lateral flow induced by spillway jets is estimated calculating flowrates in the planes shown in Figure 5-31. Only water flowing from the powerhouse towards the spillway region is considered, i.e. flows in the positive y-direction (red zone in Figure 5-31) are not computed.

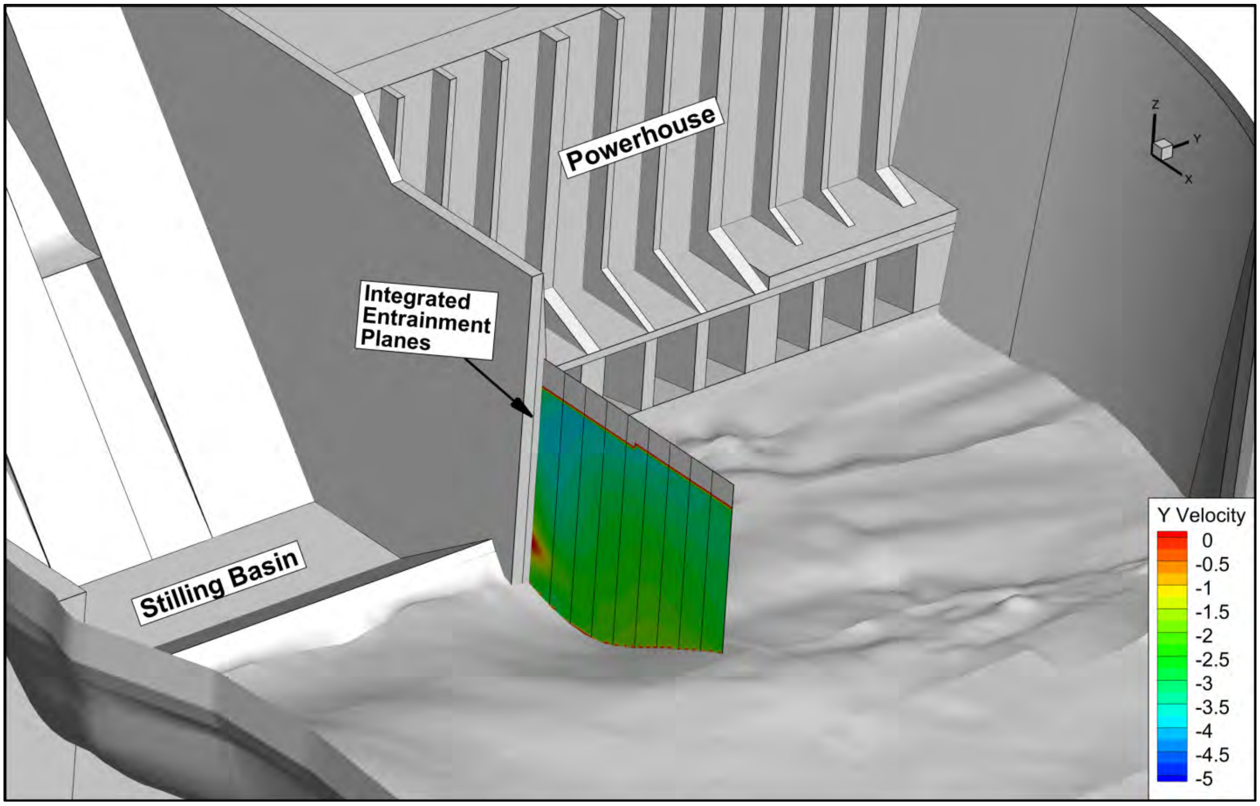


Figure 5-31. Planes used to compute powerhouse entrainment

Figures 5-32 and 5-33 show the powerhouse entrainment for 25 kcfs and 45 kcfs, respectively. Note that lateral flow for 25 kcfs is larger than powerhouse flows indicating that water from the spillway region entrained by the western eddy is entrained back towards the spillway region. The simulation with powerhouse unit #1 operating entrains slightly more water near the dam than operations with unit #2. However, the water attraction diminishes with the distance from the dam and the net total powerhouse entrainment is smaller when operating with unit #1. Lateral flows are similar for all tested deflectors, being a little larger for the deflector at higher elevation.

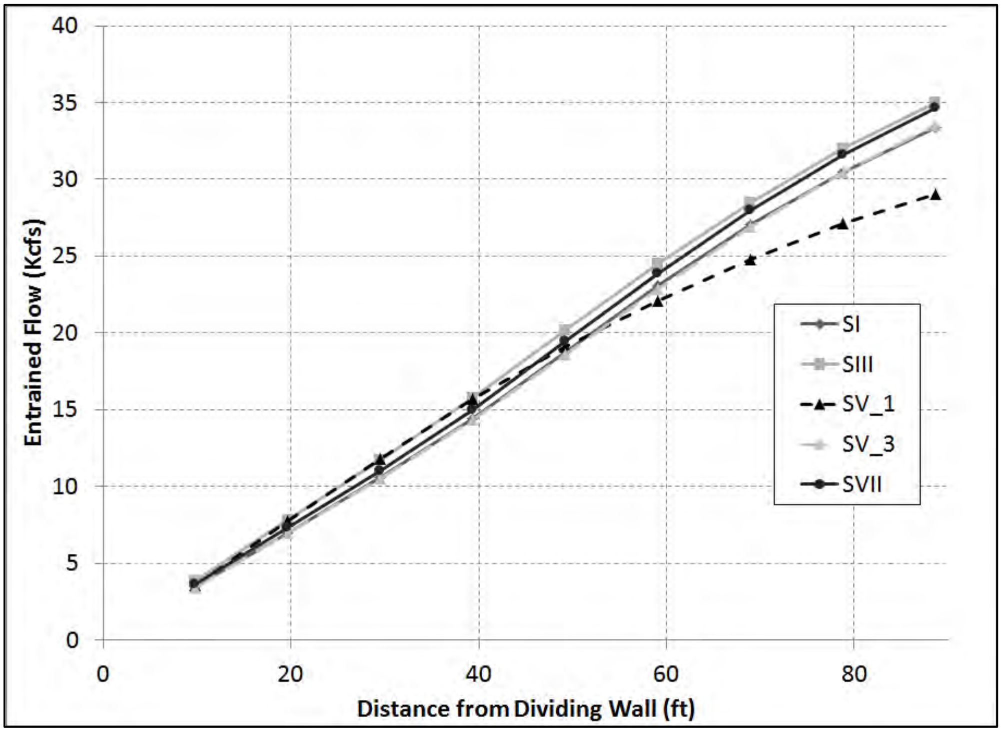


Figure 5-32. Powerhouse entrainment for 25 kcfs

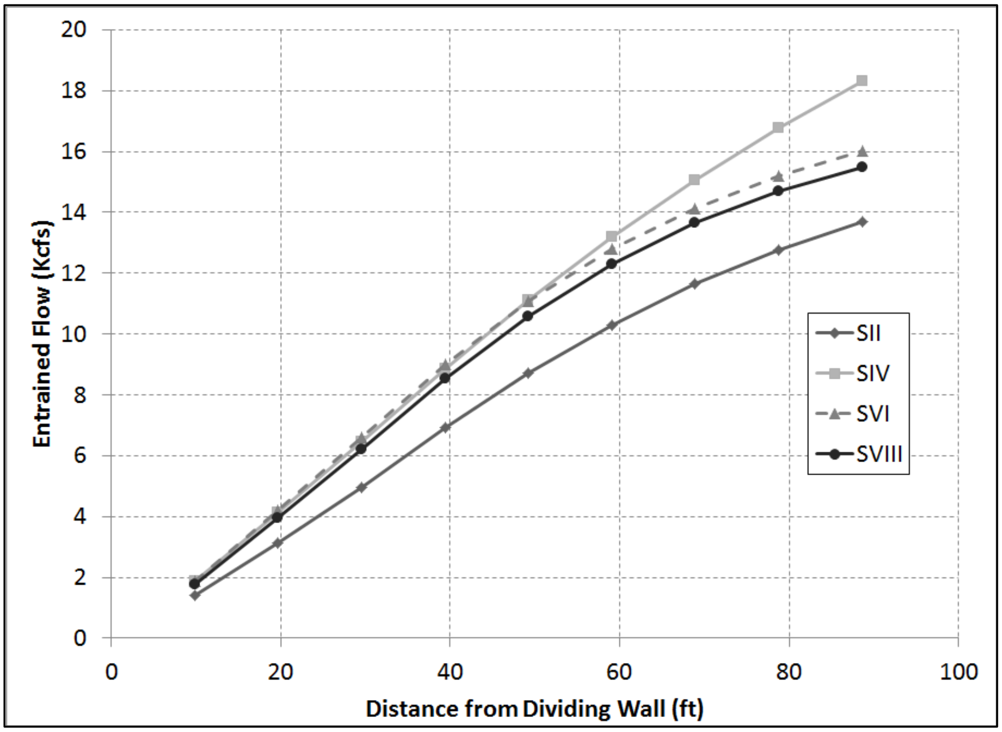


Figure 5-33. Powerhouse entrainment for 45 kcfs

Water Surface Elevation near the Fish Trap

Fish trap regions modeled for the 25 kcfs and 45 kcfs simulations do not include the region around the second, high flow, fish trap entrance since the predicted water surface elevation is lower than the entrance elevation. Therefore, for these flowrates, wave characteristics near the fish trap were computed extracting water surface elevation only near the lower fish entrance. Figures 5-34 and 5-35 show the water surface elevation for 25 kcfs and 45 kcfs, respectively. According to the model, water surface fluctuations for all simulated deflectors are minor. Initial fluctuations are a result of unsteadiness when the simulations started from an arbitrary condition (zero velocity or interpolation from another operational condition). After the flowrate at the exit was steady and when the deflector is installed, waves near the fish trap are insignificant.

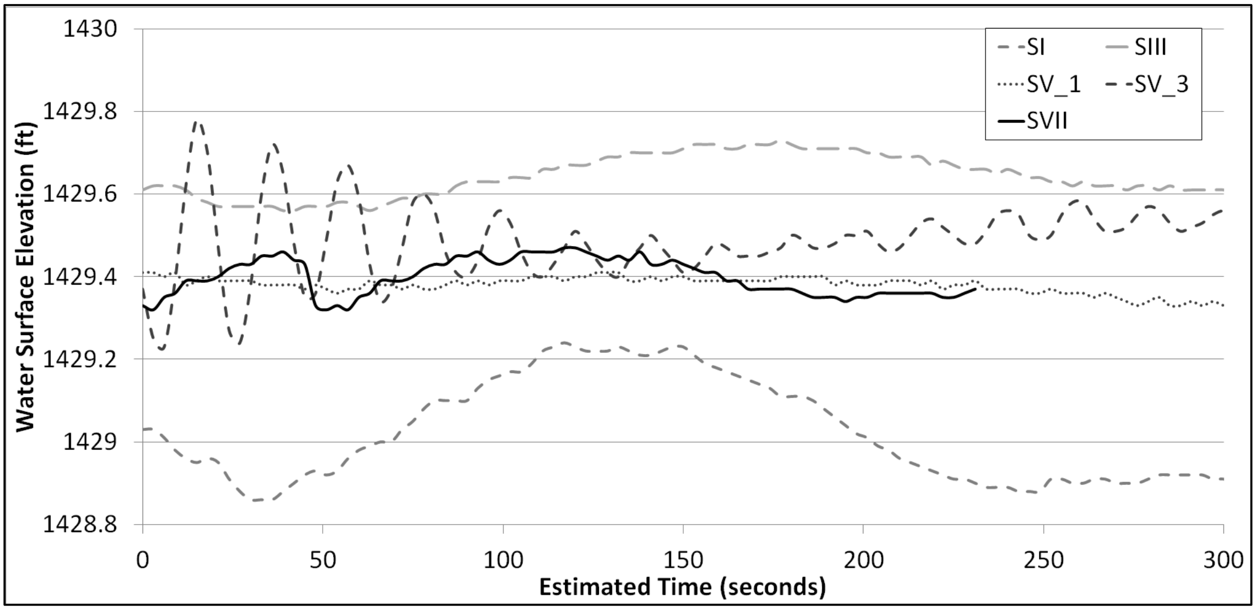


Figure 5-34. Water surface elevation for 25 kcfs

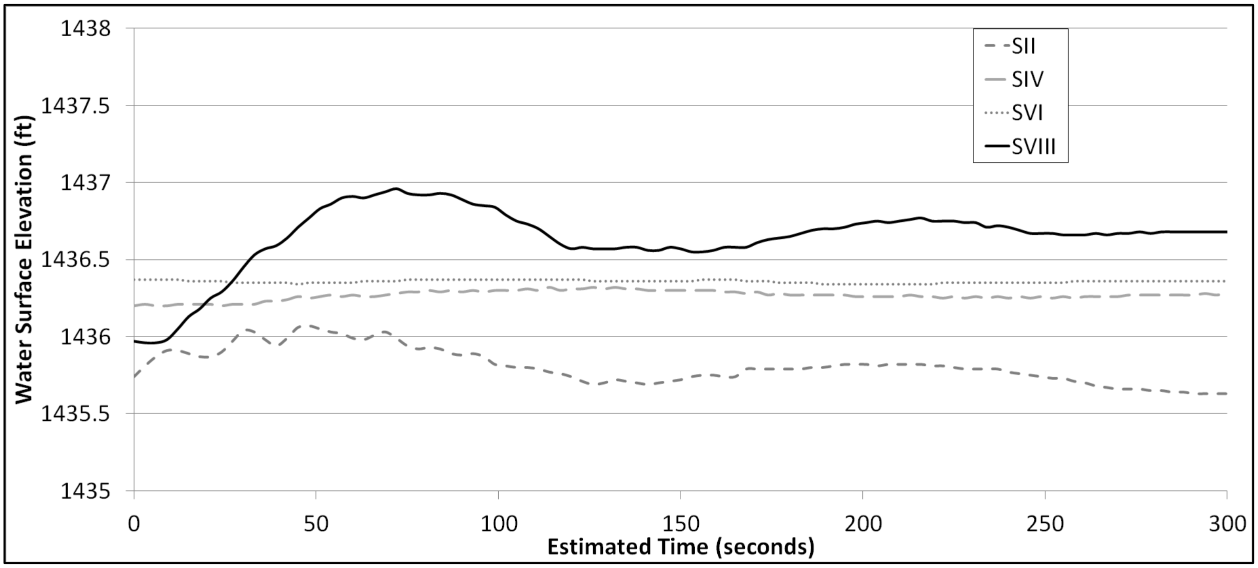


Figure 5-35. Water surface elevation for 45 kcfs

Deflector Selection

Deflectors change the flow pattern considerably in the tailrace. Surface jets created by deflectors attract water from the powerhouse creating an important eddy in the western zone. For the same sluiceway flow, decreasing powerhouse flows increase the strength of the recirculation. At 45 kcfs, the recirculation is negligible for all simulated deflectors with exception of the higher deflector, which produce a small recirculation near the fish trap.

A negligible number of bubbles is transported to depth and TDG production is small for all simulated deflectors. At 25 kcfs, no significant difference in TDG production is observed for all tested geometries. At 45 kcfs, more water plunges downstream of the stilling basin with a shorter deflector producing the highest TDG values. A bigger transition radius results also in slightly higher TDG production. The capability to reduce TDG of the original and elevated deflectors is similar.

Simulation results indicate that the original length and transition radius are the best to reduce TDG production. Increasing the elevation seems to induce powerhouse entrainment and strengthen the western recirculation. Based on the model results, the original deflector is recommended to be installed in the spillway of Hells Canyon Dam and it will be used in future simulations.

6. DEFLECTOR PERFORMANCE

VOF Simulations

Figures 6-1 to 6-3 show VOF results with the selected deflector for 37 kcfs, 45 kcfs and a 7Q10 flow. For comparison, plots for a 7Q10 flow without deflector are also included in all figures. In these simulations, all powerhouse units are operating with maximum capacity at 10 kcfs. Figure 6-1 shows the predicted free surface colored by elevation. The water surface elevation near the spillway is lower when deflectors are installed due to the effect of high velocity surface jets. Note that, for a 7Q10 flow, deflectors create a deflection of the water elevation of approximately 15 ft. In the simulation with spillway flows without deflector, a highly unsteady free surface with important wave generation near the spillway is predicted. Wave amplitude can be of the order of 20 ft. For this flowrate, water elevation near the fish trap is significantly reduced (about 9 ft) due to the inclusion of the deflectors.

Velocity vectors at a horizontal slice at 1430.4 ft is shown in Figure 6-2. Noticeable is the effect of the surface jets on the flow pattern. At the lowest flowrate, jets move downstream toward the eastern zone creating a small recirculation near the spillway. On the other hand, at 7Q10 flows a big recirculation is predicted at the western region altering completely the flow pattern near the fish trap.

Figure 6-3 shows the predicted jet regimes. At low flowrates, the deflectors create surface jets or surface jumps, which minimize bubbles entrained at depth and TDG production. However, for a 7Q10 flow surface jets plunge downstream of the stilling basin, with potential of elevated generation of TDG. The plunging is more visible downstream of sluice #1 due to the effect of lateral flows. Water flowing over the spillway without deflectors plunges deep into the stilling basin creating a hydraulic jump. This regime is the most critical for TDG production since air entrainment is increased during the plunging and also entrained bubbles are transported to depth. In addition, back rolls can increase the bubble residence time and the elevated turbulence of the phenomenon enhances further bubble dissolution.

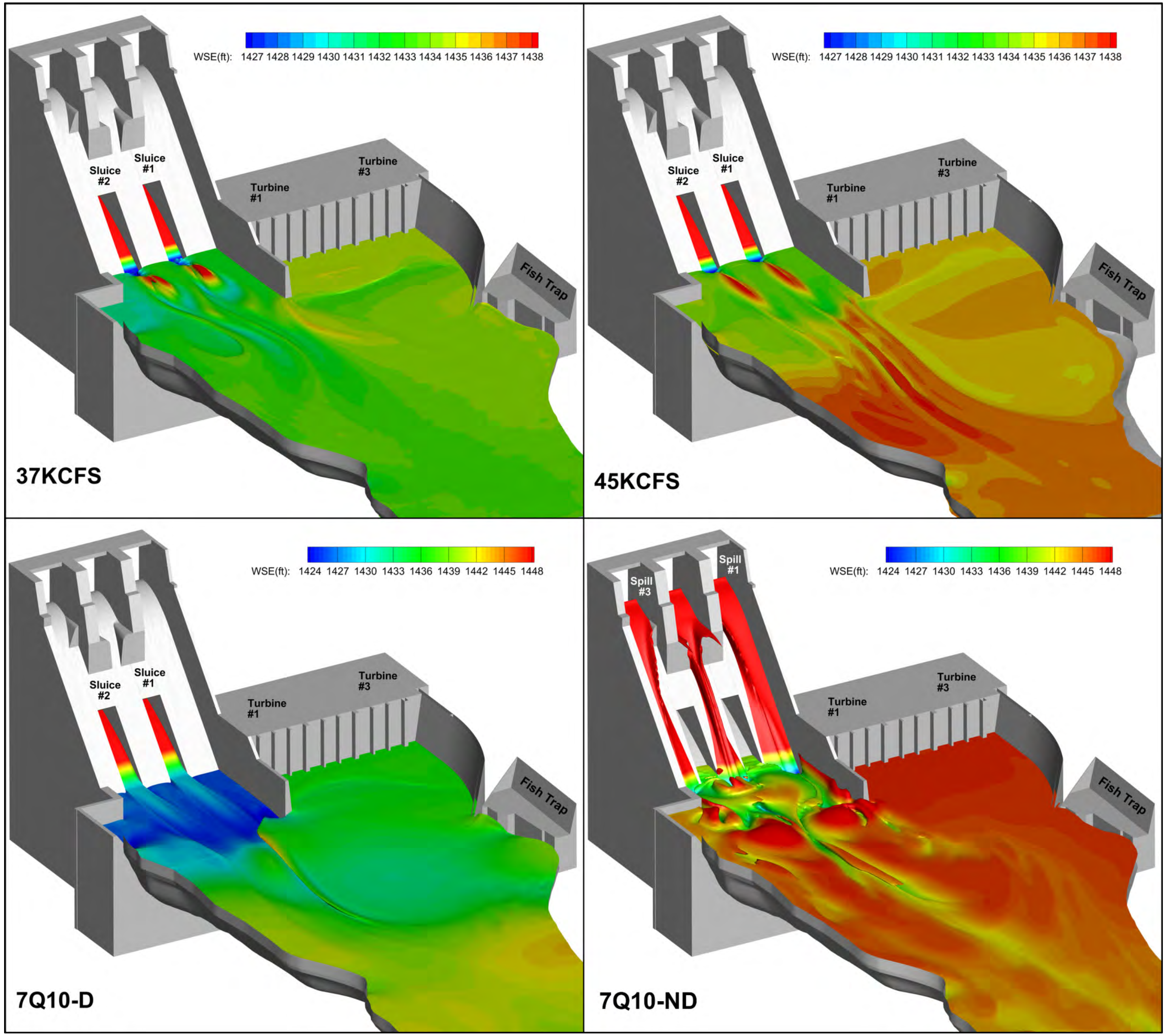


Figure 6-1. Free surface colored by elevation for selected deflector

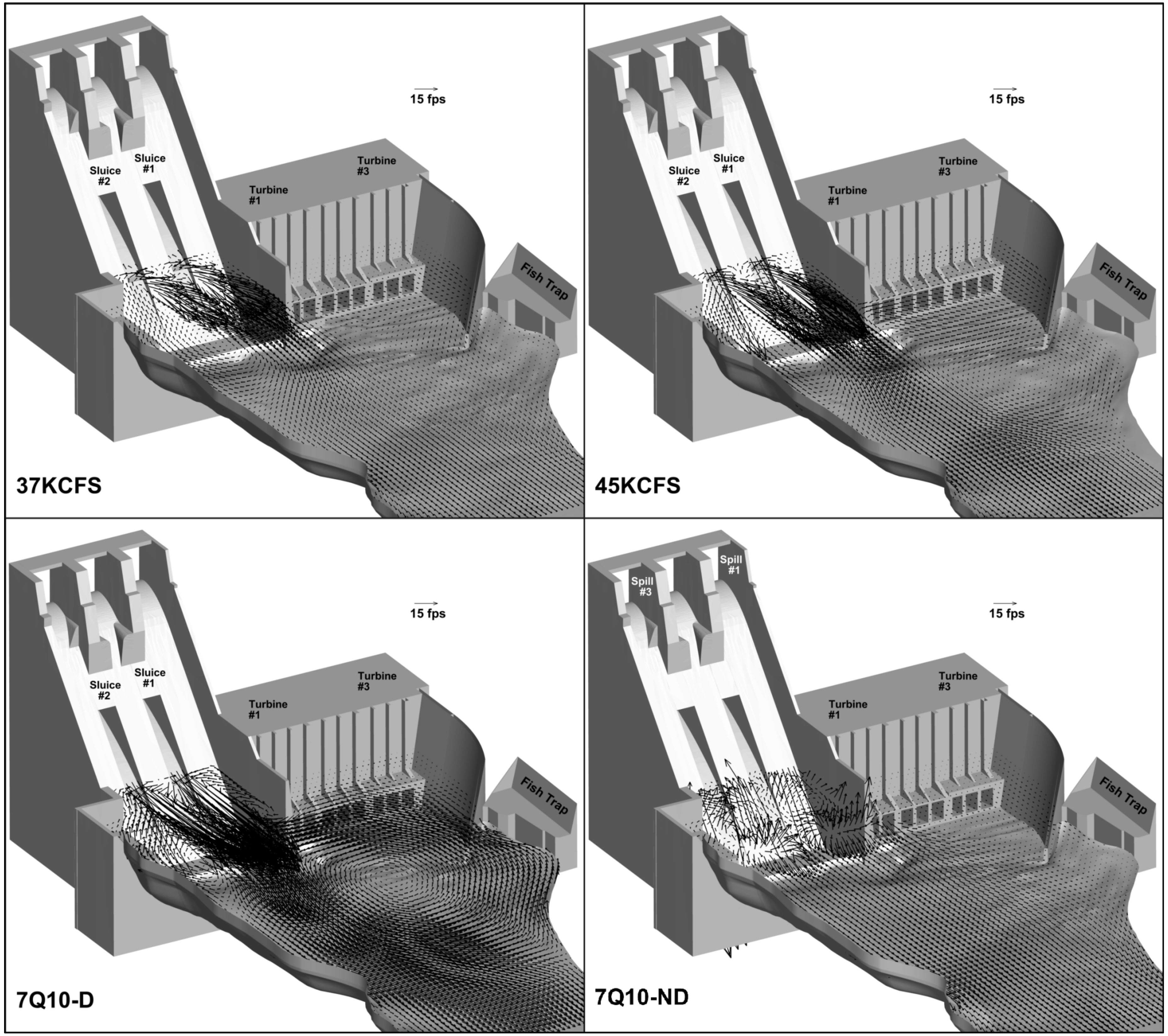


Figure 6-2. Velocity vectors at slices passing through the sluiceways for selected deflector

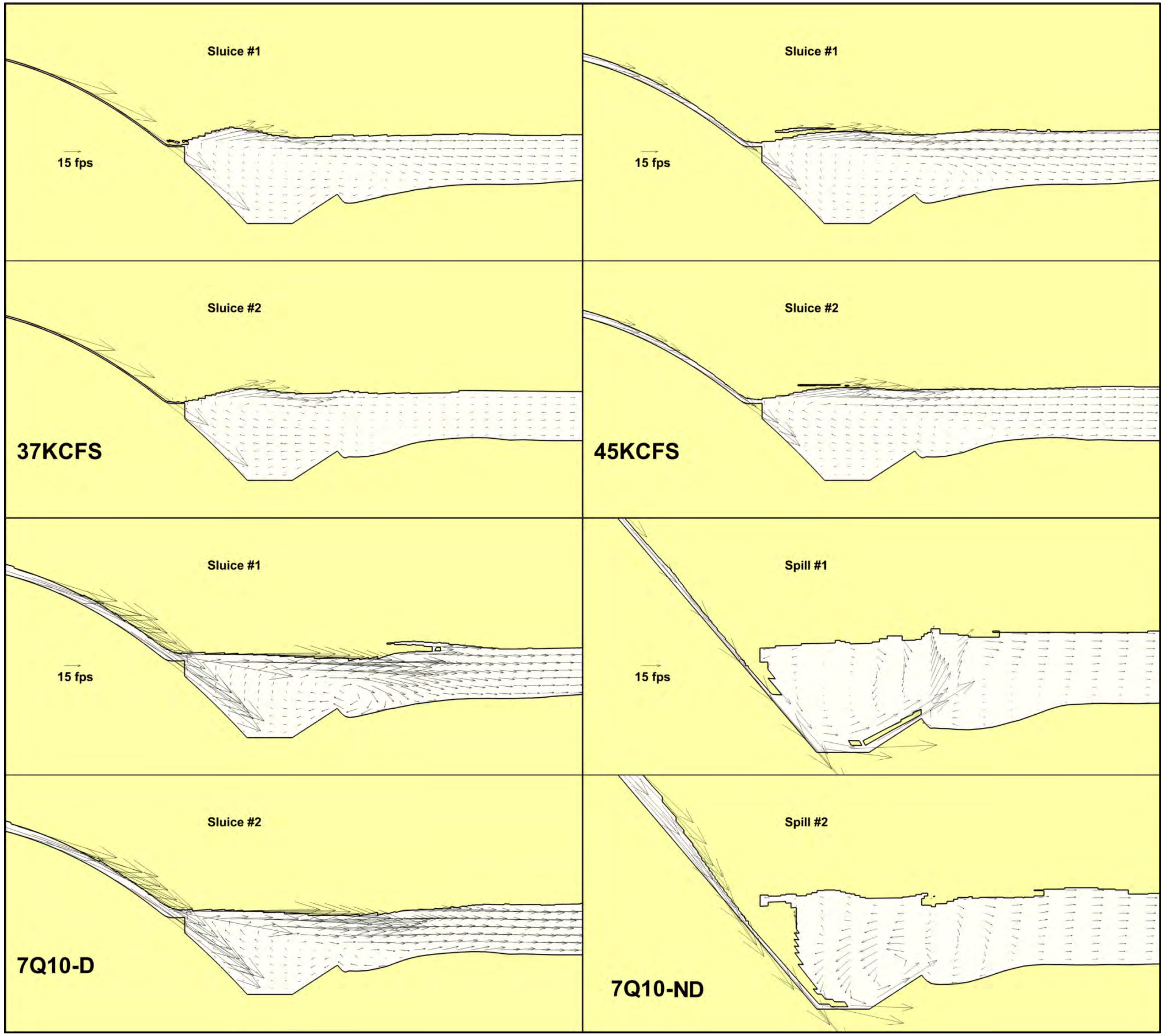


Figure 6-3. Velocity vectors at slices passing through the sluiceways for selected deflector

Rigid-lid Simulations

The flow pattern in the tailrace with the selected deflector for 37 kcfs, 45 kcfs and a 7Q10 flow are shown in Figures 6-4 to 6-7. Plots for a 7Q10 flow without deflector are also included in the figures for comparison. Figures 6-4 and 6-5 show velocity vectors at 1410.6 ft and 1424.6 ft, respectively. Contours of velocity in the streamwise direction are shown in Figures 6-6 and 6-7. The strength of surface jets increase with sluice flows. In addition, sluice jets are observed deeper in the tailrace as sluice flow increases. For all river flows, a recirculation in the eastern region is observed. Streamwise velocity in the spillway and attraction of powerhouse flows by sluice jets increases with spillway flows. Velocities near the fish trap decreases as water from the powerhouse moves to the spillway. An important recirculation is observed near the western region for the 7Q10 simulation with deflector. This recirculation causes reverse flow near the fish trap and moves water back to the aerated region in the spillway. A small recirculation at low velocity near the fish trap is predicted for 7Q10 flow without deflector.

Figures 6-8 and 6-9 show distribution of gas volume fraction at 1410 ft and 1424 ft, respectively. The gas volume fraction in the tailrace increases with sluice flows. The western eddy caused by a 7Q10 flow transports bubbles back to the spillway region. Bubbles concentrate near the eastern region for spillway without deflectors while most of them are observed in the center of the dam when deflectors are in place. With deflectors, surface jets concentrate most of the bubbles near the free surface. However, as can be seen in Figures 6-10, some bubbles are transported to depth for a 7Q10 flow. In Fig. 6-10 contour levels are different for easy visualization. This is more visible in sluice #1, where downstream plunging water increases the gas volume fraction in the entire stilling basin. For a 7Q10 flow without deflector, bubbles plunge to deep regions in the stilling basin and they are then transported near the free surface back toward the spillway.

Figure 6-11 shows TDG source distribution. Contour levels are different for low and high flowrates to help visualization. High TDG source values indicate regions with elevated TDG production whereas negative values show regions of degasification. TDG production increases with sluice flows. For low sluice flows, most of TDG production happens at about the deflector elevation. At deeper zones bubbles are not present and since near the free surface pressure is low degasification is promoted. For a 7Q10 flow with deflector, most of the TDG production is observed downstream of the stilling basin where some plunging is observed. On the other hand, when deflectors are not installed bubbles are transported to depth in the stilling basin where high pressure forces their dissolution into water, resulting in the highest TDG production.

An isosurface of gas volume fraction 10^{-4} is shown in Figure 6-12. Gas volume fractions higher than 10^{-4} are not found downstream of this zone and therefore at least 99.7% of the bubbles that entered the domain are found upstream of this region. In other words, less than 0.3% of the bubbles that enter the tailrace are found downstream of this isosurface. This zone corresponds to a TDG source of approximately $-2\ 10^{-5}$ (Figure 6-13), which represents degasification due to gas transfer from the liquid to bubbles near the free surface at low pressure. Beyond this zone, TDG source is negligible and the degasification occurs by mass transfer at the free surface, which is a less efficient process.

Figures 6-14 and 6-15 show distribution of TDG at 1410 ft and 1424 ft, respectively. TDG contours at different flowrates are different to allow visualization of TDG lateral gradients. TDG concentration increases with sluice flowrate. The western bank eddy induced by deflectors transports supersaturated water (respect to atmospheric pressure) back to the spillway favoring TDG mixing in the tailrace and increasing TDG concentration near the fish trap. On the other hand, when deflectors are not installed low TDG water from the powerhouse flows straight towards the fish trap reducing TDG concentration in this region. Maximum TDG values for a 7Q10 flow with and without deflectors are 1.38 and 1.88, respectively. However, average TDG values near the fish trap for the simulations with and without deflectors are 1.27 and 1.16, respectively.

Streamlines illustrating the flow pattern and TDG distribution in the tailrace are shown in Figures 6-16 and 6-17. Attraction of powerhouse flows by surface jets can be seen with streamlines released from the powerhouse (Figures 6-16). TDG saturation in powerhouse flows increases as water moves to the aerated zone. For the 7Q10 simulation, TDG also increases due to mixing with supersaturated water from the western bank eddy. Note that attraction of powerhouse flows by spillway jets is also observed at depth when deflectors are not installed. However, this entrainment is weaker and occurs downstream in the tailrace. Streamlines released from the spillway (Figure 6-17) show that most of the water from the sluices moves straight due to the elevated streamwise velocity of surface jets. However, at low flowrates some water is transported by the eastern eddy back to the spillway. Some streamlines from the 7Q10 simulation are deflected towards the east due to the western eddy.

In order to evaluate the effect of powerhouse flows on the TDG production, TDG in equilibrium at the local pressure was calculated and is shown in two slices at 85 ft and 190 ft from the dam. Local TDG is represented with lines in Figure 6-18. If local TDG is bigger than that at equilibrium, degasification is promoted. This is observed near the free surface, particularly downstream of the spillway. On the other hand, TDG production is possible if local TDG is smaller than equilibrium TDG and bubbles are present. Note that water entrained with the western eddy is still undersaturated at local conditions and therefore they can increase TDG production if bubbles are available.

Figures 6-19 to 6-21 show isosurfaces of gas volume fraction, TDG production and TDG concentration. Gas volume fraction isosurfaces show that most of the bubbles are found near the free surface when deflectors are installed and close to the bottom of the stilling basin for the 7Q10 simulation without deflector. Most of the TDG production occurs downstream of the stilling basin. However, as the flowrate increases the production moves upstream toward the spillway. For a 7Q10 flow with deflectors, an important TDG production is observed as far as at the diversion tunnel location and near the fish trap due to bubbles transported by the western tailrace eddy. As shown with TDG isosurfaces, TDG propagates straight downstream for low flowrates. However, for a 7Q10 simulation, supersaturated water transported by the western eddy can be also found close to the powerhouse. Without deflectors, TDG concentration near the spillway is significantly higher. In this case, however, supersaturated water is not transported to the western bank near the fish trap.

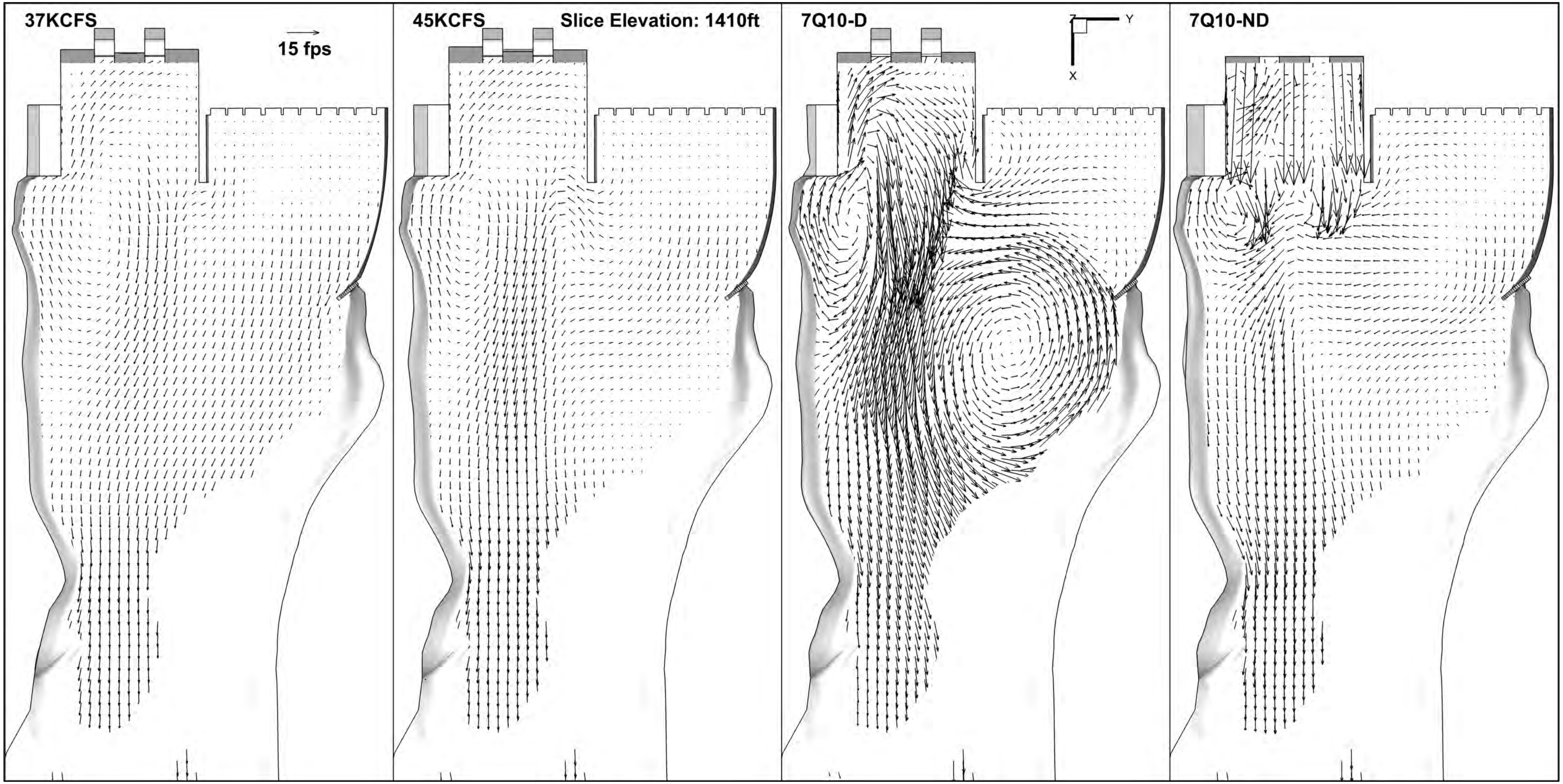


Figure 6-4. Velocity vectors at 1410 ft for the selected deflector

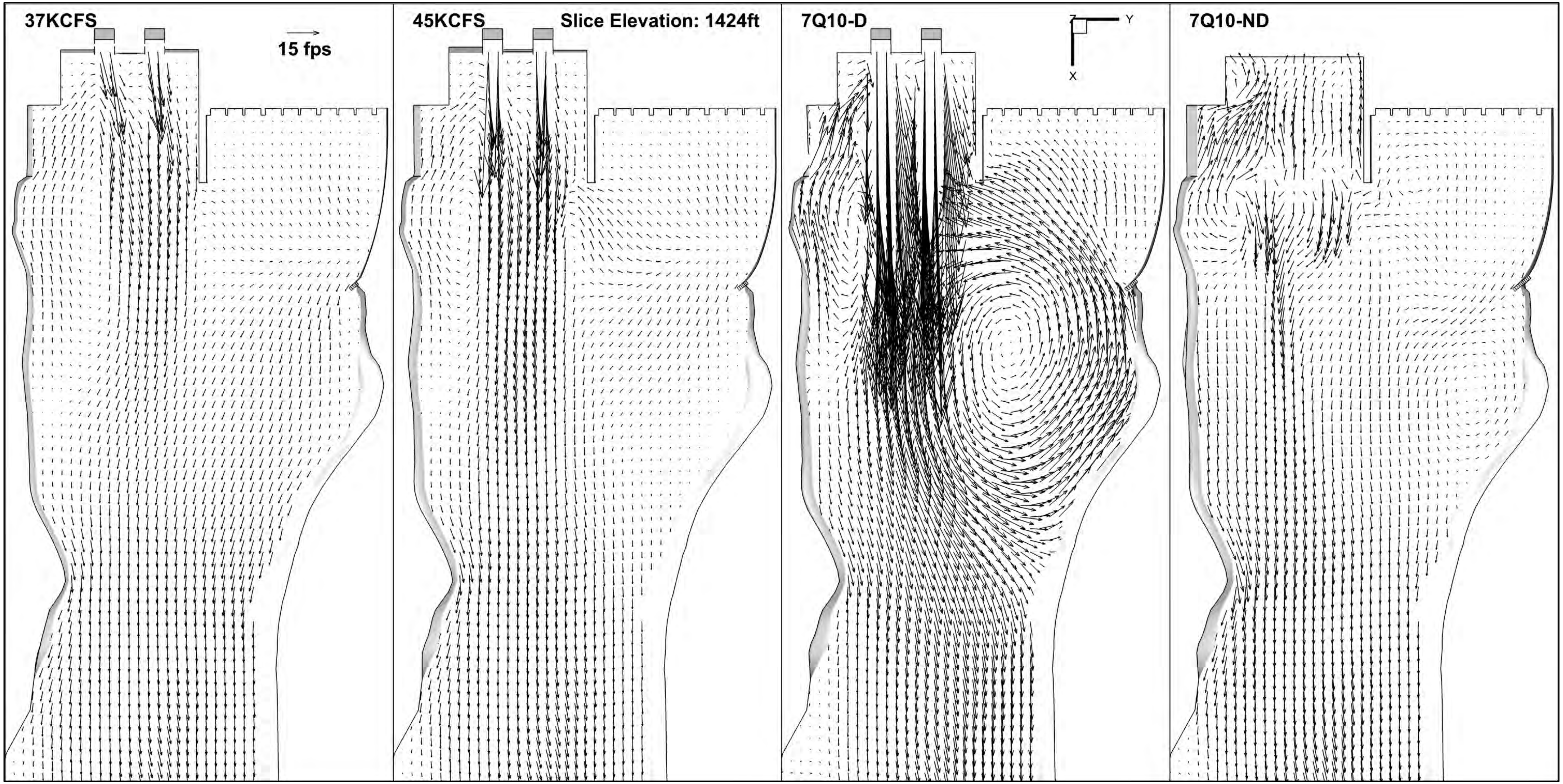


Figure 6-5. Velocity vectors at 1424 ft for the selected deflector

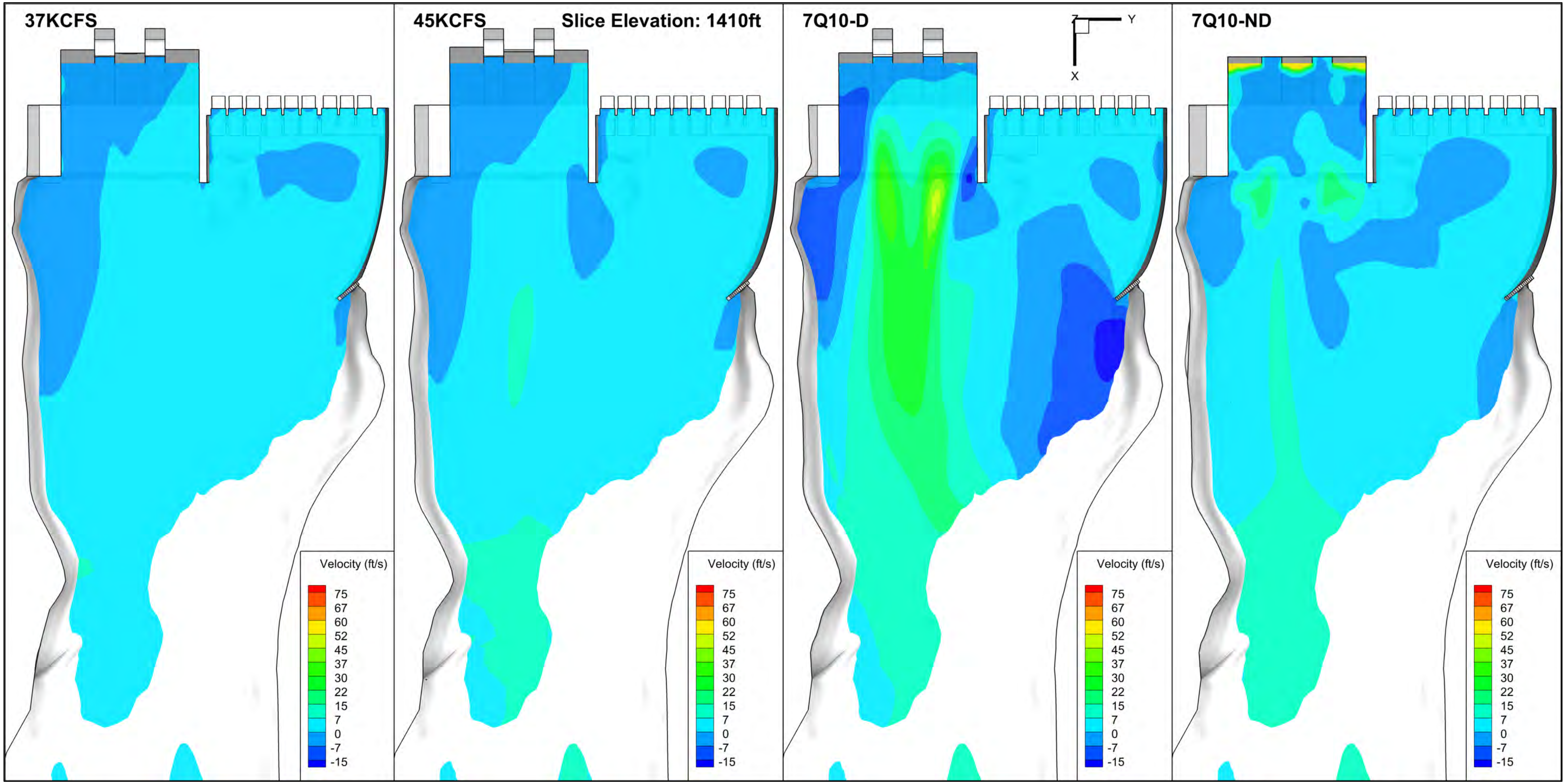


Figure 6-6. Velocity contours at 1410 ft for the selected deflector

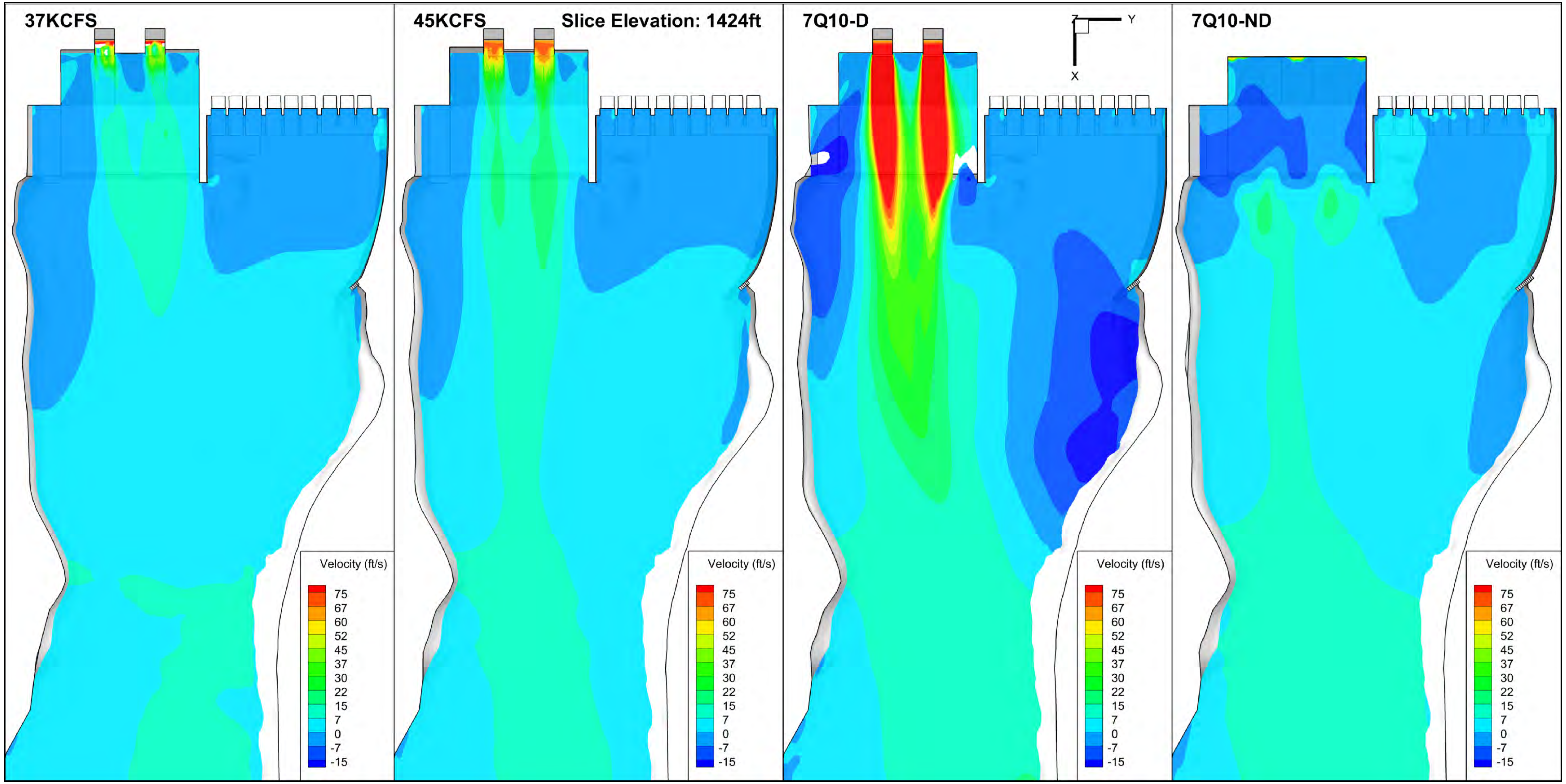


Figure 6-7. Velocity contours at 1424 ft for the selected deflector

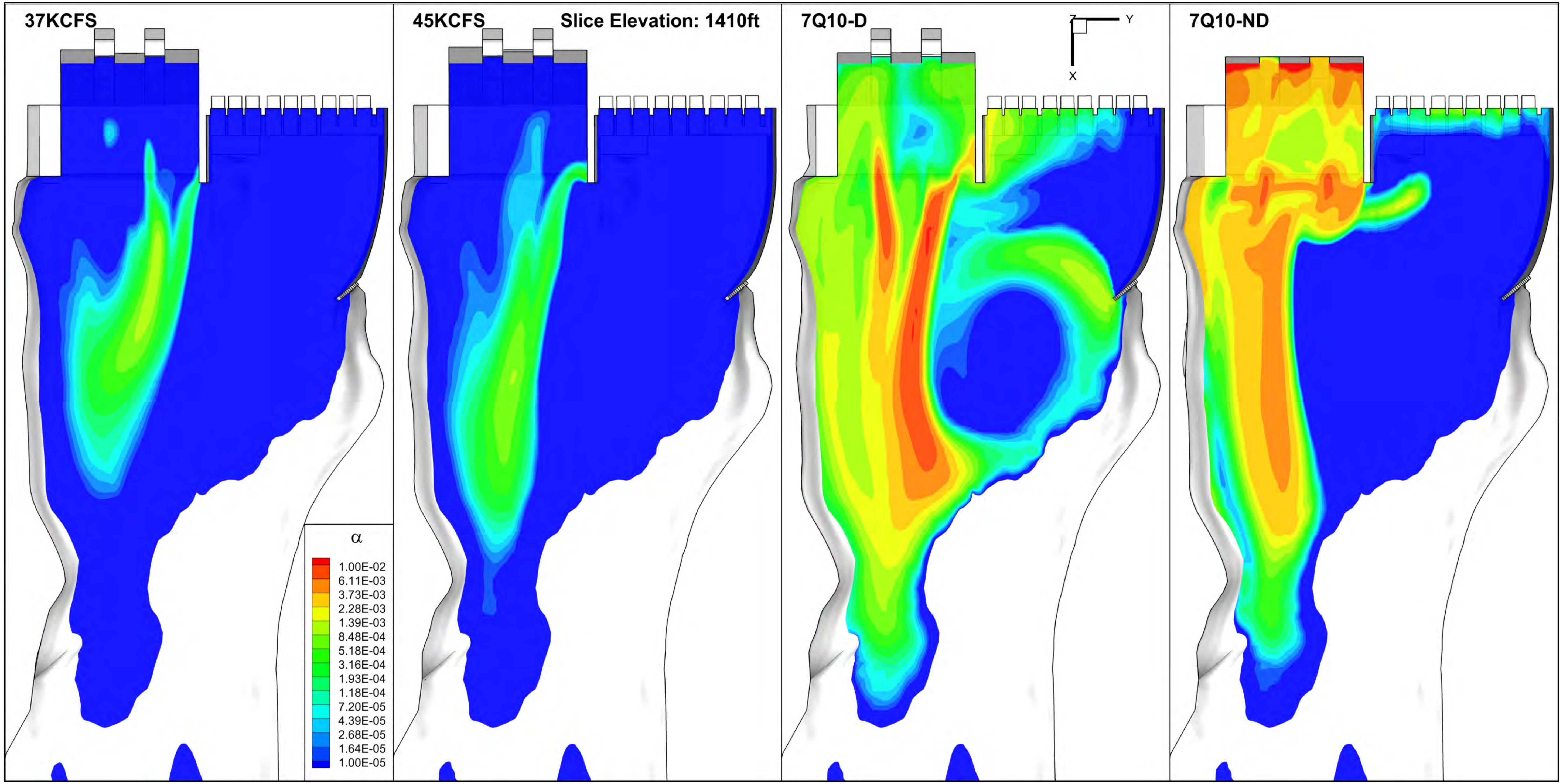


Figure 6-8. Gas volume fraction contours at 1410 ft for the selected deflector

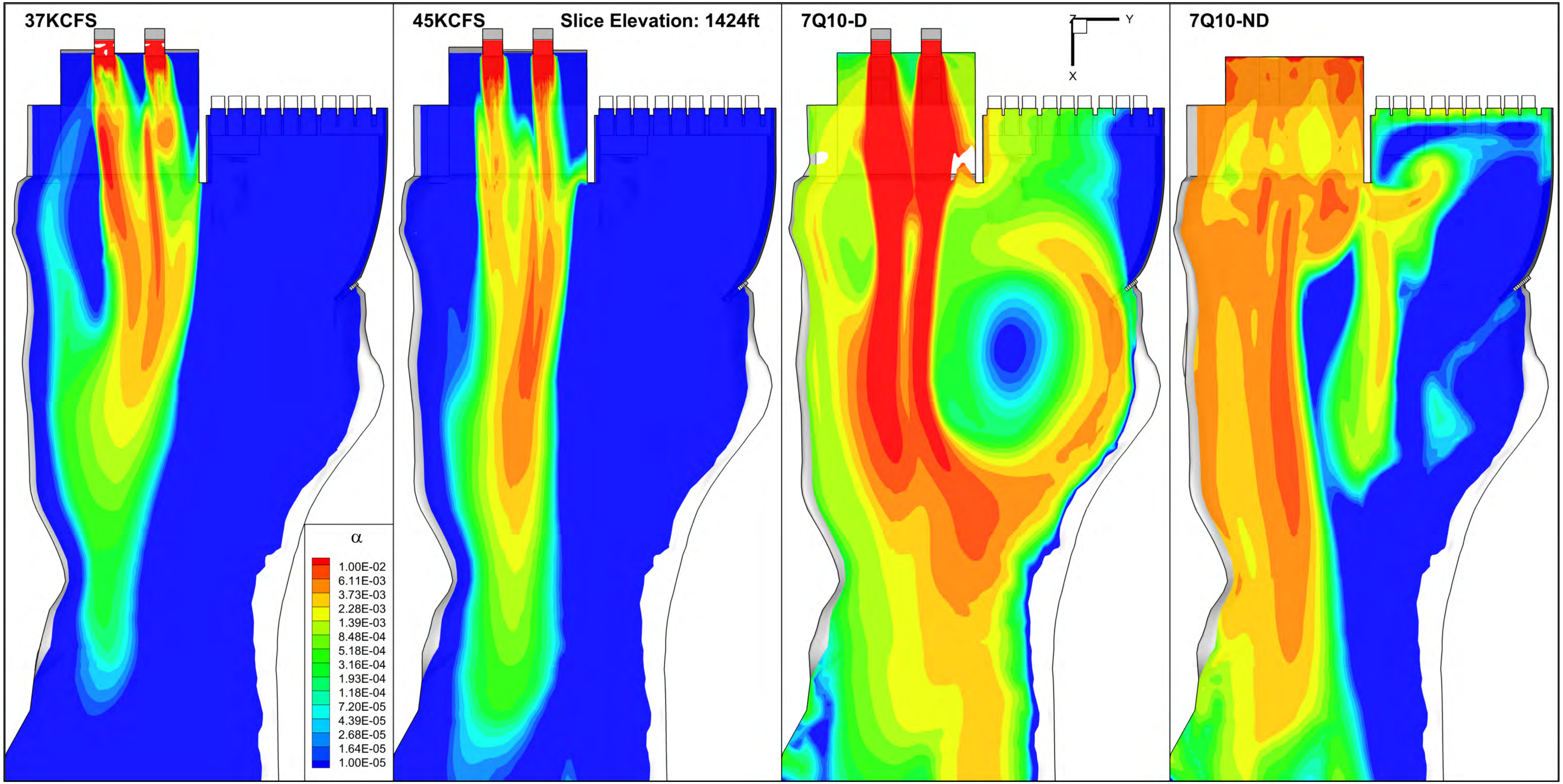


Figure 6-9. Gas volume fraction contours at 1424 ft for the selected deflector

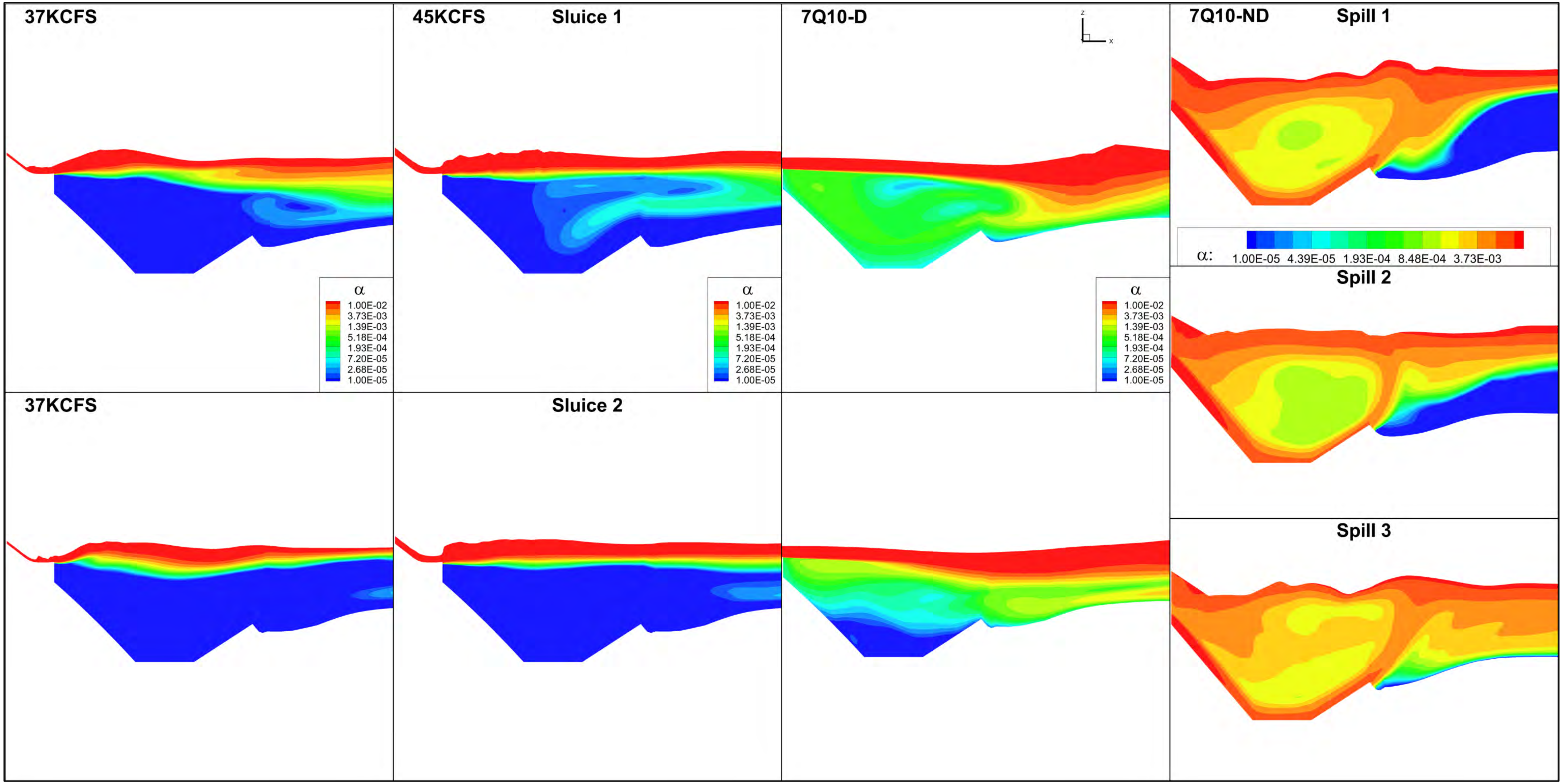


Figure 6-10. Gas volume fraction contours at vertical slices for the selected deflector

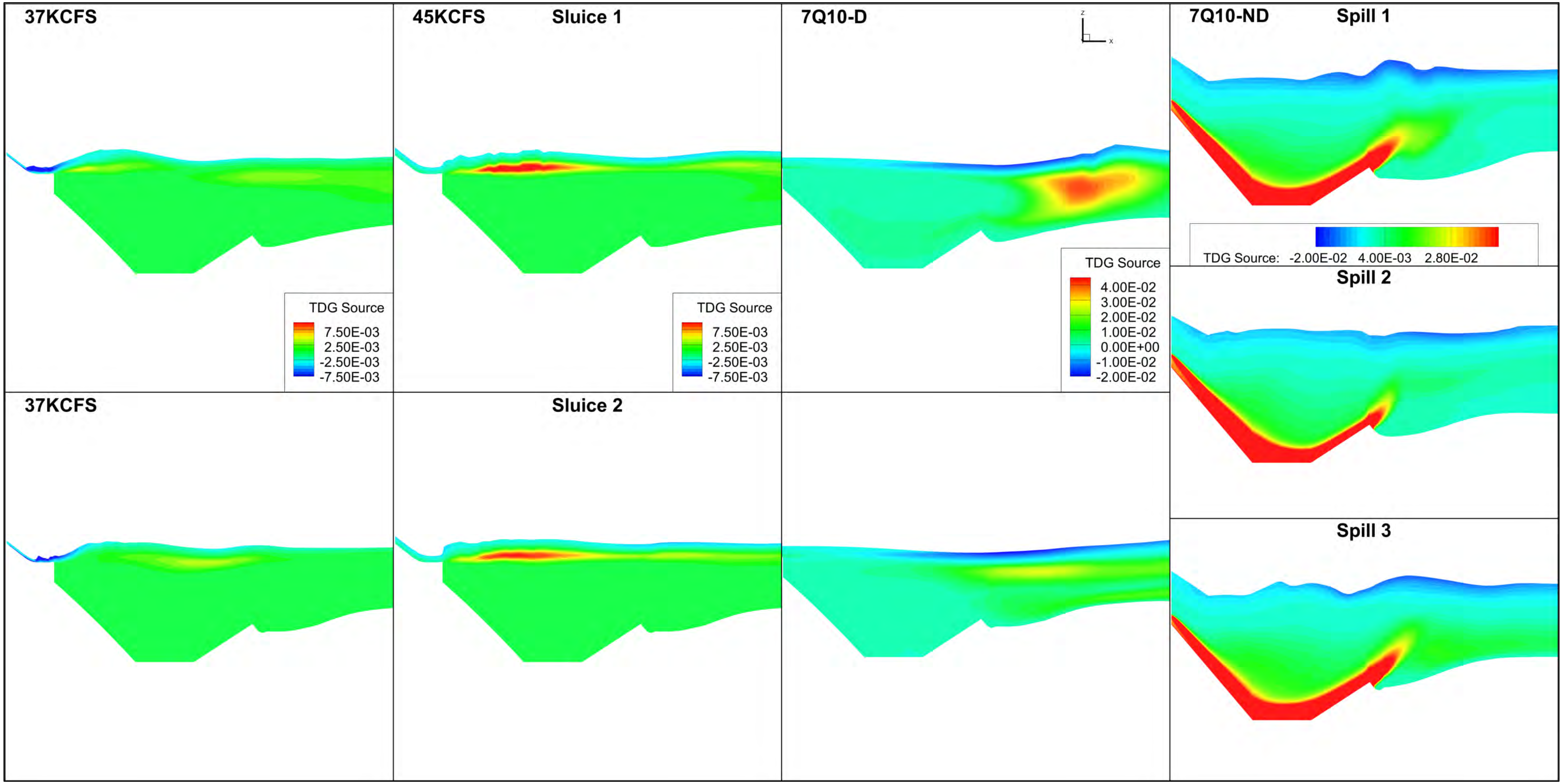


Figure 6-11. TDG source contours at vertical slices for the selected deflector

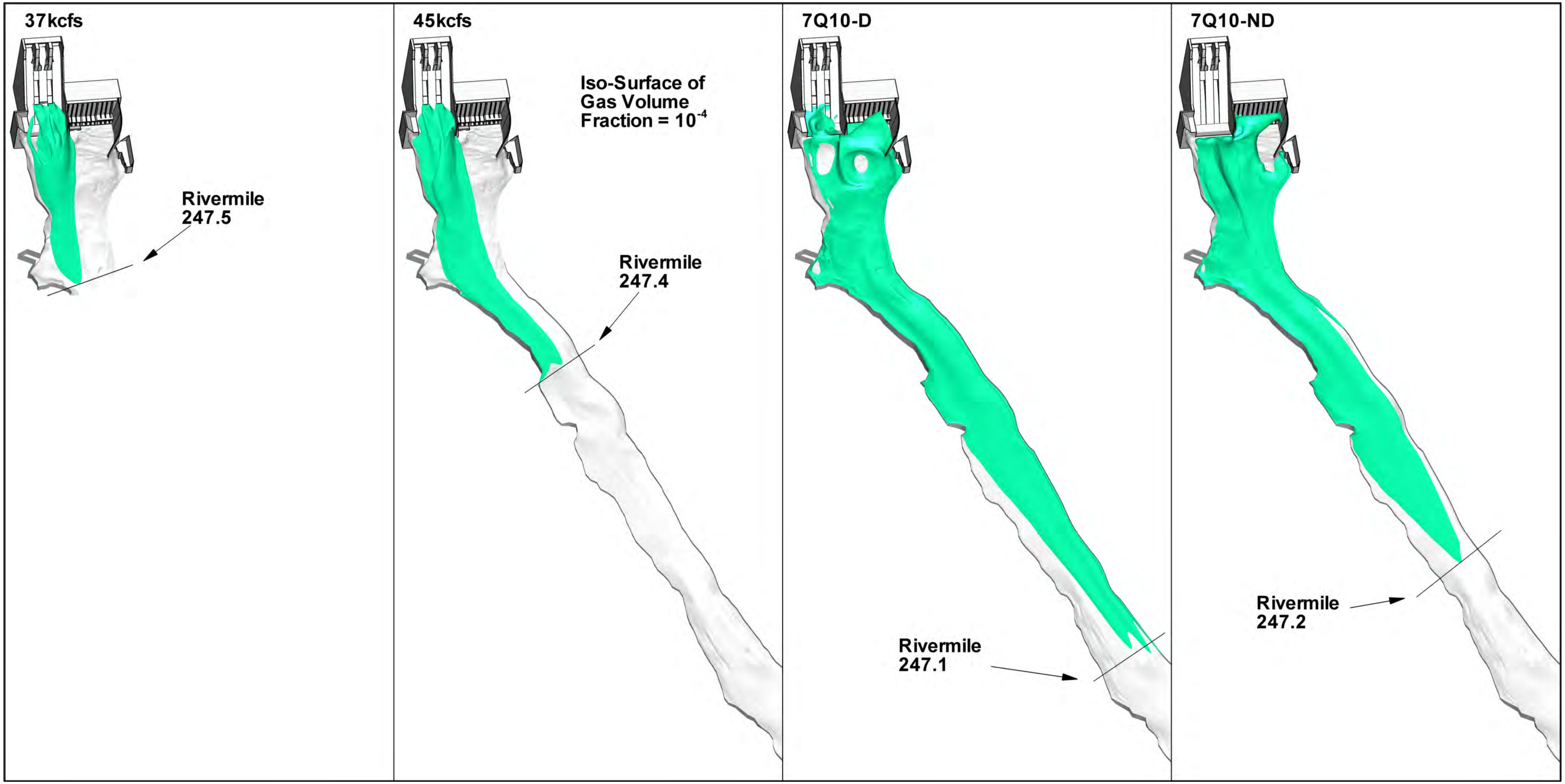


Figure 6-12. Isosurface of gas volume fraction 10^{-4}

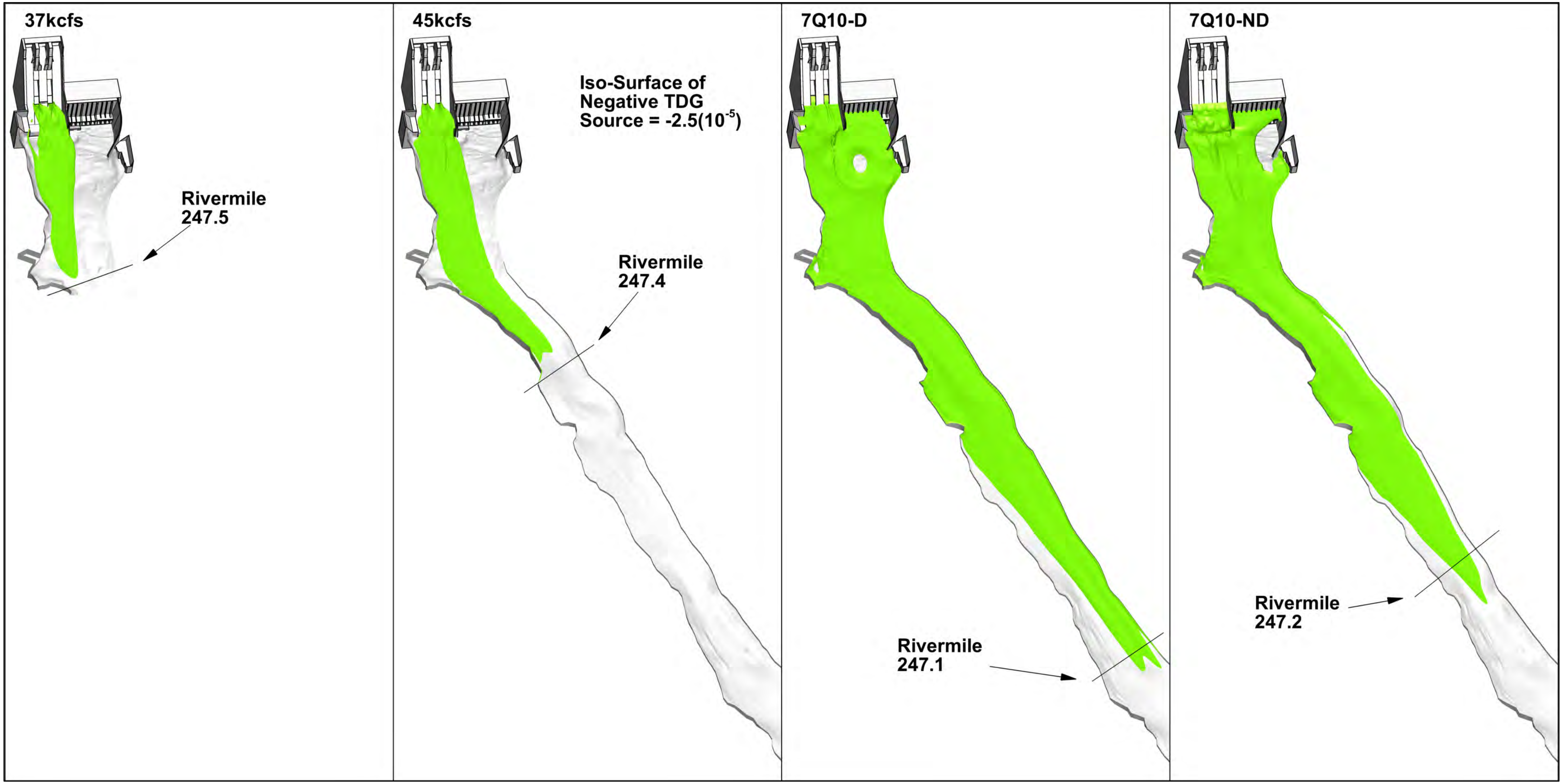


Figure 6-13. Isosurface of TDG source 2 10^{-5}

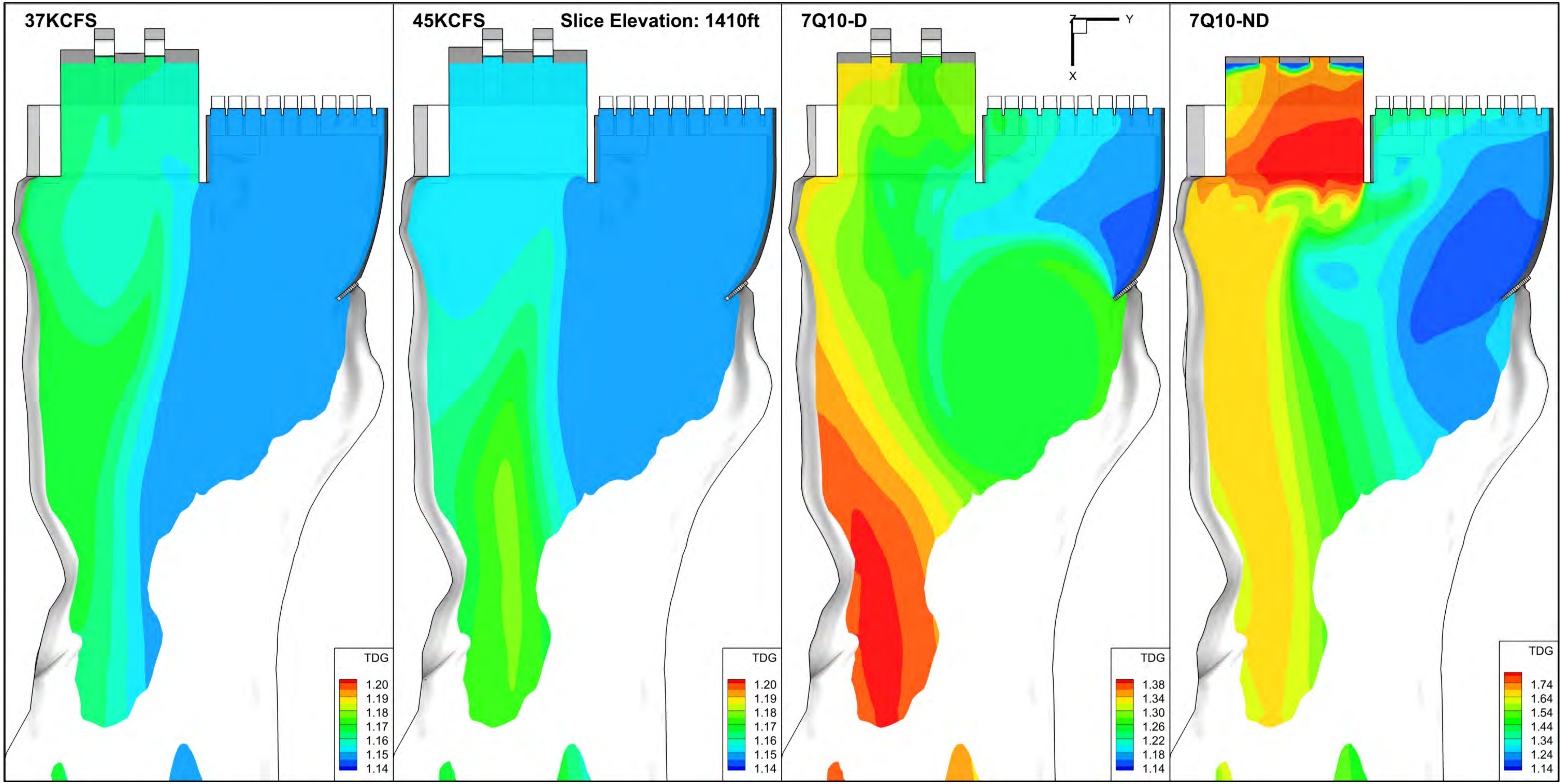


Figure 6-14. TDG contours at 1415.6 ft for the selected deflector

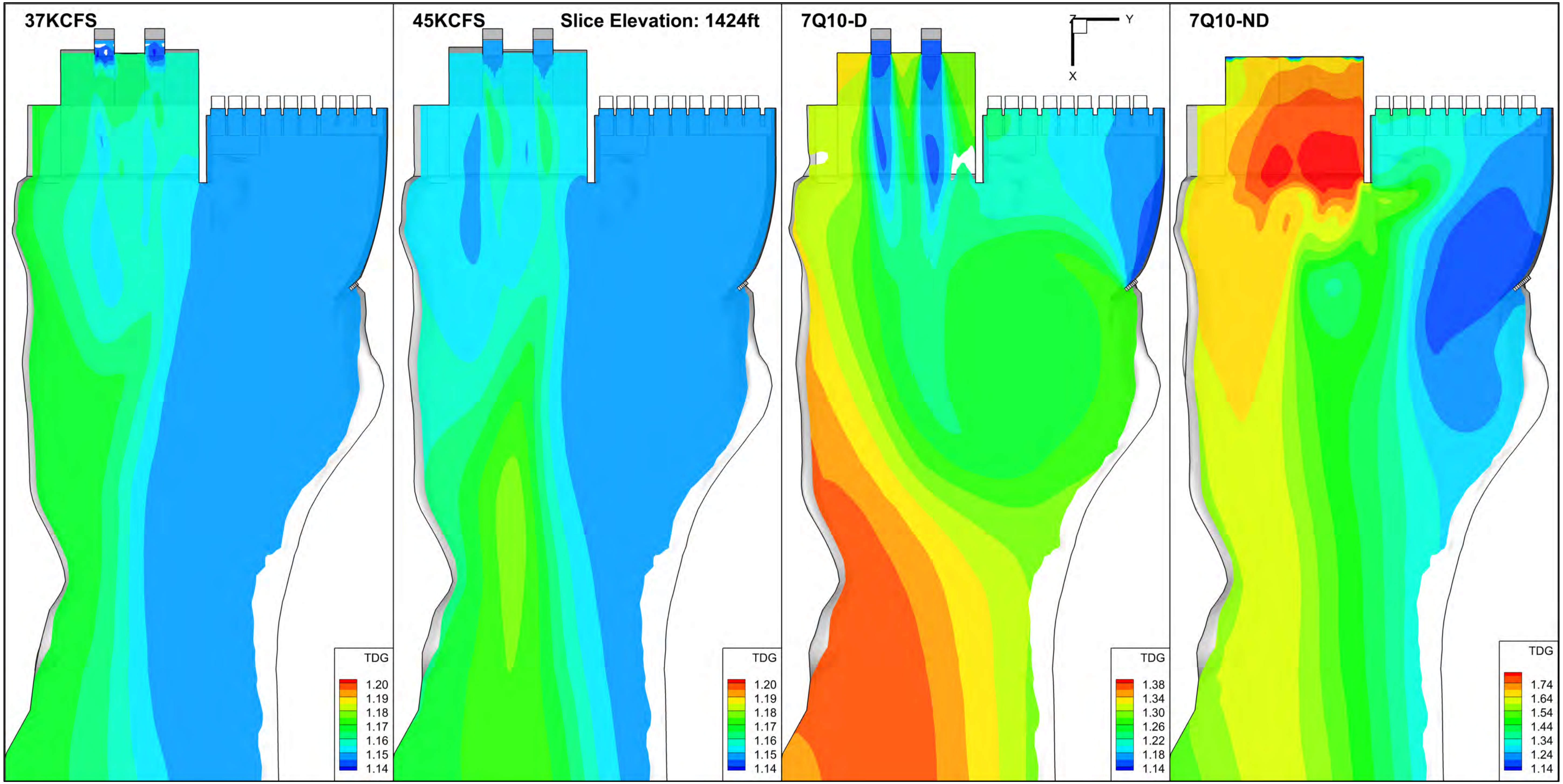


Figure 6-15. TDG contours at 1424.6 ft for the selected deflector

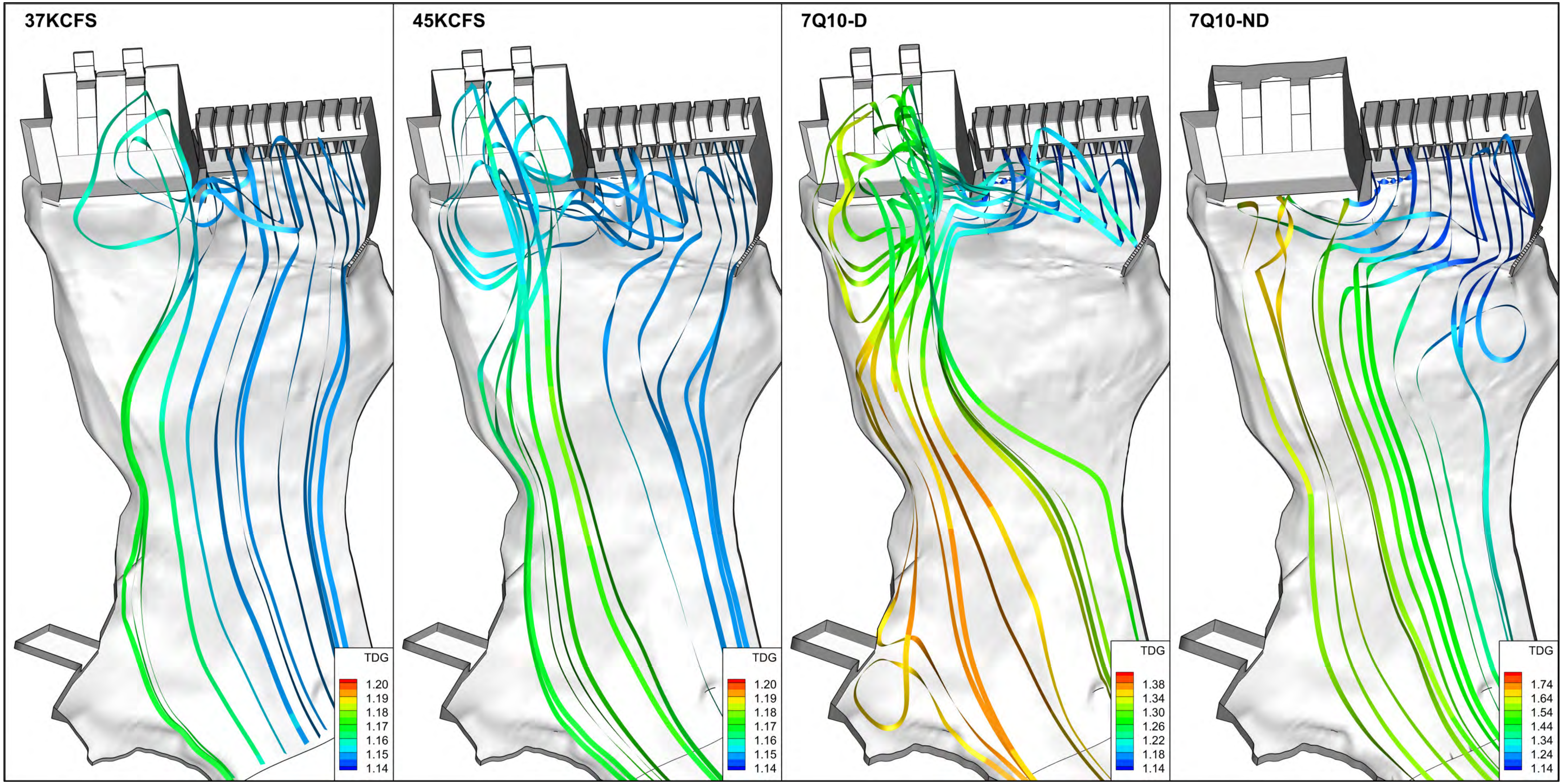


Figure 6-16. Streamlines released from the powerhouse colored by TDG for the selected deflector

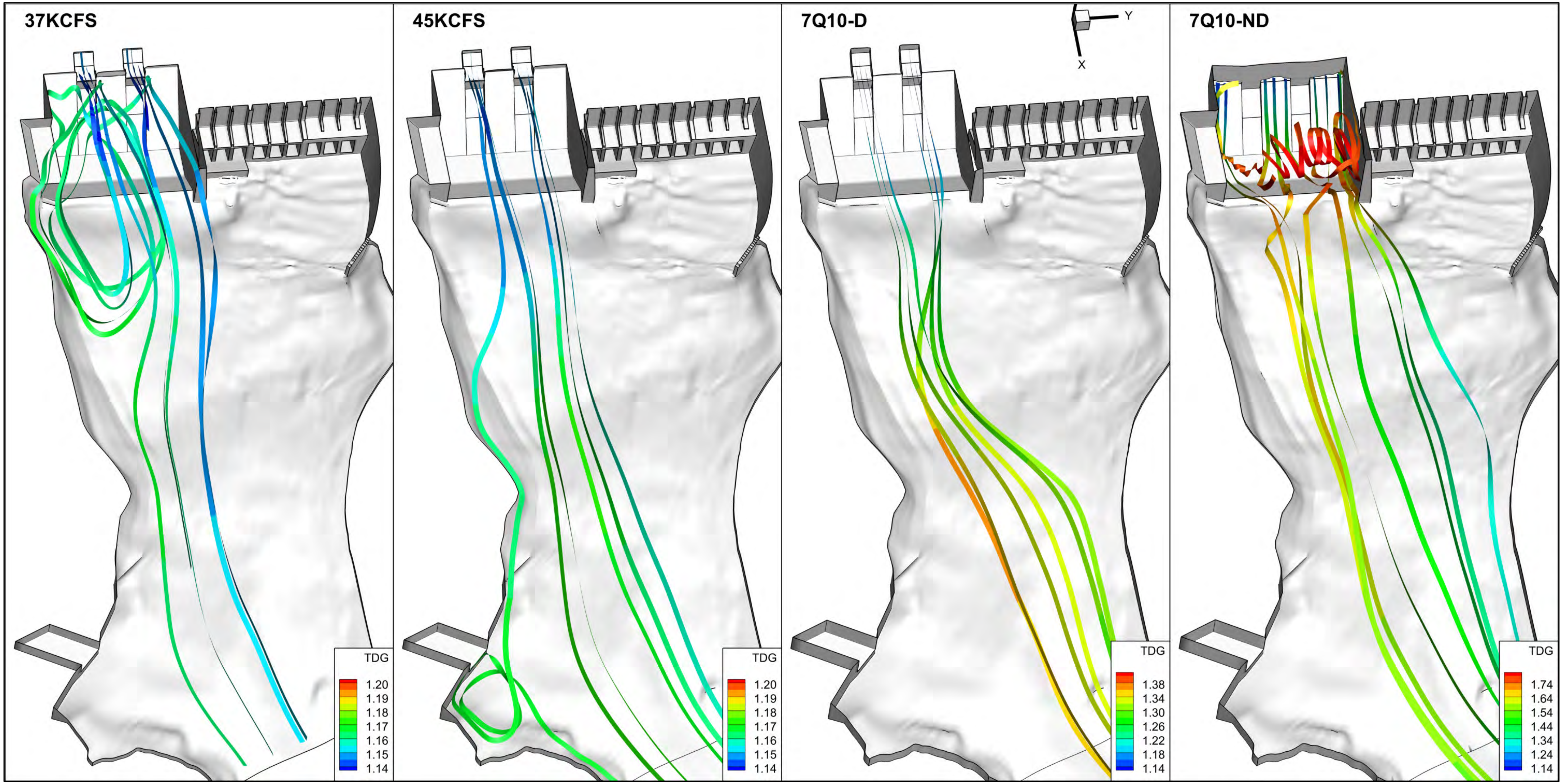


Figure 6-17. Streamlines released from the spillway colored by TDG for the selected deflector

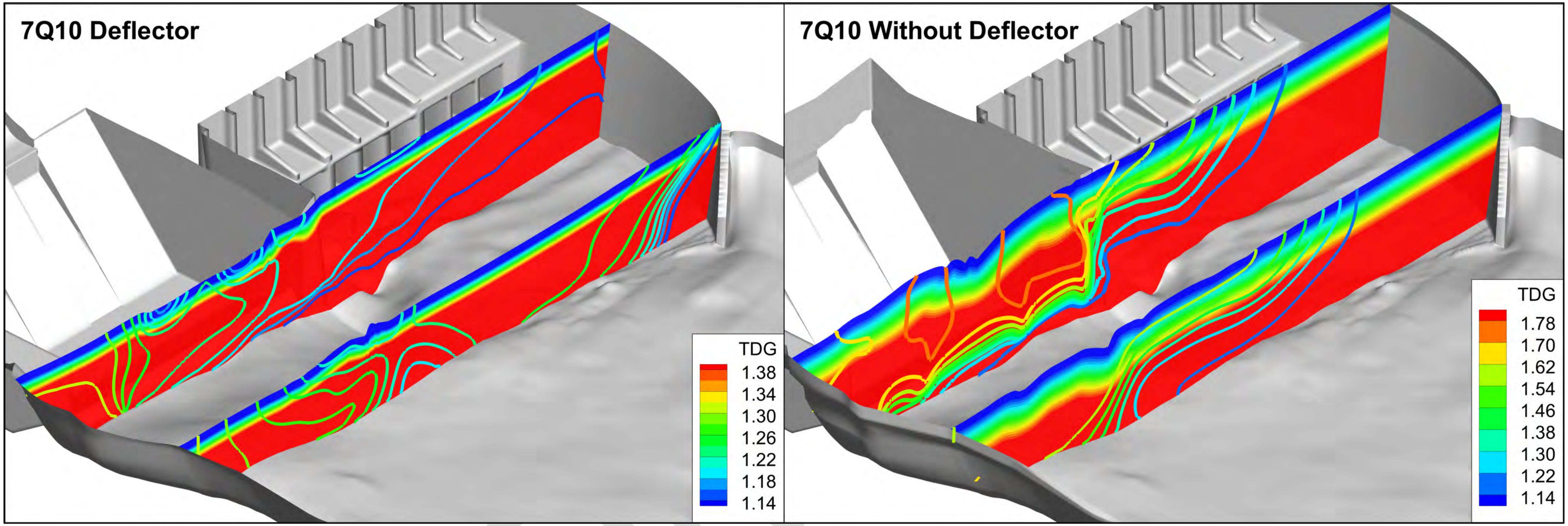


Figure 6-18. Local and equilibrium TDG for 7Q10 simulations

DR

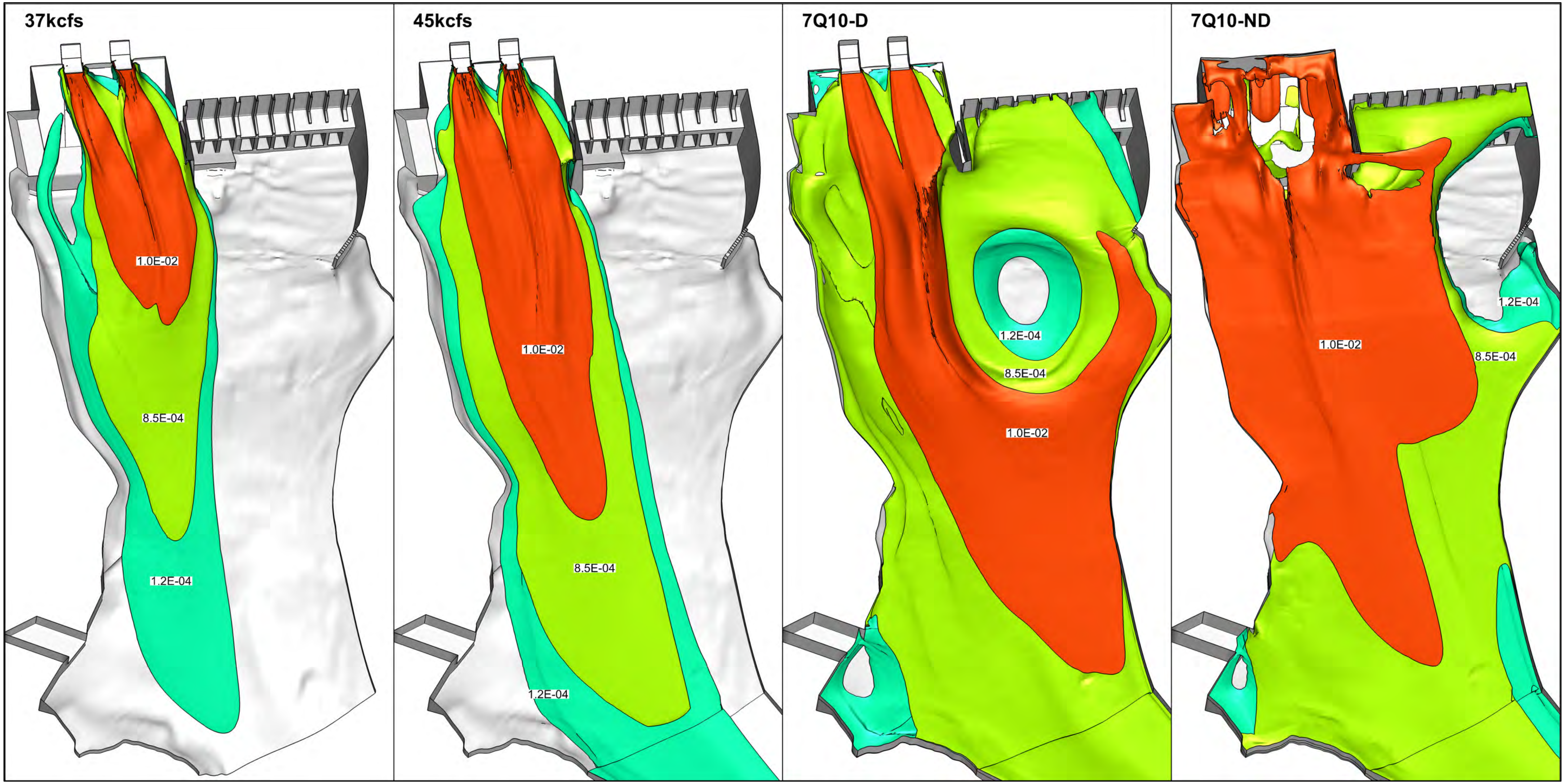


Figure 6-19. Gas volume fraction isosurfaces for the selected deflector

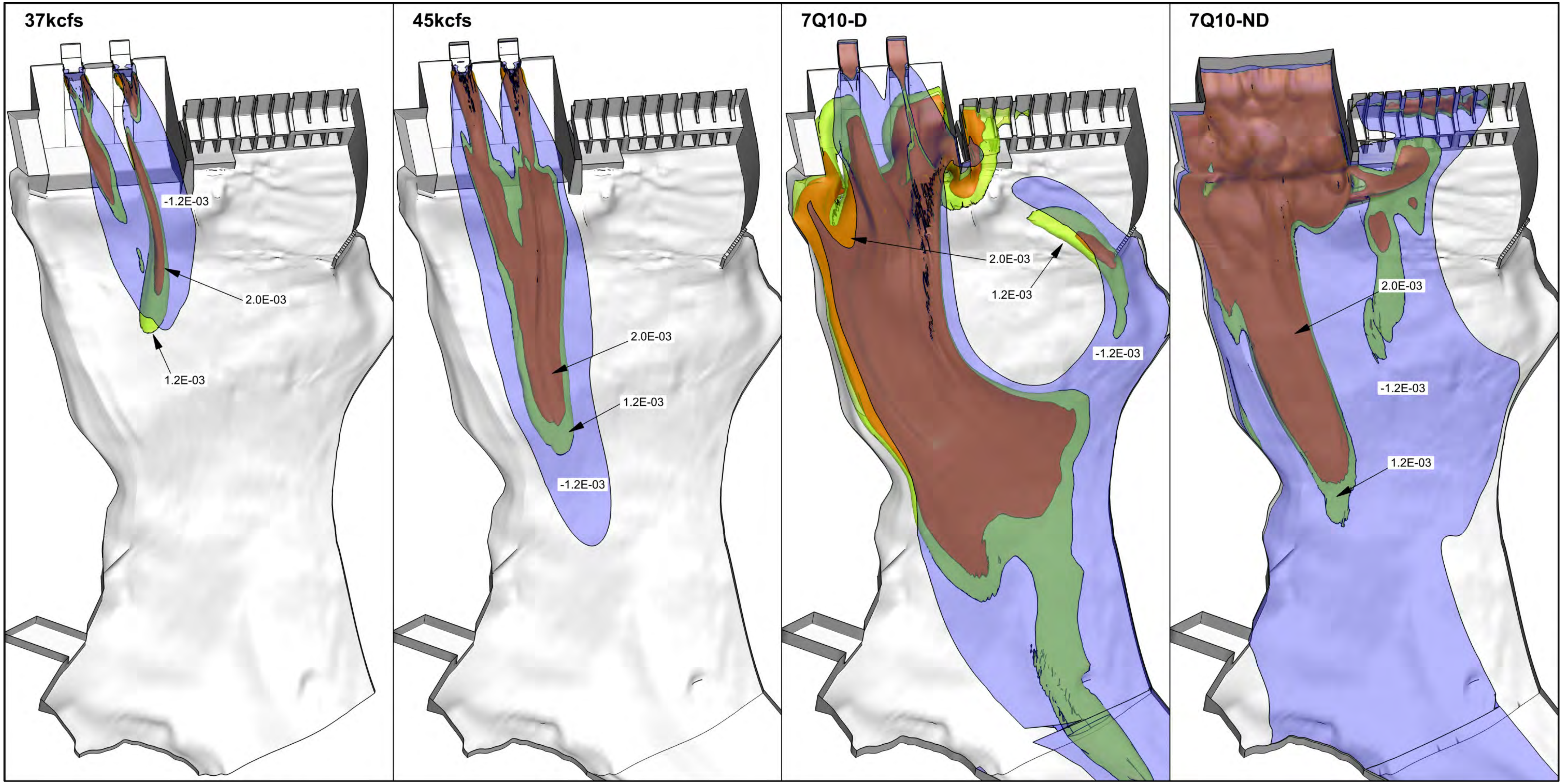


Figure 6-20. TDG source isosurfaces for the selected deflector

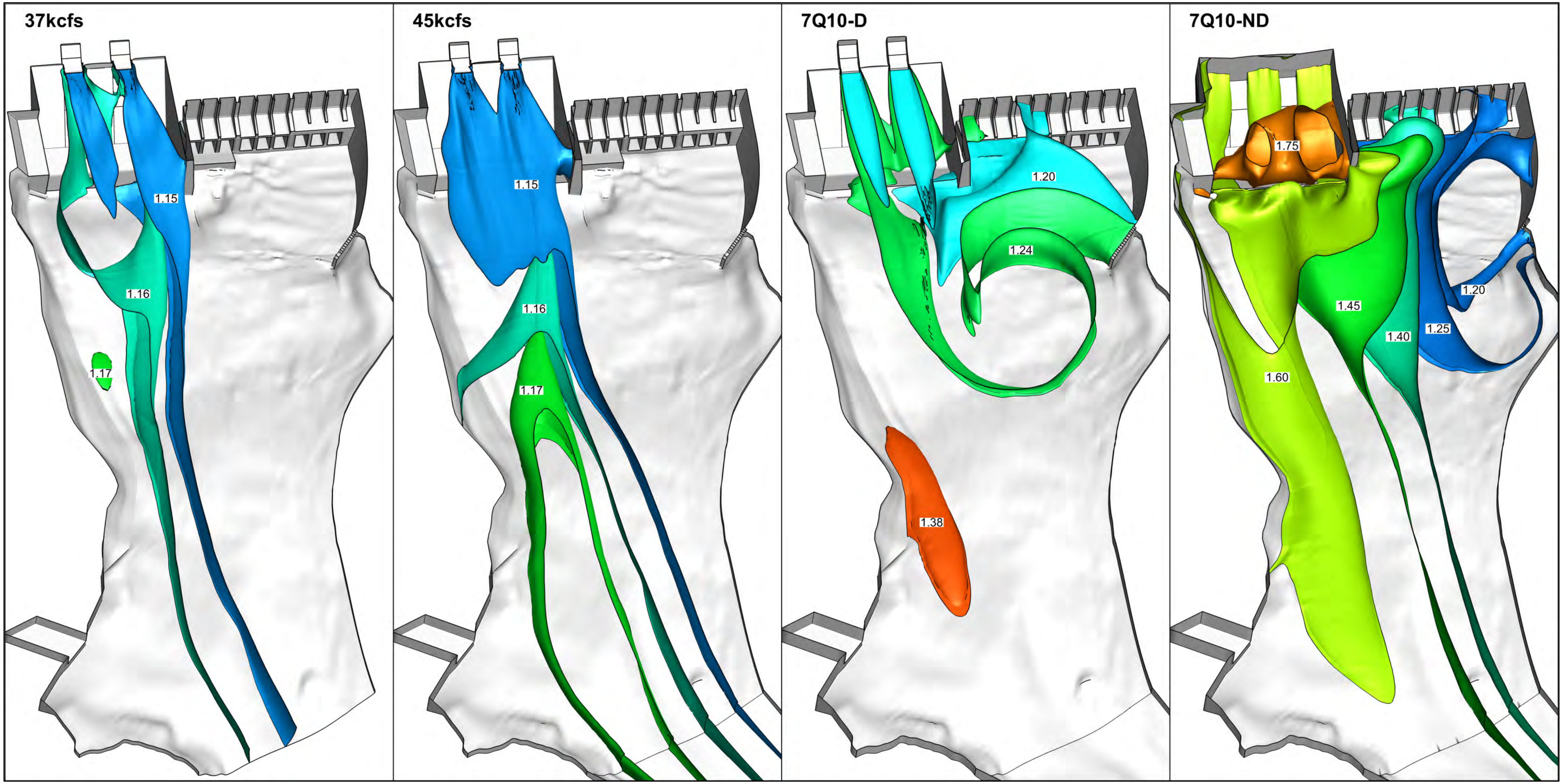


Figure 6-21. TDG isosurfaces for the selected deflector

Downstream TDG Simulations

Figures 6-22 to 6-25 show TDG distribution every one mile in the river downstream of the dam for 37 kcfs, 45 kcfs and a 7Q10 flow with and without deflectors, respectively. TDG contour levels are different to visualize TDG vertical and lateral gradients along the river. TDG values closer to saturation are found near the free surface due to degasification by mass exchange with the atmosphere. The model does not consider any effect of the rapids on the gas saturation. For a 7Q10 flow, an important vertical TDG gradient is predicted. Table 6-1 shows flowrate averaged TDG concentration and TDG values at the western and eastern regions every mile. Averaged TDG is computed in a cross sectional plane. Note that near the dam, upstream of the dividing wall, high TDG values generated downstream of the spillway as well as low TDG from the powerhouse are averaged. According to the model, the average TDG produced by spill at Hells Canyon Dam disappears after one and three miles for the 37 kcfs and 45 kcfs, respectively. In other words, at that location averaged TDG levels are the same as the forebay TDG. According to the model, TDG concentration of about 1.27 is predicted 7 miles downstream of the dam for the 7Q10 flow with deflector and a value of 1.40 is predicted without deflectors.

Net TDG production in a given location, S_{TDG}, can be defined as:

$$S_{TDG} = \frac{C - C_F}{C_F} \qquad (3)$$

where C and C_F are TDG concentration at that location and forebay, respectively. Net TDG production at RM 247.5, 244.5 and 241.5 for a 7Q10 flow without deflector is 32%, 25% and 22%, respectively. With deflectors installed these values are reduced to 18%, 14% and 11% for the same 7Q10 flow.

The flowrate averaged TDG as a function of river mile is shown in Figure 6-26. TDG increases abruptly near the dam due to the dissolution of entrained bubbles. As bubbles in the tailrace rise to low pressure regions, they can absorb gas from supersaturated water reducing TDG concentration. This process is more efficient for elevated TDG concentration and therefore is more noticeable for the 7Q10 simulation without deflector. After bubbles left the domain, the degasification occurs in a slower process due to mass exchange at the free surface.

Figure 6-27 shows TDG at the western and eastern banks as a function of river mile. For all flowrates and when deflectors are installed, lateral TDG gradients (or differences between TDG levels at the west and east banks) at about 1.5 miles from the dam are smaller than 0.5%. However, lateral TDG gradients can still be significant downstream in the river. At 1.5 miles from the dam, vertical TDG distributions are important. High TDG values, created at depth in the stilling basin, have moved downstream and are found near the bed. On the other hand, values near saturation are found close to the free surface due to mass transfer with the atmosphere. Secondary currents created for the curving stream move water with low TDG, surface water, towards the outer bank and supersaturated water, deep water, to the inner bank. These currents induce new lateral TDG gradient.

Both TDG concentration and lateral TDG downstream in the river increases with spill flowrate. For a 7Q10 flow without deflectors, lateral TDG gradients downstream in the river are larger. Mixing between spill and powerhouse flows is less important and therefore lateral TDG gradients are more pronounced near the dam when deflectors are not installed. In addition, higher TDG production at depth originate larger vertical TDG gradients, which results later in elevated lateral TDG gradient.

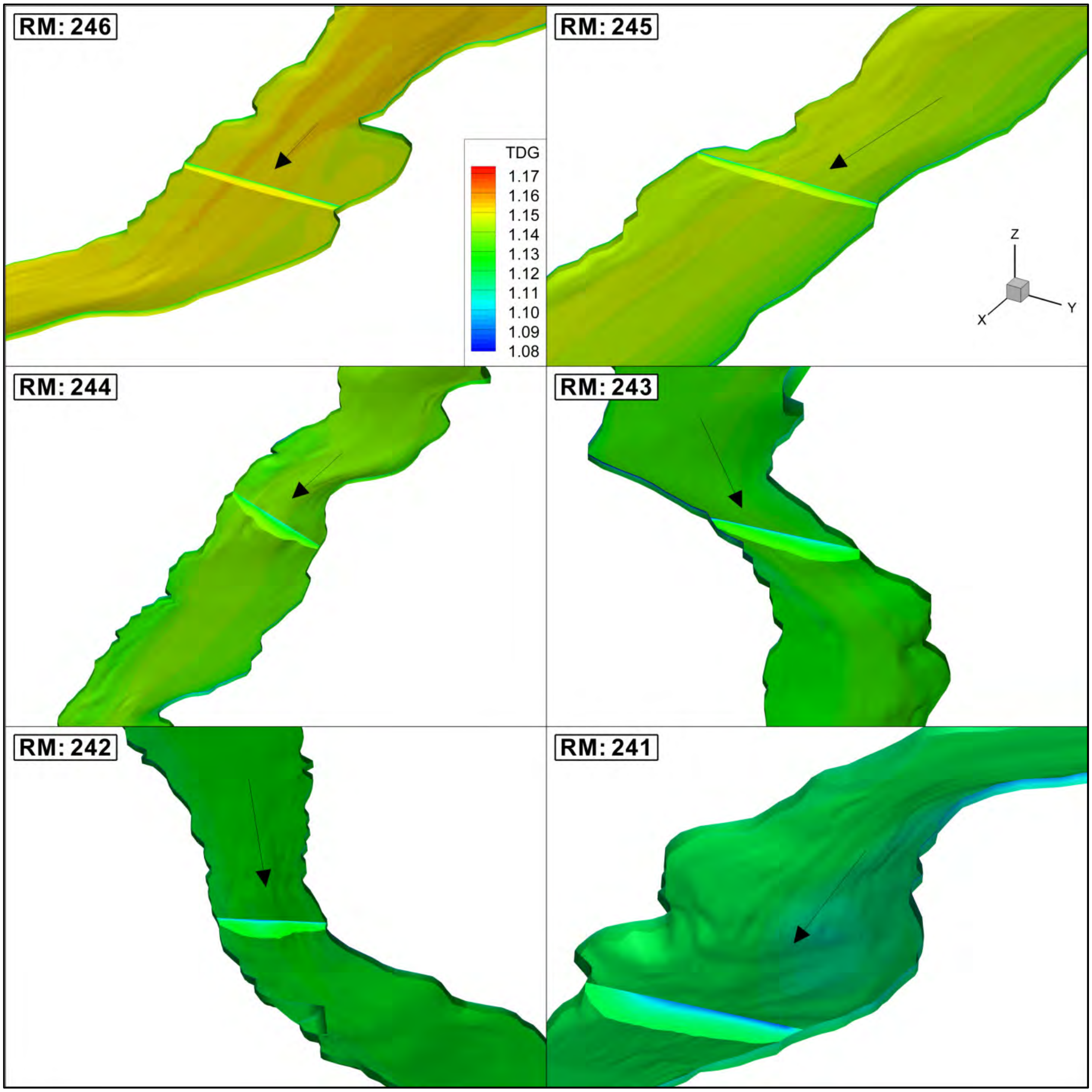


Figure 6-22. TDG in the downstream region to show distribution for 37 kcfs

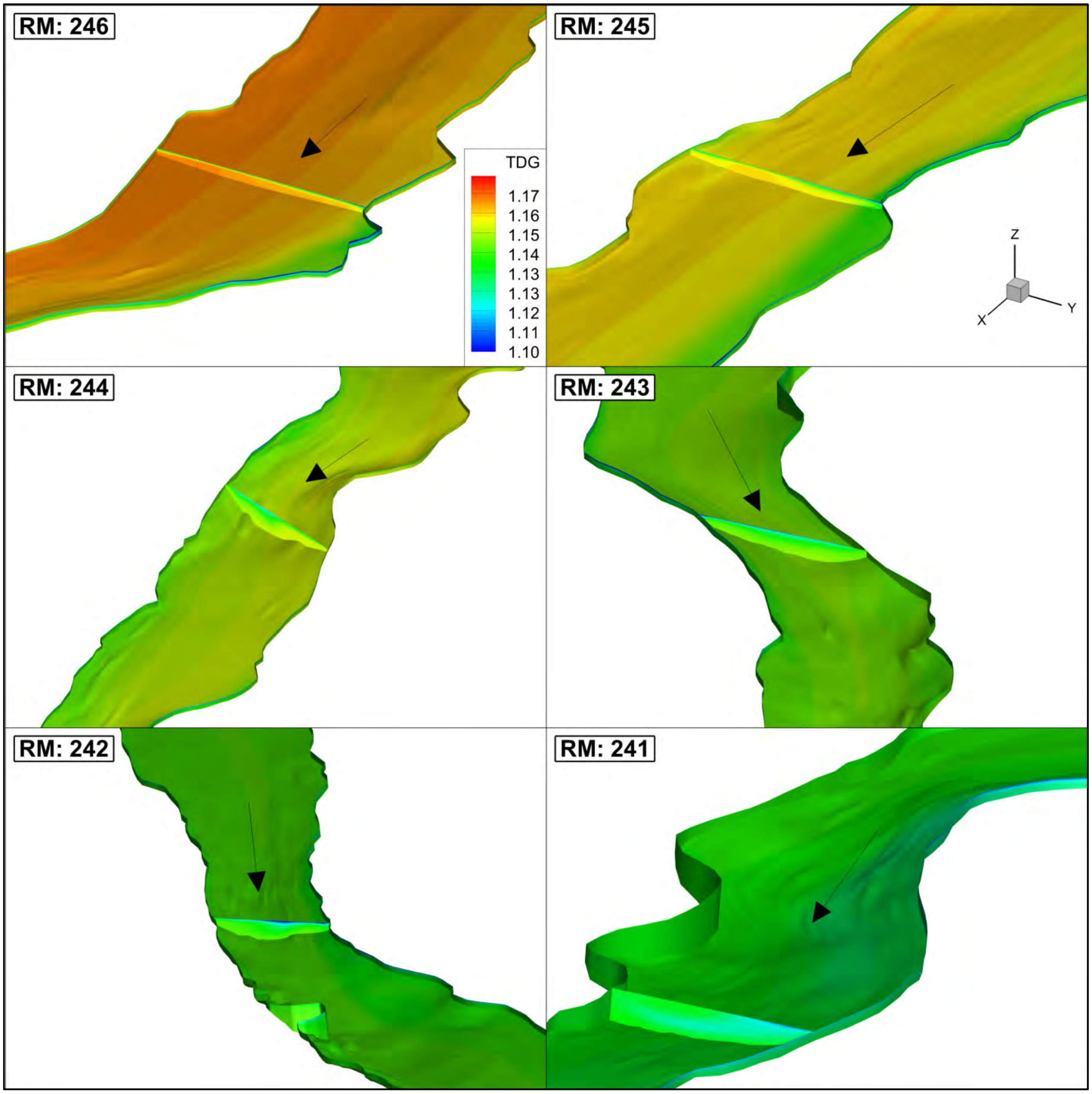


Figure 6-23. TDG in the river downstream for 45 kcfs

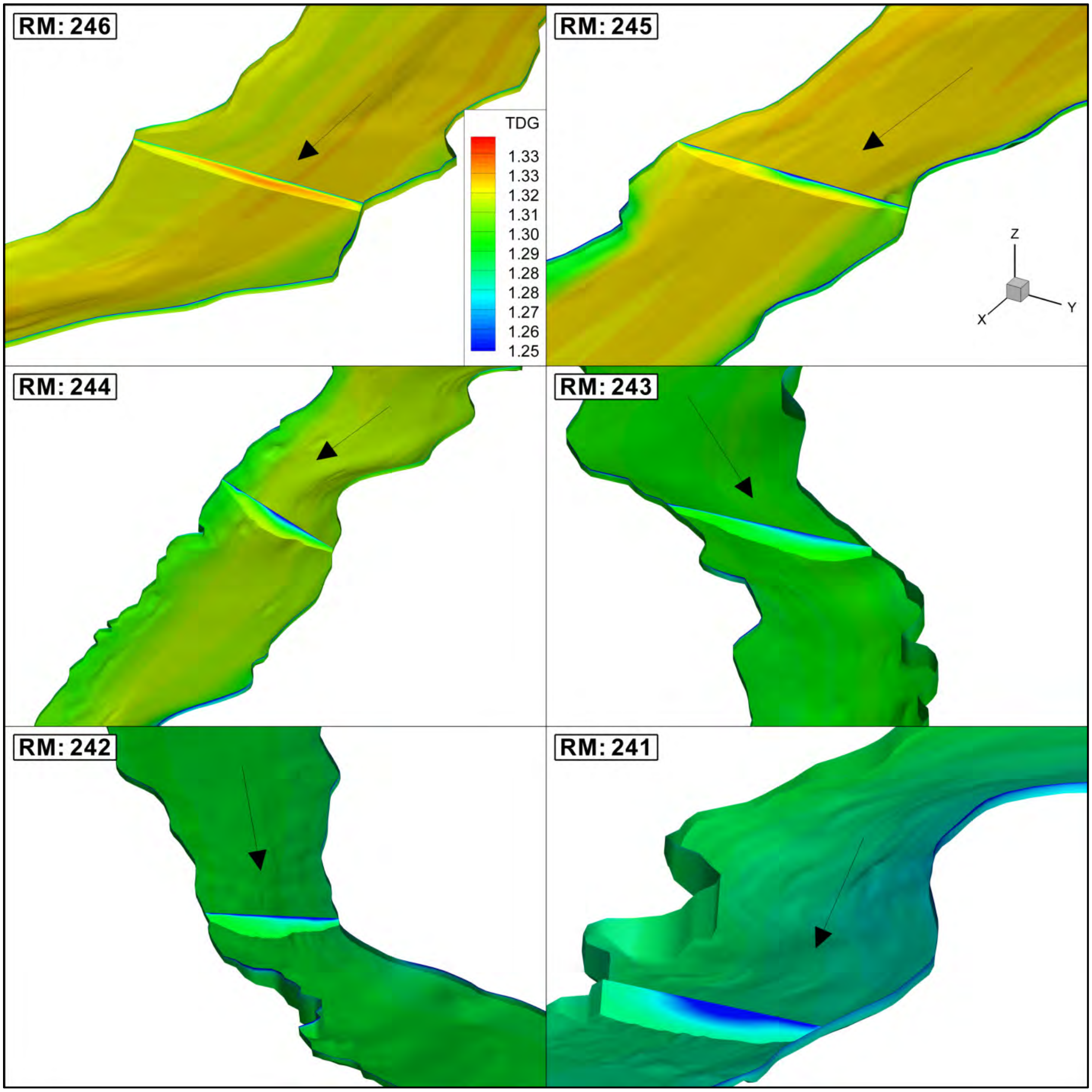


Figure 6-24. TDG in the river downstream for 7Q10 Deflector flows

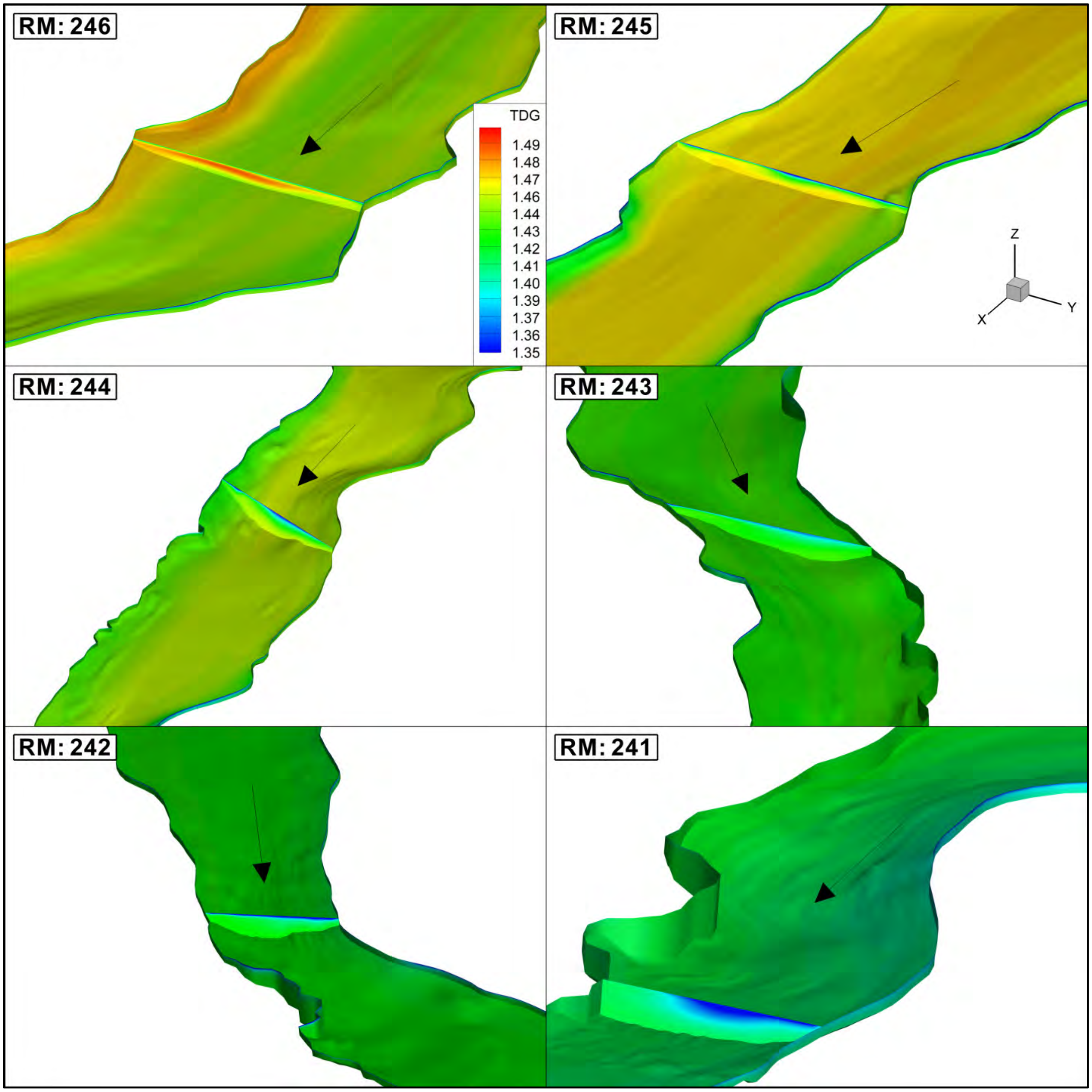


Figure 6-25. TDG in the river downstream for 7Q10 flows without deflector

Table 6-1. TDG concentration as a function of river mile. HCD is at RM 247.7 and RM 248 represents the forebay.

TDG by River Mile

	37kcfs			45kcfs			7Q10 Deflector			7Q10 No Deflector		
River Mile	Average	West Bank	East bank	Average	West Bank	East bank	Average	West Bank	East bank	Average	West Bank	East bank
248	1.150	1.150	1.150	1.150	1.150	1.150	1.150	1.150	1.150	1.150	1.150	1.150
247.6	1.155	1.169	1.151	1.152	1.157	1.151	1.209	1.321	1.164	1.501	1.205	1.674
247.5	1.159	1.171	1.151	1.168	1.169	1.151	1.352	1.368	1.287	1.518	1.210	1.656
247	1.154	1.160	1.151	1.169	1.174	1.159	1.339	1.352	1.295	1.479	1.313	1.553
246.5	1.151	1.156	1.152	1.166	1.171	1.163	1.326	1.329	1.330	1.476	1.391	1.524
246	1.147	1.152	1.143	1.163	1.165	1.152	1.321	1.322	1.320	1.468	1.465	1.483
245.5	1.144	1.150	1.137	1.158	1.164	1.158	1.313	1.322	1.319	1.456	1.455	1.477
245	1.140	1.145	1.133	1.154	1.159	1.141	1.306	1.322	1.310	1.446	1.461	1.450
244.5	1.135	1.139	1.134	1.151	1.159	1.154	1.301	1.306	1.322	1.438	1.441	1.464
244	1.132	1.137	1.132	1.148	1.150	1.157	1.297	1.307	1.309	1.432	1.468	1.441
243.5	1.130	1.137	1.131	1.146	1.150	1.155	1.294	1.307	1.305	1.428	1.453	1.440
243	1.126	1.133	1.127	1.143	1.148	1.147	1.290	1.302	1.295	1.422	1.444	1.448
242.5	1.125	1.130	1.130	1.142	1.149	1.146	1.289	1.298	1.287	1.421	1.428	1.438
242	1.122	1.123	1.122	1.139	1.147	1.140	1.283	1.296	1.288	1.412	1.427	1.429
241.5	1.118	1.117	1.118	1.135	1.138	1.135	1.278	1.288	1.281	1.404	1.412	1.431
241	1.116	1.116	1.116	1.133	1.136	1.130	1.273	1.285	1.274	1.398	1.408	1.423

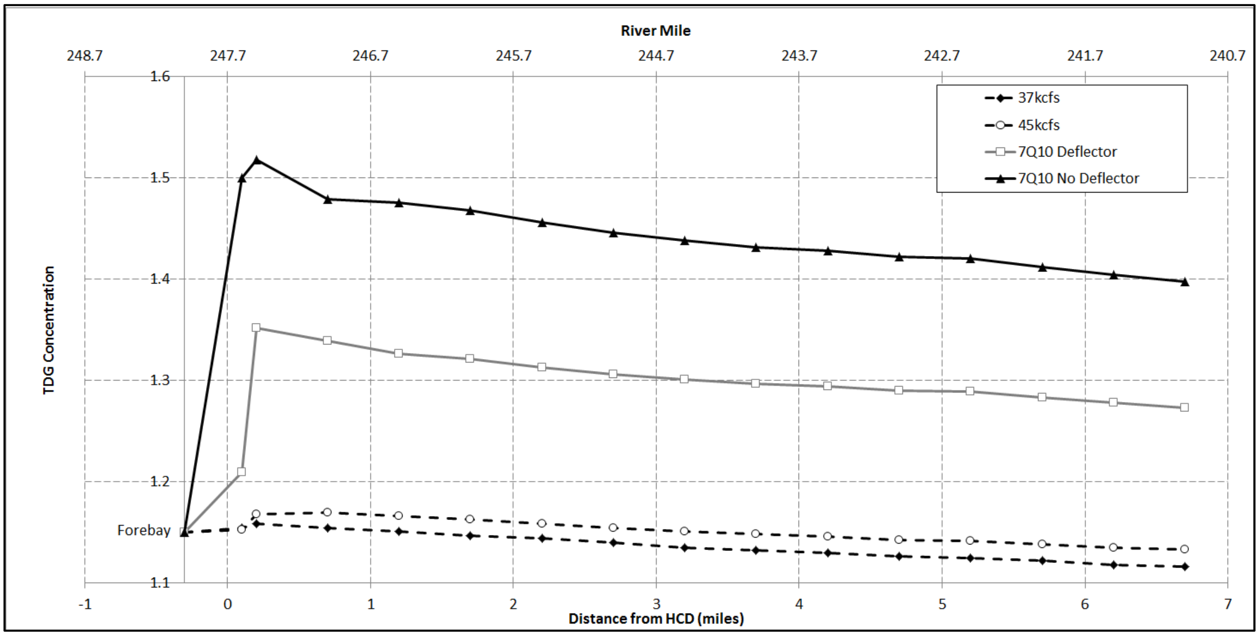


Figure 6-26. Average TDG downstream

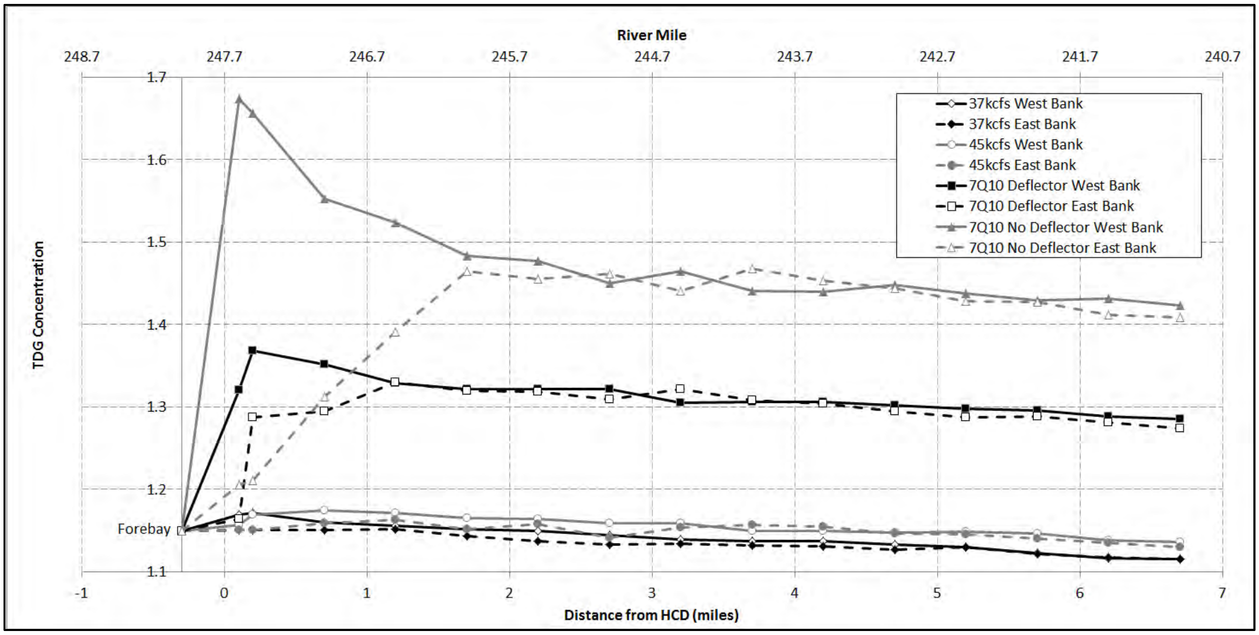


Figure 6-27. TDG at western and eastern banks downstream

Powerhouse Entrainment

The induced lateral flow is estimated calculating flowrates in the planes shown in Figure 5-31. The accumulated powerhouse entrainment for the predictive simulations is shown in Figure 6-28. Powerhouse entrainment increases with spill flowrate. Stronger surface jets promote surface currents attracting more water towards the spillway region. The lateral flow induced by deflectors is noticeable for the 7Q10 simulation. At 90 ft from the dividing wall, approximately 2.5 times more water is entrained into the spillway region due to the inclusion of deflectors.

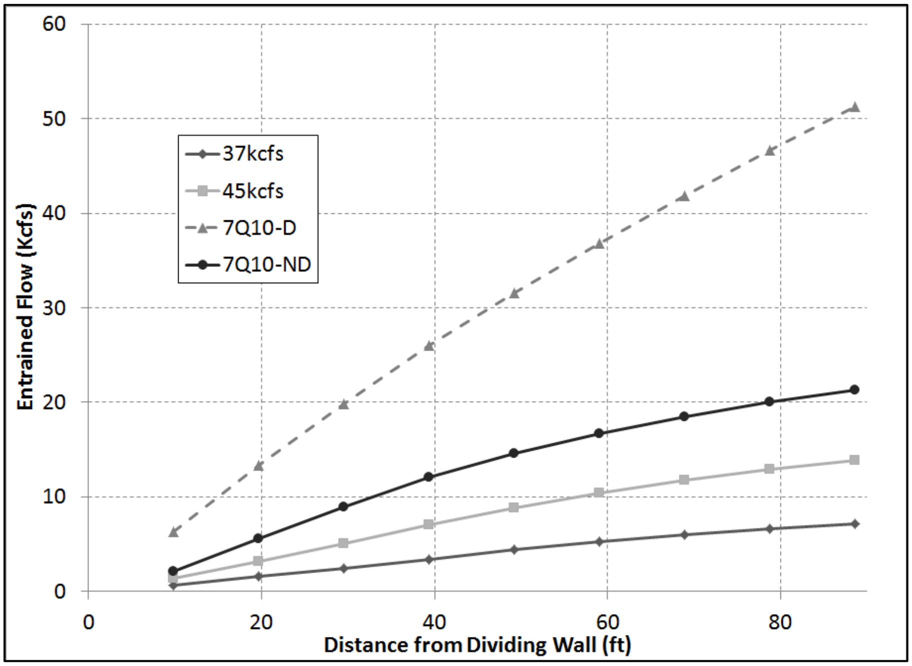


Figure 6-28. Accumulated powerhouse entrainment

Fish Injury

A comprehensive review on injury mechanisms associated with fish passage through hydroelectric turbines is found in Jacobson (2011). Deng et al. (2005) exposed juvenile salmonids to a laboratory-generated shear environment. In this study, fish were introduced into a high velocity water jet. According to the authors, acceleration is the strongest predictive variable to correlate eye and operculum injuries and overall injury level, and it is proposed to link laboratory studies of fish injury, field studies, and numerical modeling. Curves of probability of fish injury as a function of flow acceleration were determined by the authors. Figures 6-29 to 6-32 show the probability of major and minor fish injury as well as eye and operculum damage reported by Deng et al. (2005). For an acceleration of approximately 900 ft/s^2 the probability of major injury is below 0.05. At about 1500 ft/s^2, the probabilities of fish suffering minor and major injuries are 0.50 and 0.18 respectively. Life-threatening injuries are almost certain for accelerations above 4200 ft/s^2.

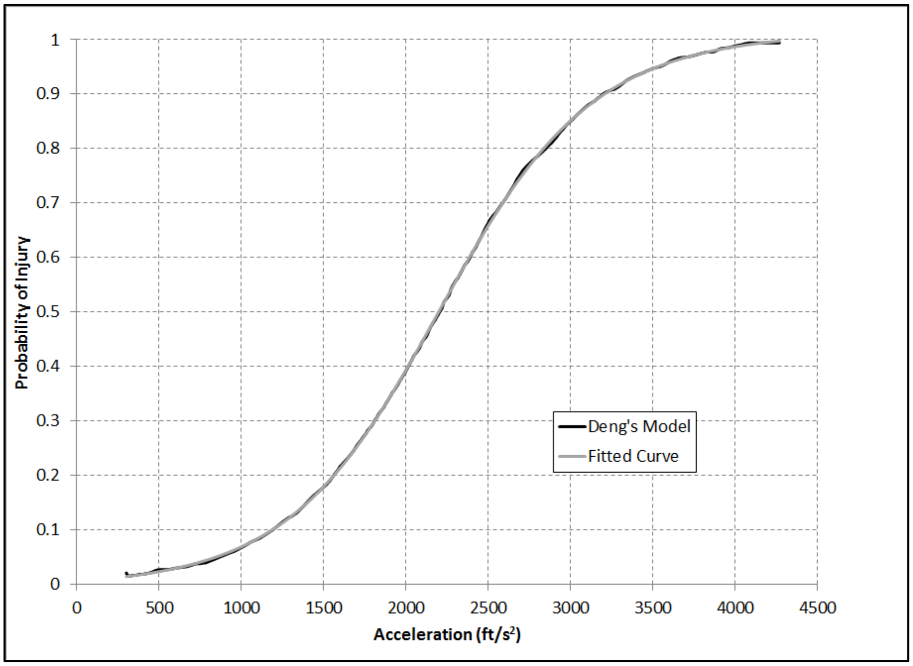


Figure 6-29. Probability of major injury

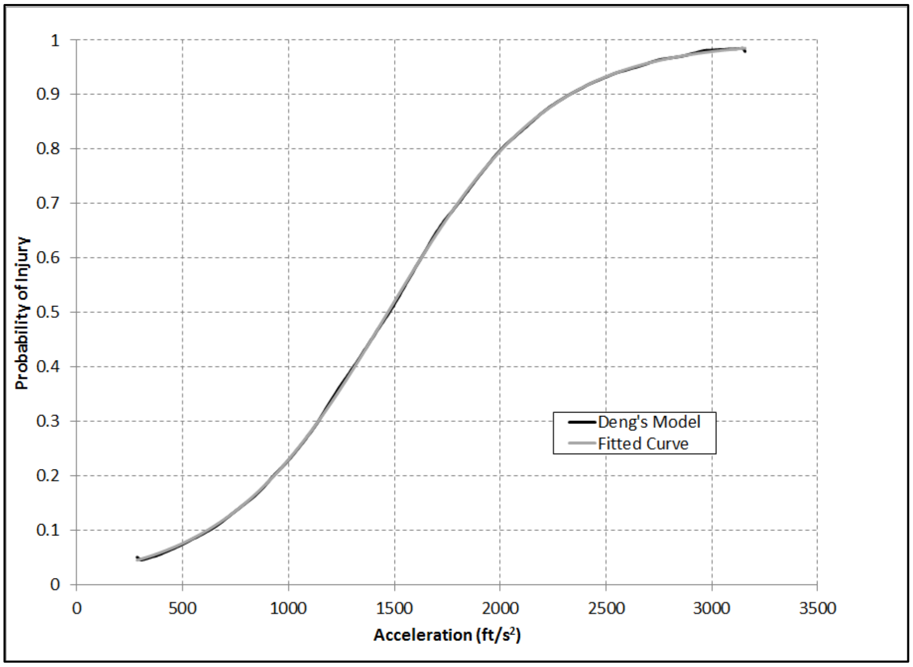


Figure 6-30. Probability of minor injury

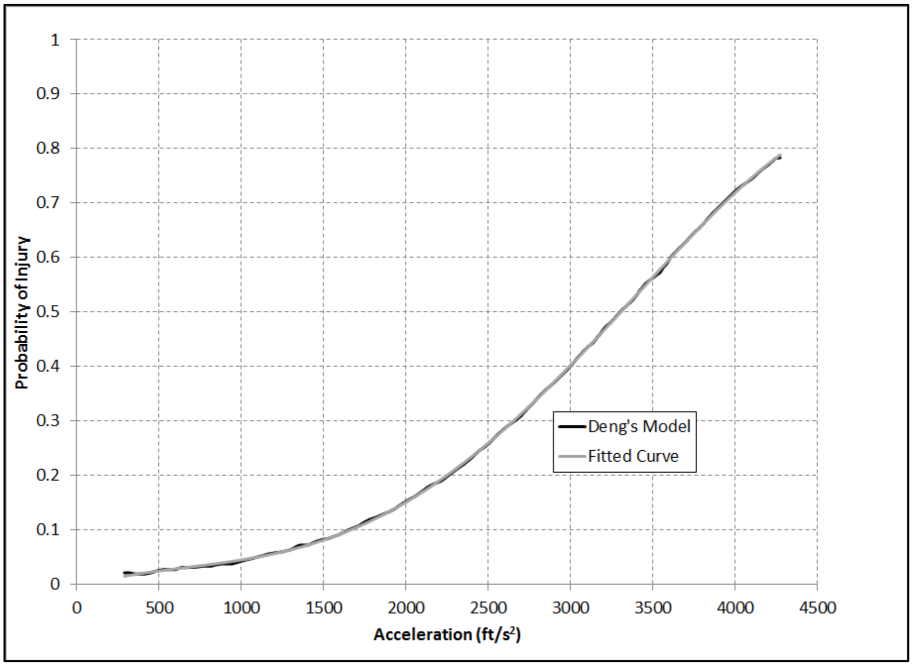


Figure 6-31. Probability of eye injury

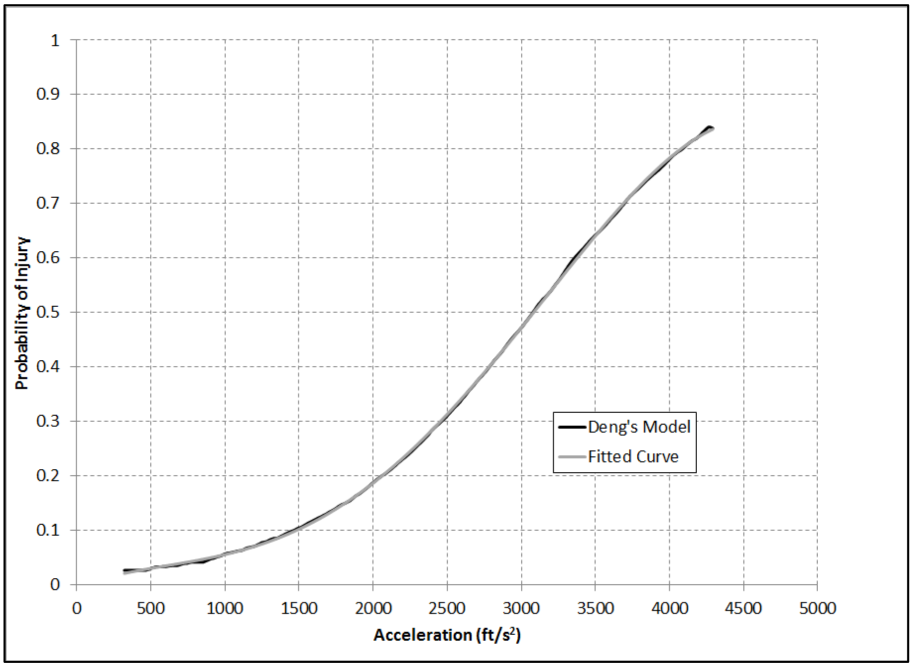


Figure 6-32. Probability of operculum injury

Turnpenny et al. (1992) exposed salmonids to a high-velocity water jet in a water tank. According to the authors, no injuries or mortalities from shear stress values at or below 774 N/m^2

were observed. In concurrence, Neitzel et al. (2000) reported that exposures to shear strain rates above 850 s^{-1} would be harmful to juvenile fish. Later, Foust et al. (2010) found that values of strain rate above 360 s^{-1} can be harmful to fish. Neitzel et al. (2000) reported that injury or mortality is unlikely to occur at strain rates less than about 500 s^{-1} and Neitzel et al. (2004) reported that major injuries were not observed at or below a strain rate of 517 $s^{-1.}$

The potential for injury due to pressure changes were examined in several experimental studies (Jacobson, 2011). The level of injury depends on the magnitude and rates of pressure change and the fish acclimation pressure. Salmonids exposed to low pressures showed higher mortality than those exposed to gradual or rapid increases in pressure. Little or no mortality was observed when fish were exposed to pressure as high as 300 psi followed by decompression to atmospheric pressure (Harvey 1963, Rowley 1955, Foye and Scott 1965). Pressures at or above 7.25 psi and rates of pressure change at or below 508 psi/s could be expected to provide safe passage for salmonids (Becker at al. 2003).

Averaged acceleration and strain rate experienced by particles along the spillway for 37 kcfs, 45 kcfs and a 7Q10 flow are shown in Figures 6-33 to 6-36. The solid black line shows the sluiceway shape and the blue line the water surface elevation. The maximum averaged acceleration is observed when particles impact the deflector. Maximum averaged values, of the order of 450 ft/s^2, are predicted for the 7Q10 simulation with deflector. For a 7Q10 flow without deflector, maximum accelerations are found at the bottom of the stilling basin. For this case, elevated acceleration is also observed when particles impact the spillway nappe deflectors.

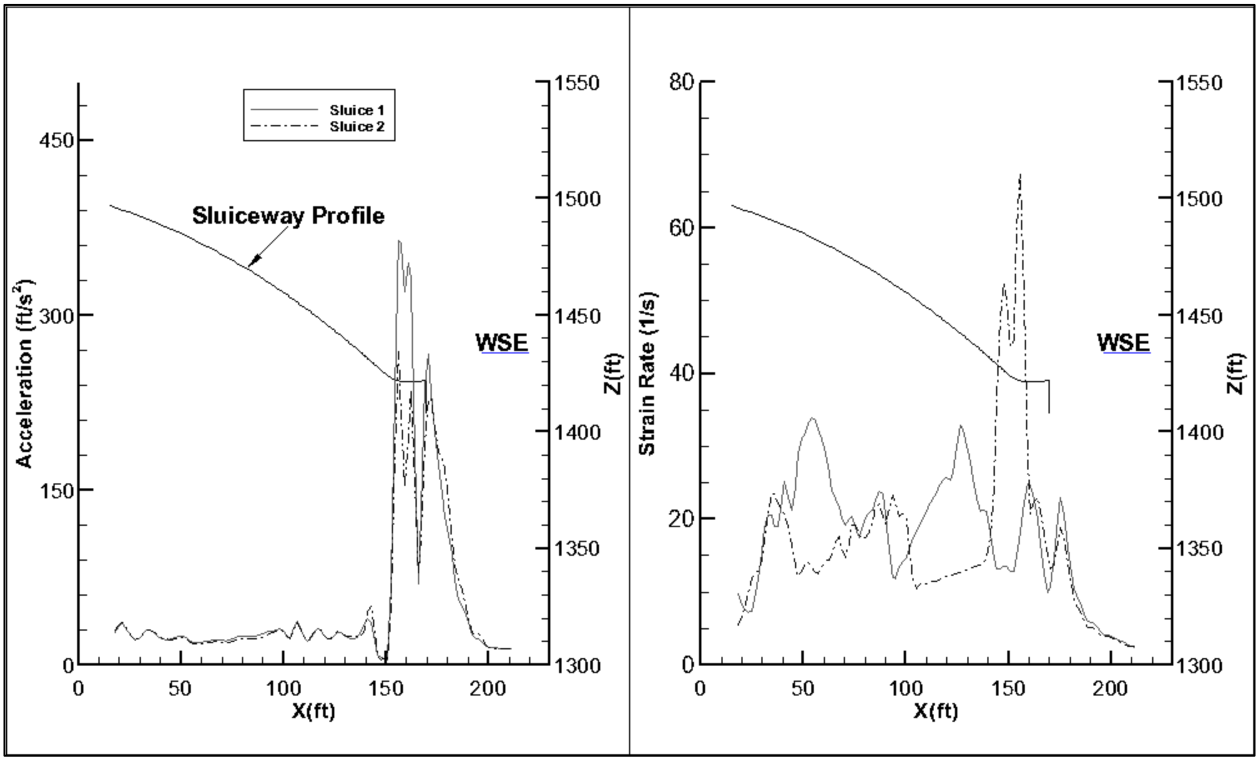


Figure 6-33. Acceleration and strain rate for 37 kcfs

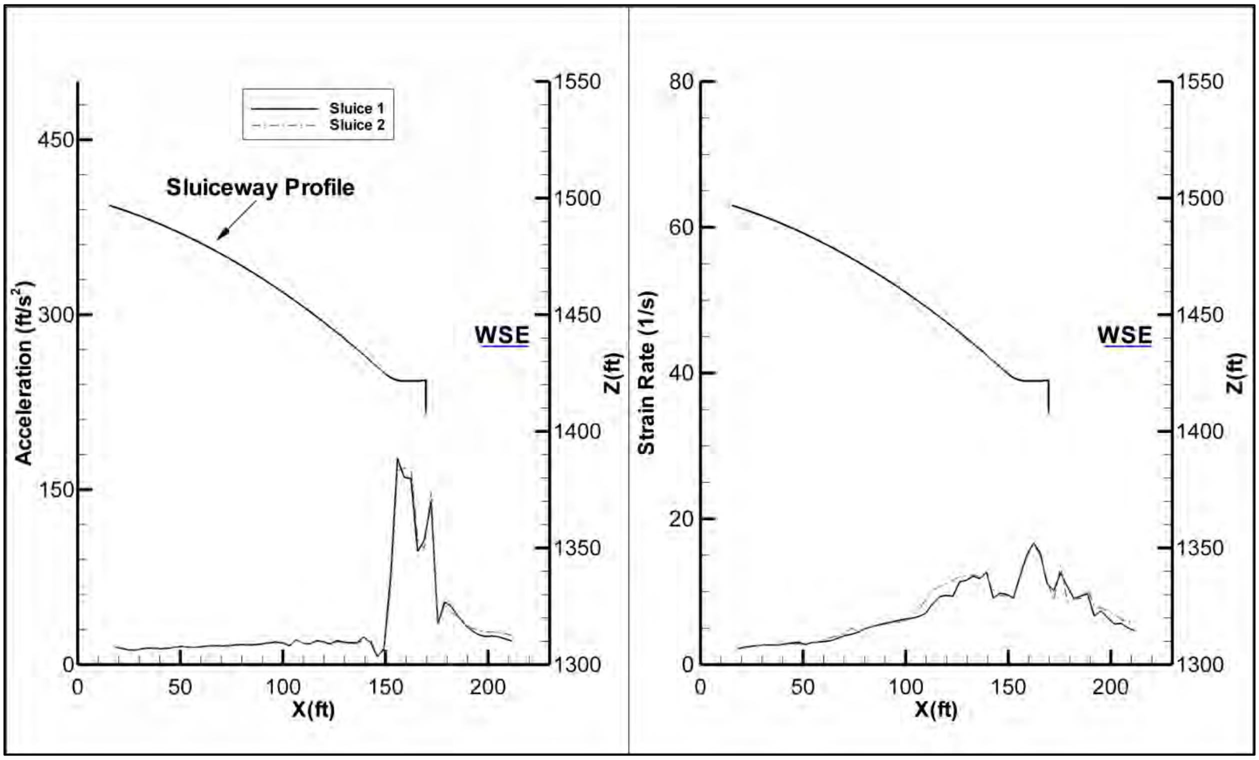


Figure 6-34. Acceleration and strain rate for 45 kcfs

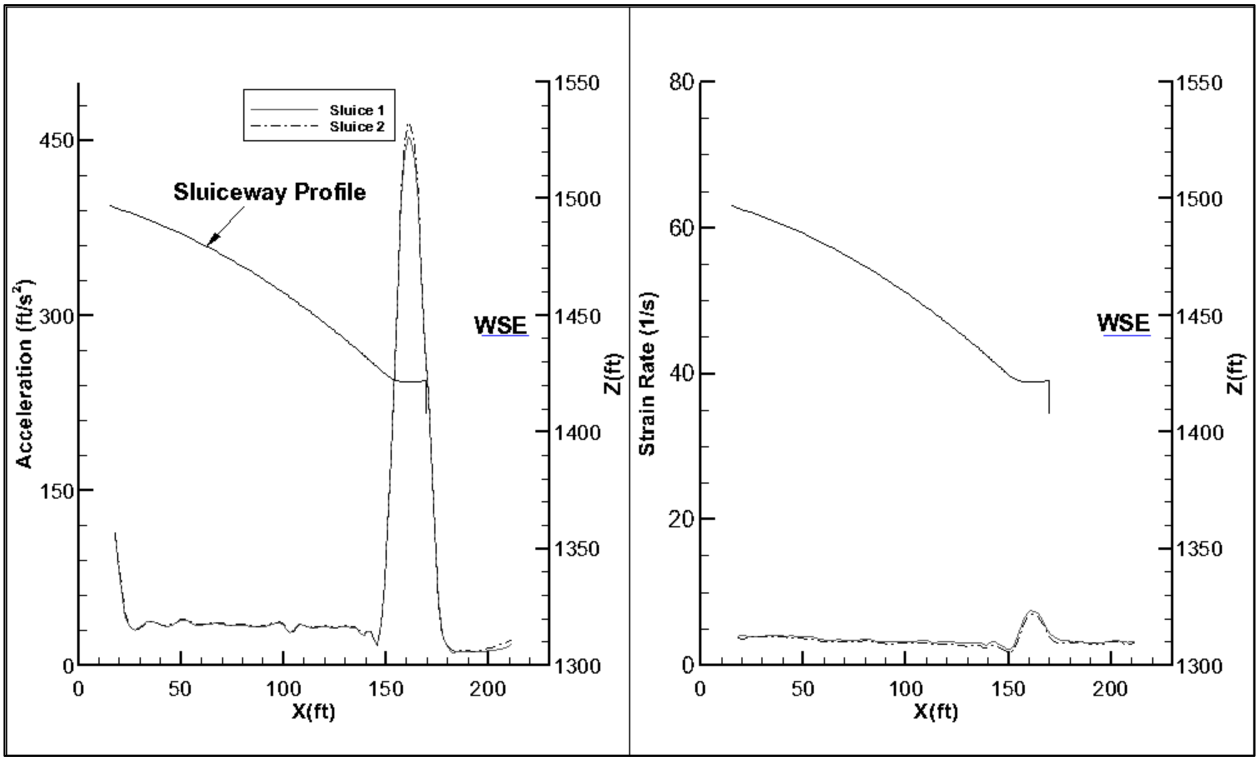


Figure 6-35. Acceleration and strain rate for 7Q10 with deflectors

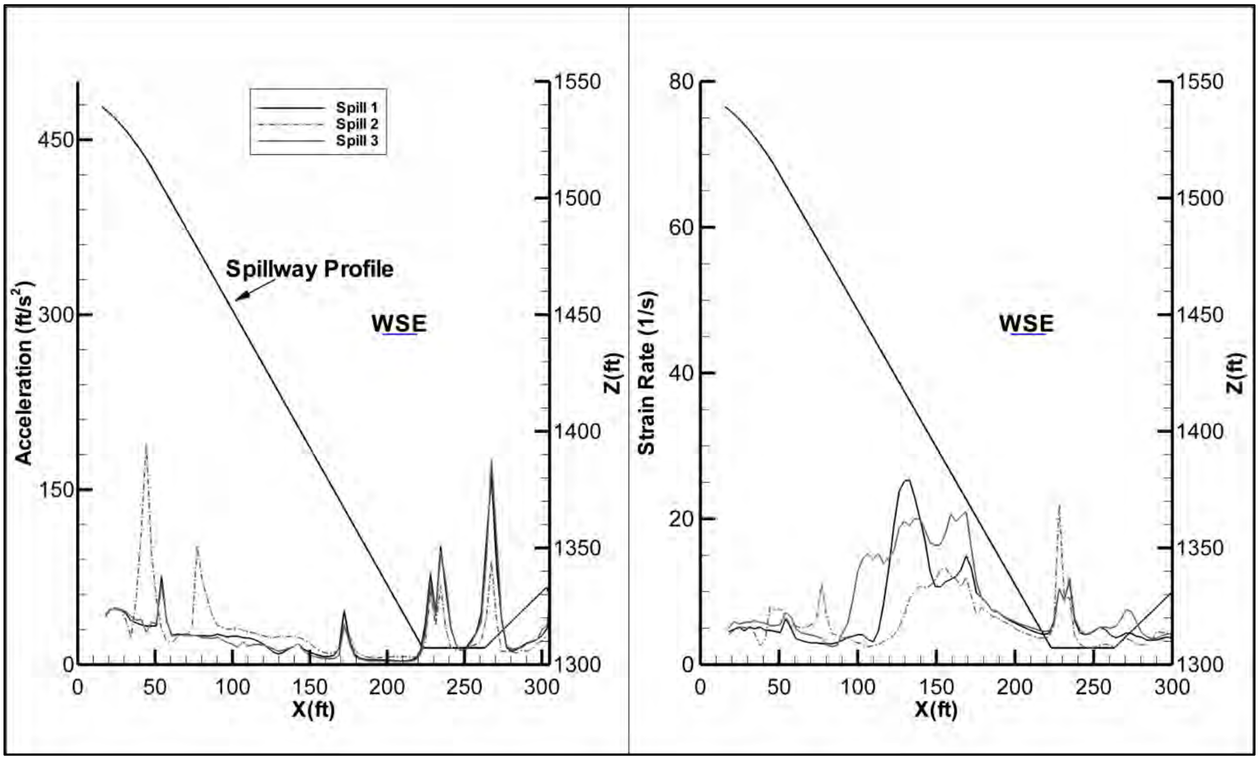


Figure 6-36. Acceleration and strain rate for 7Q10 without deflectors

Figures 6-33 to 6-36 provide averaged acceleration of all particles found in a given longitudinal location. In order to estimate the probability of injury of fish traveling through the spillway, the probability of injury of each particle released from sluice or spillway gates was calculated using the maximum acceleration a particle experienced. In this study, Deng's curves were fitted by polynomial and sigmoidal functions:

$$y = -0.0057 + 1.02059\left(\frac{0.7681}{1+10^{0.00331(665.60708-x)}} + \frac{0.2319}{1+10^{0.00221(706.05854-x)}}\right) \text{ major injury} \tag{3}$$

$$y = \frac{0.998}{1+e^{-0.00847(x-447.33824)}} \qquad \text{minor injury} \tag{4}$$

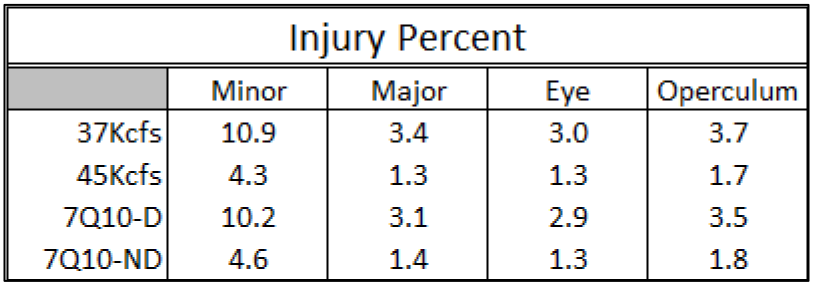
$$y = -8.19649\,10^{-13}x^4 + 2.02954\,10^{-9}x^3 - 1.02567\,10^{-6}x^2 + 3.14856\,10^{-4}x - 0.00662 \text{ eye injury} \tag{5}$$

$$\begin{aligned} y = {} & -1.01137\,10^{-12}x^4 + 2.33151\,10^{-9}x^3 - 1.08654\,10^{-6}x^2 + \\ & 3.38219\,10^{-4}x - 0.0042 \qquad \text{operculum injury} \end{aligned} \tag{6}$$

Gray lines in Figures 6-29 to 6-32 show the above fitted functions. Table 6-2 and Figure 6-37 show the percent of injured fish. The most critical cases are the 37 kcfs and 7Q10 flow. In these conditions, about 10% and 3% of fish can suffer minor and major injuries, respectively. The inclusion of the deflector in a 7Q10 flow increases the percent of fish with minor injuries from about 4% to 10% and from 1% to 3% for major injuries.

The largest values of strain rate occur when fish impact the deflector. The largest predicted value occurs for 37 kcfs and is of the order of 200 s^{-1}, which is well below the critical value of 517 s^{-1} where, according to Neitzel et al. 2004, major injuries were not observed.

Table 6-2. Injury percent due to acceleration



Injury Percent				
	Minor	Major	Eye	Operculum
37Kcfs	10.9	3.4	3.0	3.7
45Kcfs	4.3	1.3	1.3	1.7
7Q10-D	10.2	3.1	2.9	3.5
7Q10-ND	4.6	1.4	1.3	1.8

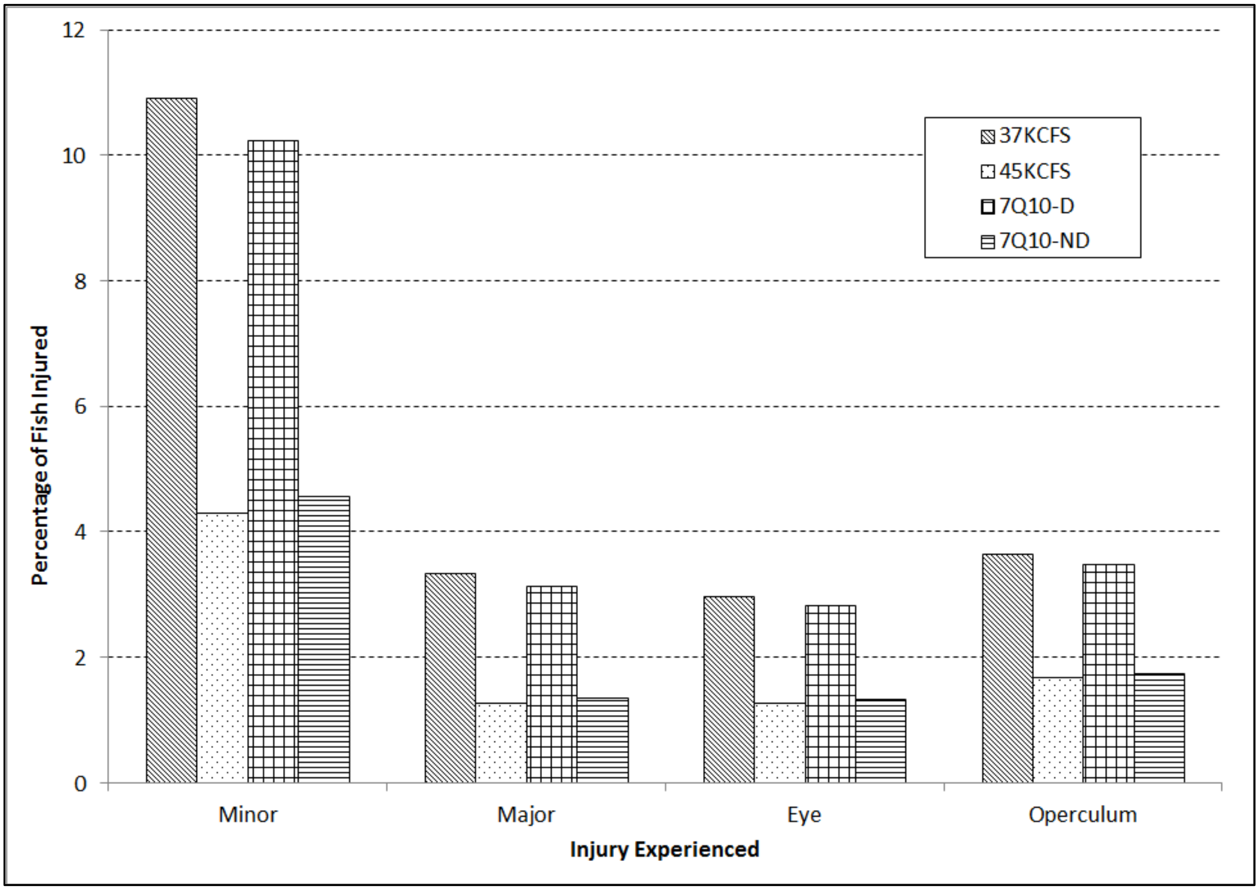


Figure 6-37. Percent of fish injured

Residence Time

The residence time in the tailrace was calculated by releasing particles from sluiceway and spillway bays as well as powerhouse units. The number of particles released was proportional to the injection flowrate. The time spent for particles to travel from the released location to a plane at about 650 ft from the dam was computed. The distance of 650 ft was chosen because it was within the bound of all the simulations and sufficiently past any recirculation that would cause false readings. Table 6-3 shows average, mean and standard deviation of the residence time distributions. Figures 6-38 to 6-41 show the residence time of particles released in the spillway for 37 kcfs, 45 kcfs and the 7Q10 simulations, respectively. The residence time of particles from turbine units are shown in Figures 6-42 and 6-43.

Paths of particles released from sluice/spillway and turbines colored by time (sec) for 37 kcfs, 45 kcfs and 7Q10 simulations, are shown in Figures 6-44 to 6-51. Figures 6-52 to 6-55 show the paths of an individual particle for each injection site to help visualization. Note that particles released from different locations in a given injection site can follow different paths and therefore there is not a single particle that can represent the behavior of the whole injection.

For the same powerhouse flow, the eastern eddy is weaker and the western eddy stronger as the spill increases. For 37 kcfs and 45 kcfs, the residence time of particles from sluice #2 (circles in Figures 6-52 and 6-53) is larger than particles from sluice #1 since some of them are trapped by the eastern eddy. The difference in residence time of particles released in sluice #1 or sluice #2 is the largest for the 37 kcfs simulation since it has the strongest eastern eddy. The total residence time for 37 kcfs and 45 kcfs is comparable. Particles released from the sluiceway in a total river flow of 37 kcfs have larger residence time than those in a 45 kcfs flowrate. On the other hand, particles released from the powerhouse for 37 kcfs present a smaller residence time.

For 37 kcfs, most of the powerhouse particles travel straight in the tailrace. As spill increases to 45 kcfs, some powerhouse particles are entrained beneath the sluice surface jets at depth in the stilling basin. Note that, in this region, a low velocity recirculation occurs beneath the surface jets increasing the overall residence time.

The residence time of the 7Q10 flow with deflectors is significantly smaller than those obtained for smaller flowrates. For this simulation, a small number of particles from the sluiceways are trapped in the eastern or western eddy. Some powerhouse particles can follow the main flow leaving the domain as fast as 40 sec. while other particles present larger residence times because they are trapped beneath the surface jets and in the strong eastern and western eddies.

At a 7Q10 flow, deflectors decrease the particle residence time mainly because of the smaller residence time of particles released from the powerhouse. These particles are entrained into the spillway region close to the high-speed jets. In addition, deflectors prevent the formation of back rolls, which trap particles back to the spillway, decreasing also the residence time of powerhouse particles entrained into the spillway region and those released from the sluiceways.

Table 6-3. Tailrace residence time

Residence Time Statistical Summary				
	37Kcfs	45Kcfs	7Q10-D	7Q10-ND
Average Residence (s)	154.1	180.1	89.3	157.5
Mean Residence (s)	164.2	175.5	97.6	157.7
Standard Deviation (s)	154.1	101.7	65.2	111.8
Total Particles	4640	5643	8966	8966

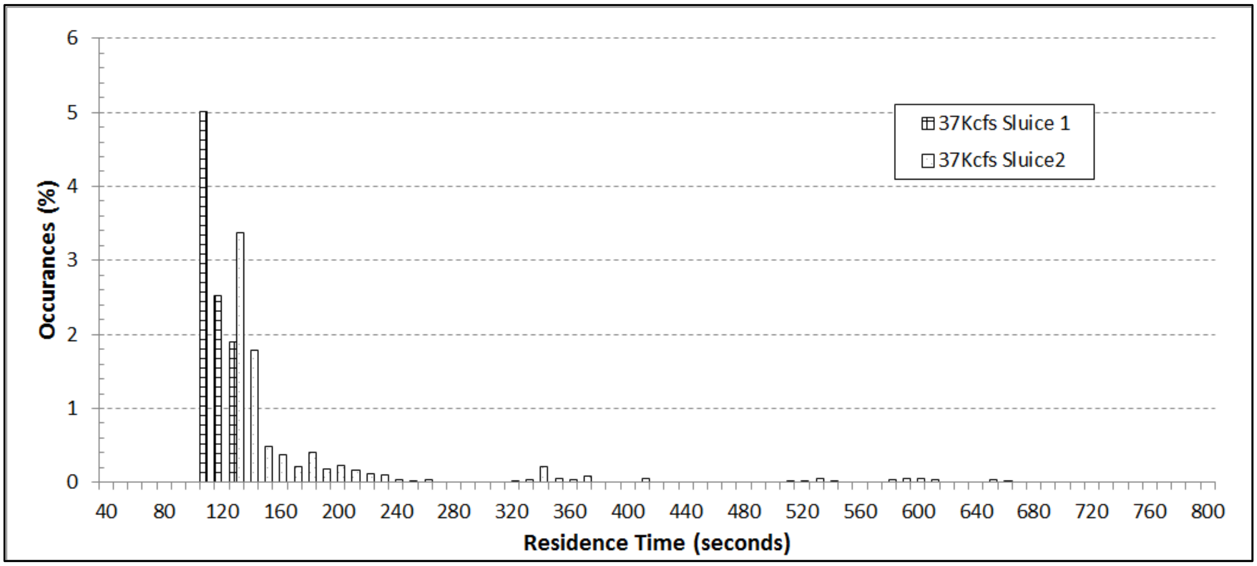


Figure 6-38. Residence time of particles released from the sluices for 37 kcfs

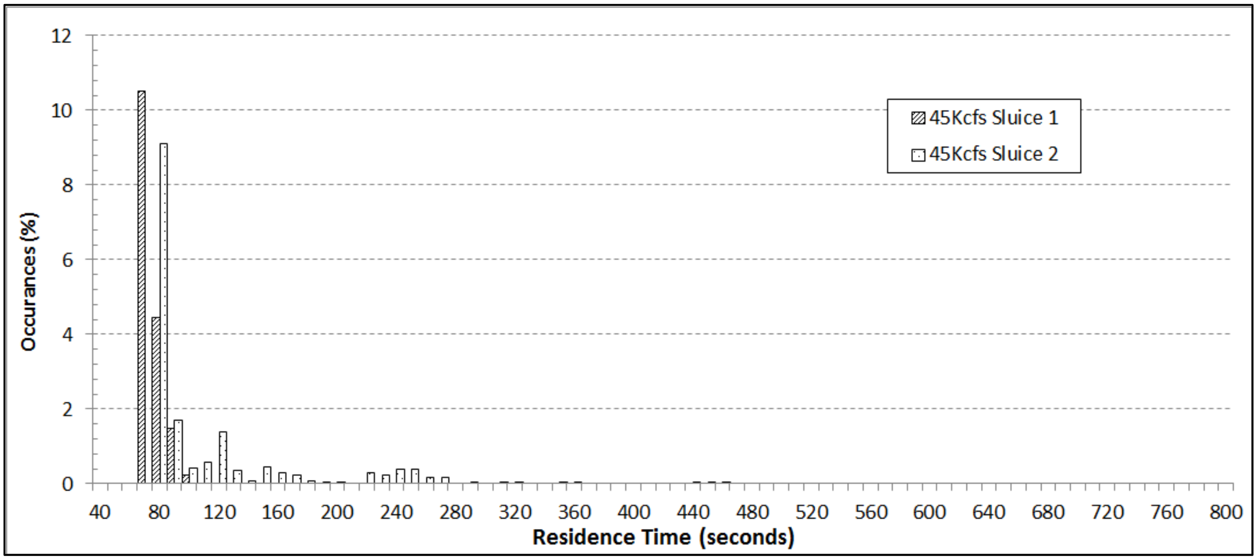


Figure 6-39. Residence time of particles released from the sluices for 45 kcfs

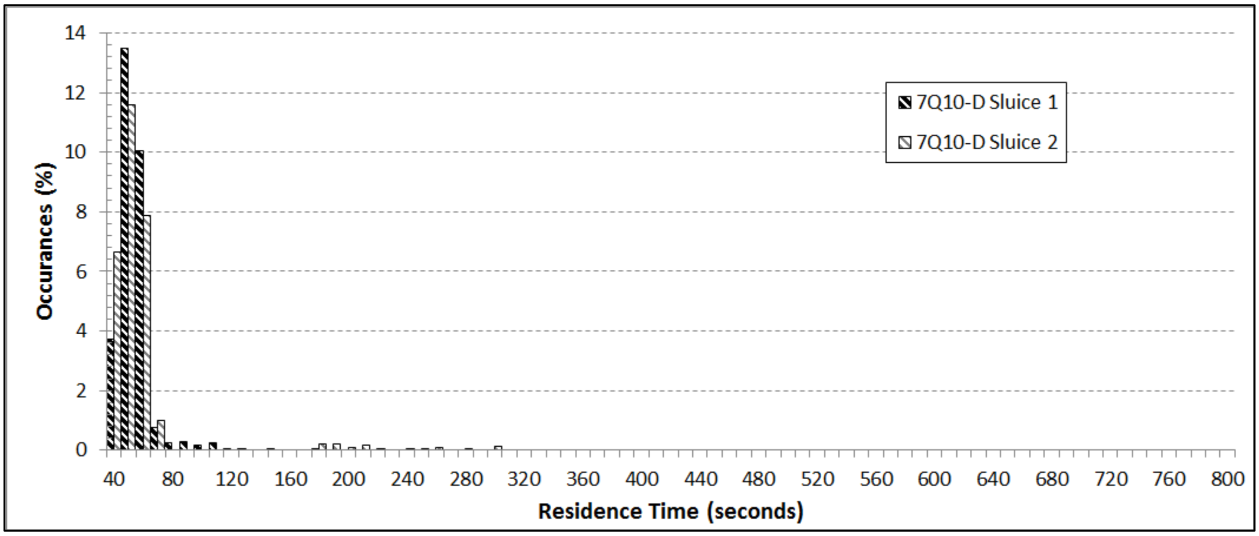


Figure 6-40. Residence time of particles released from the sluices for 7Q10 with deflectors

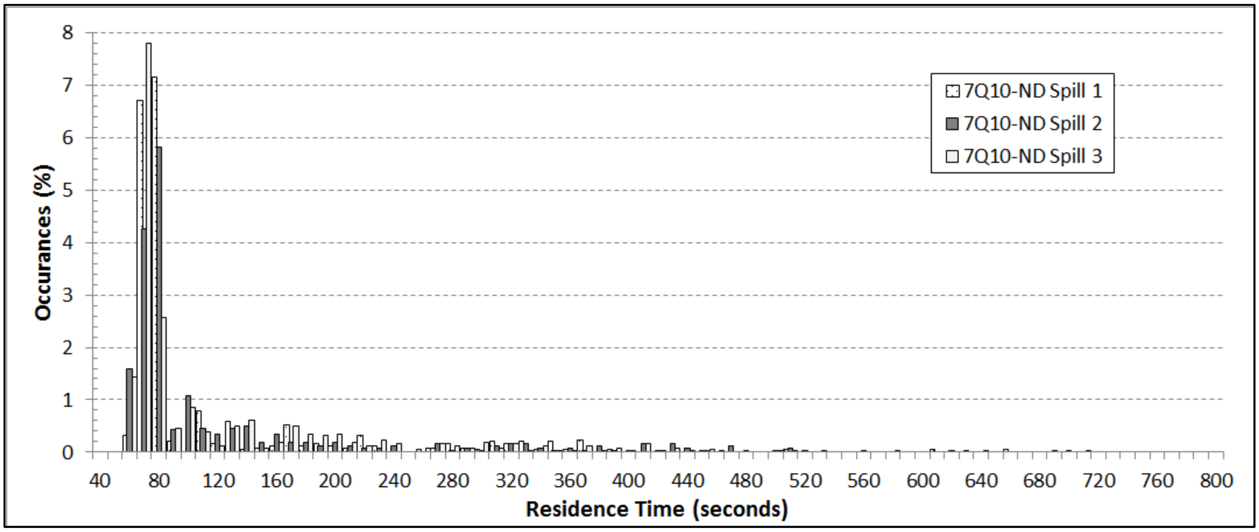


Figure 6-41. Residence time of particles released from the spillway for 7Q10 without deflectors

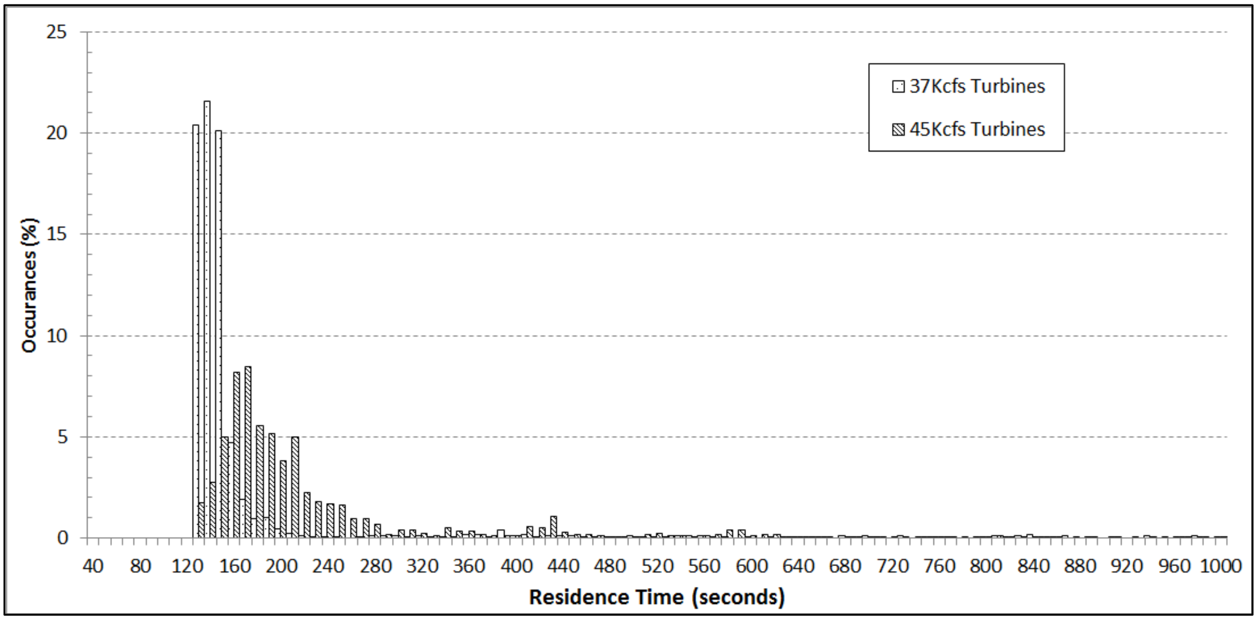


Figure 6-42. Residence time of particles released from the turbine units for 37 kcfs and 45 kcfs

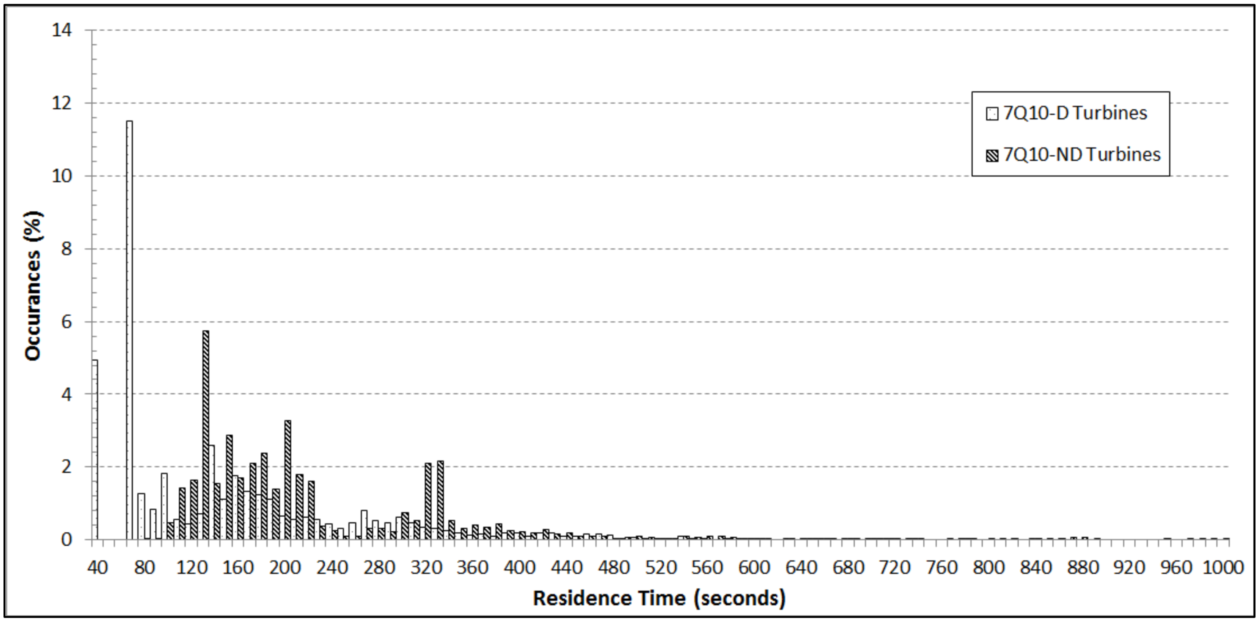


Figure 6-43. Residence time of particles released from the turbine units for a 7Q10 flow

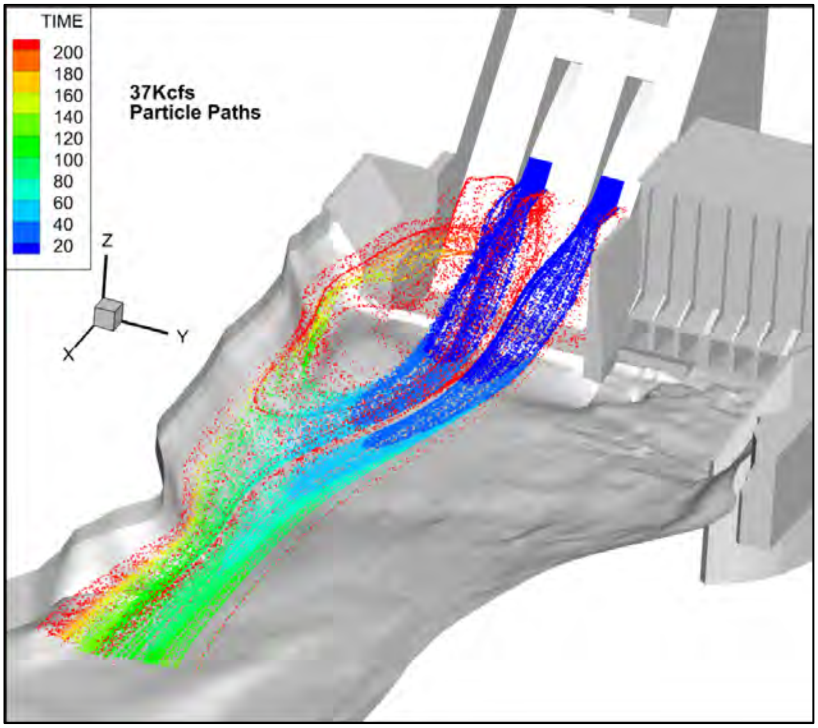


Figure 6-44. Paths of particles released from the sluices colored by time (sec) for 37 kcfs

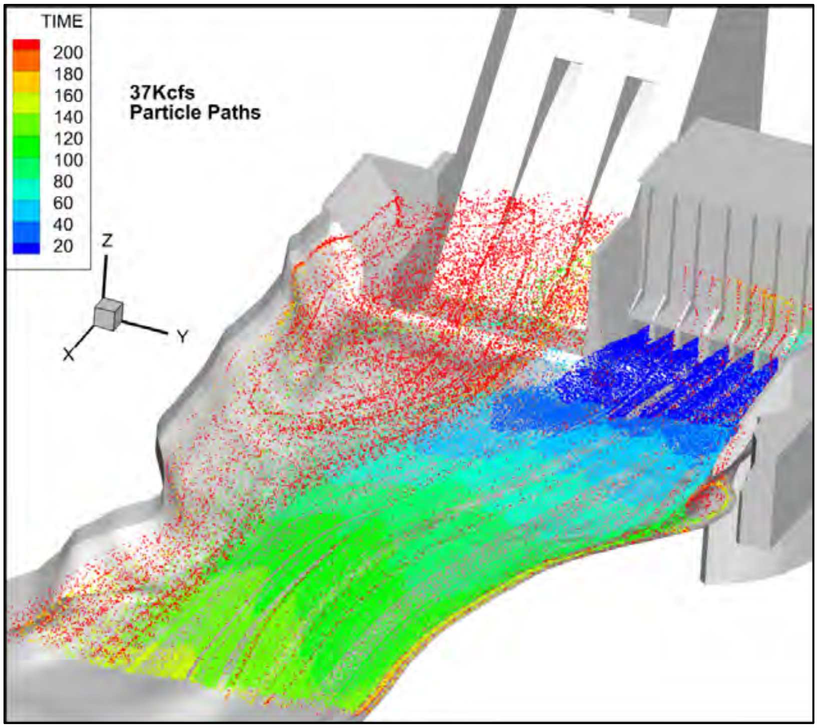


Figure 6-45. Paths of particles released from the powerhouse colored by time (sec) for 37 kcfs

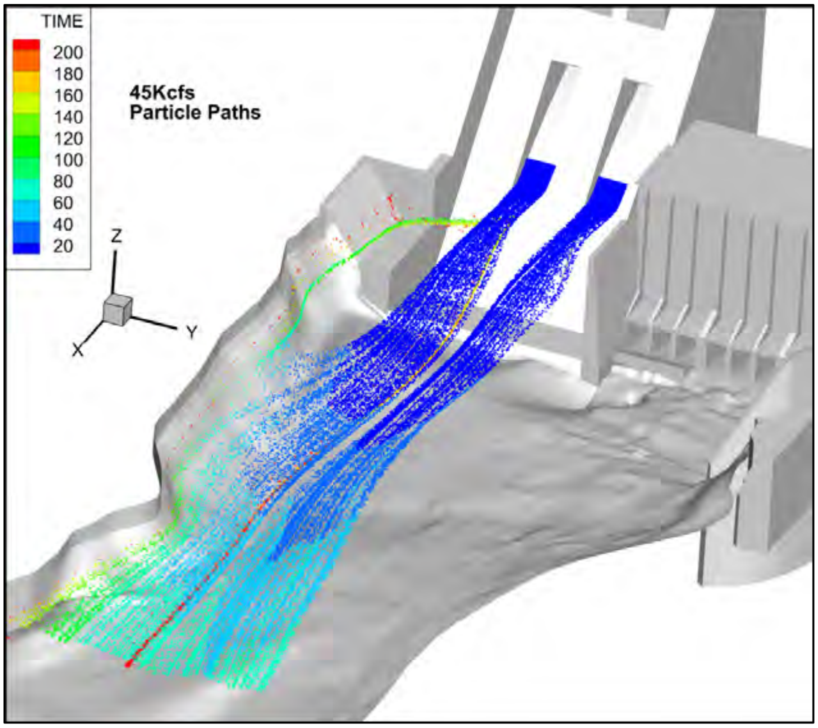


Figure 6-46. Paths of particles released from the sluices colored by time (sec) for 45 kcfs

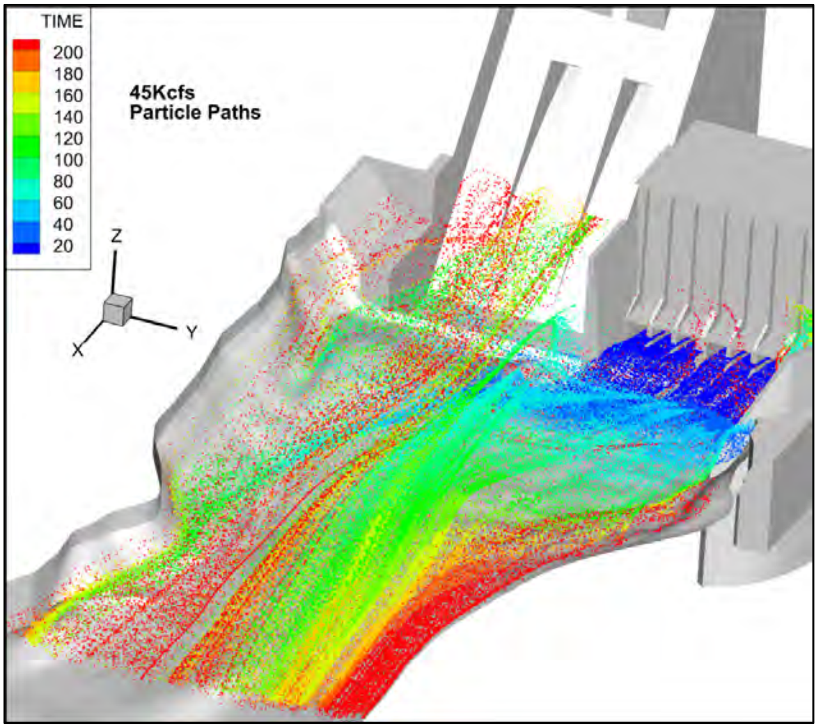


Figure 6-47. Paths of particles released from the powerhouse colored by time (sec) for 45 kcfs

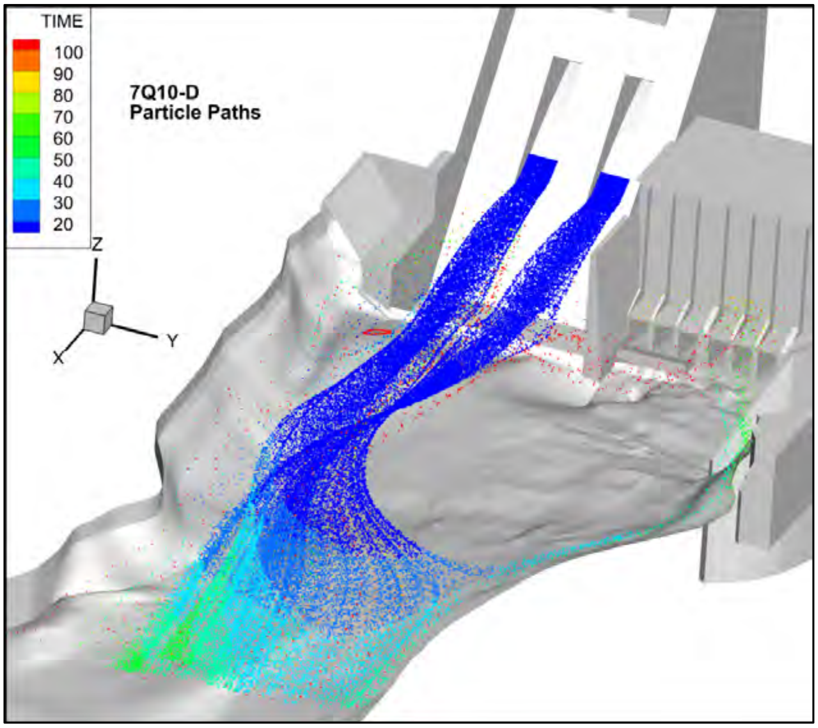


Figure 6-48. Paths of particles released from the sluices colored by time (sec) for a 7Q10 flow with deflectors

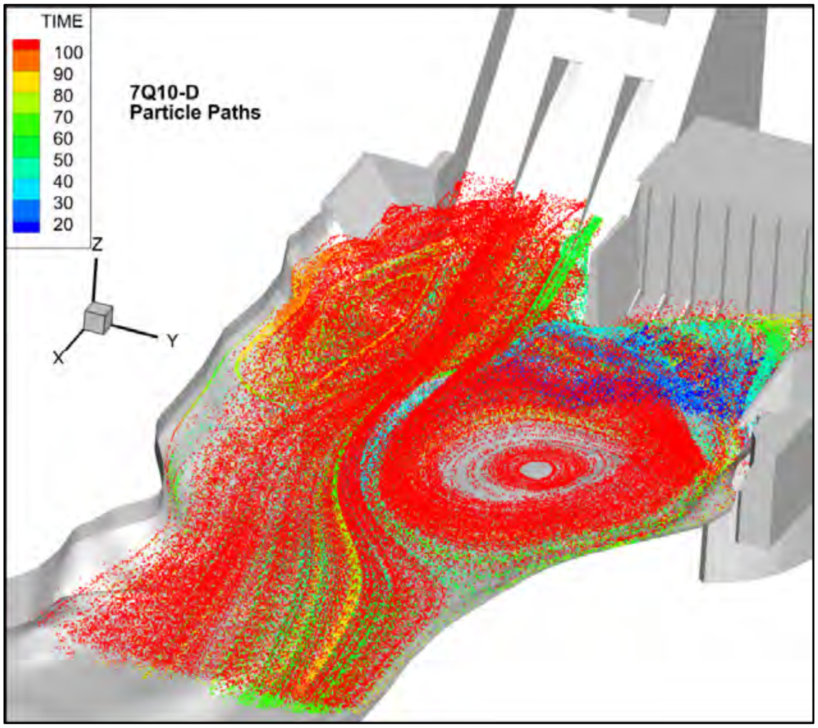


Figure 6-49. Paths of particles released from the powerhouse colored by time (sec) for a 7Q10 flow with deflectors

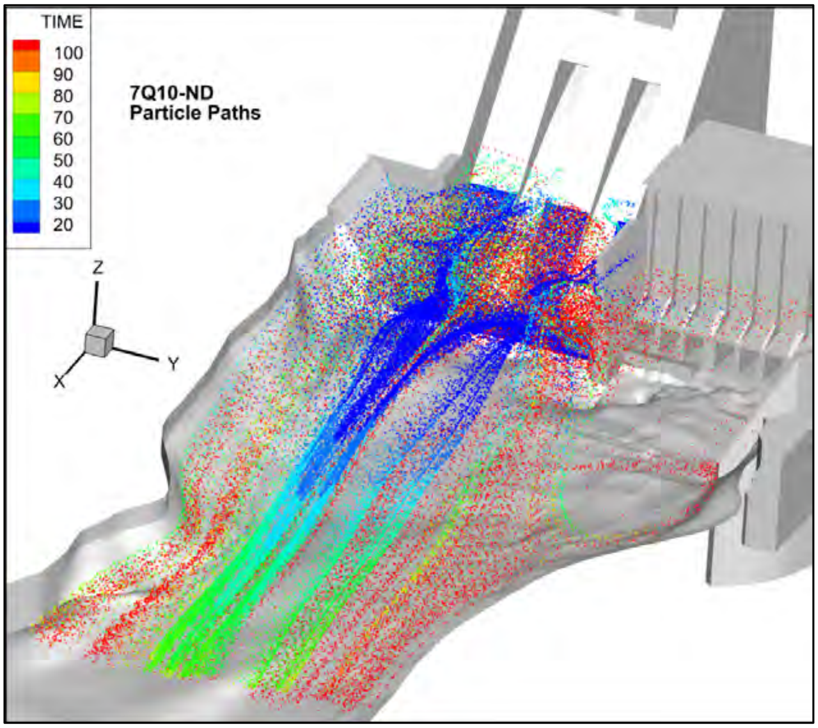


Figure 6-50. Paths of particles released from the spillway colored by time (sec) for a 7Q10 flow without deflectors

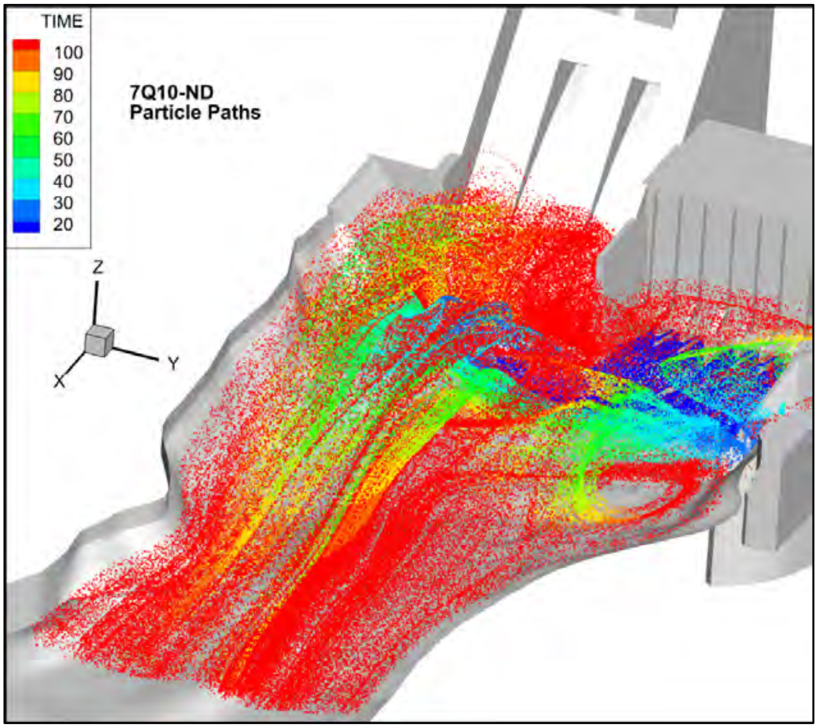


Figure 6-51. Paths of particles released from the powerhouse colored by time (sec) for a 7Q10 flow without deflectors

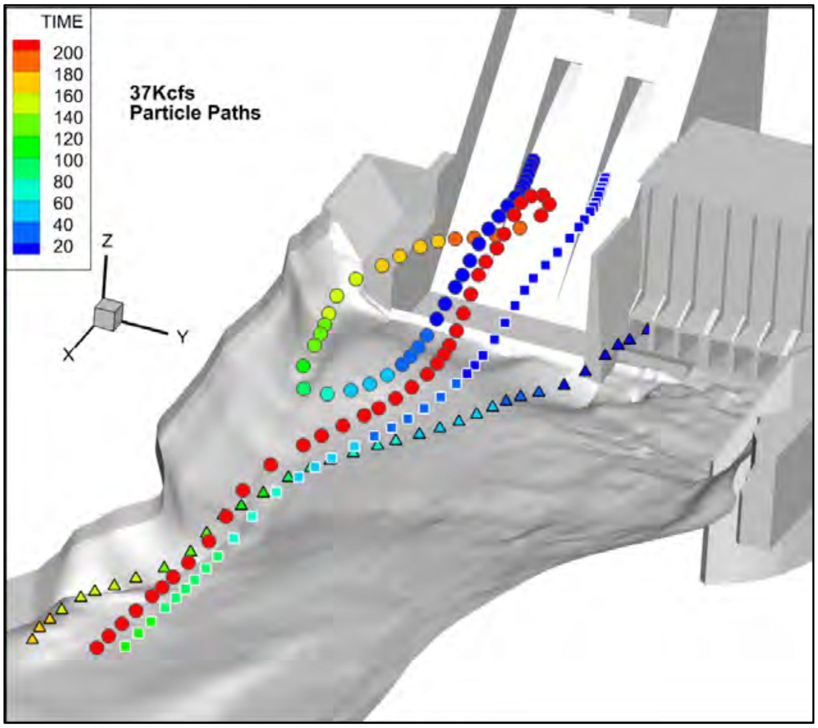


Figure 6-52. Path of a particle from each injection site colored by time (sec) for 37 kcfs

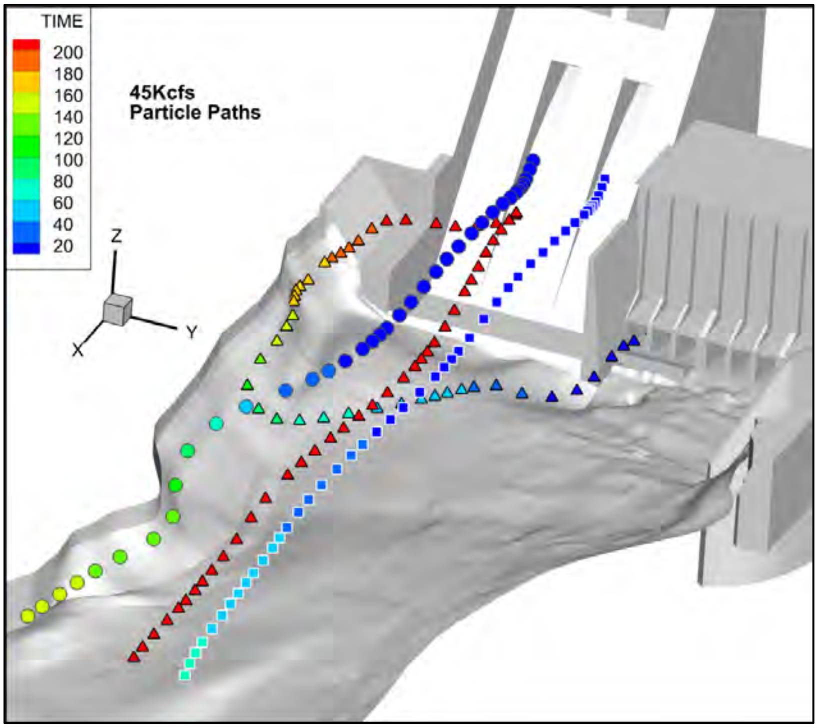


Figure 6-53. Path of a particle from each injection site colored by time (sec) for 45 kcfs

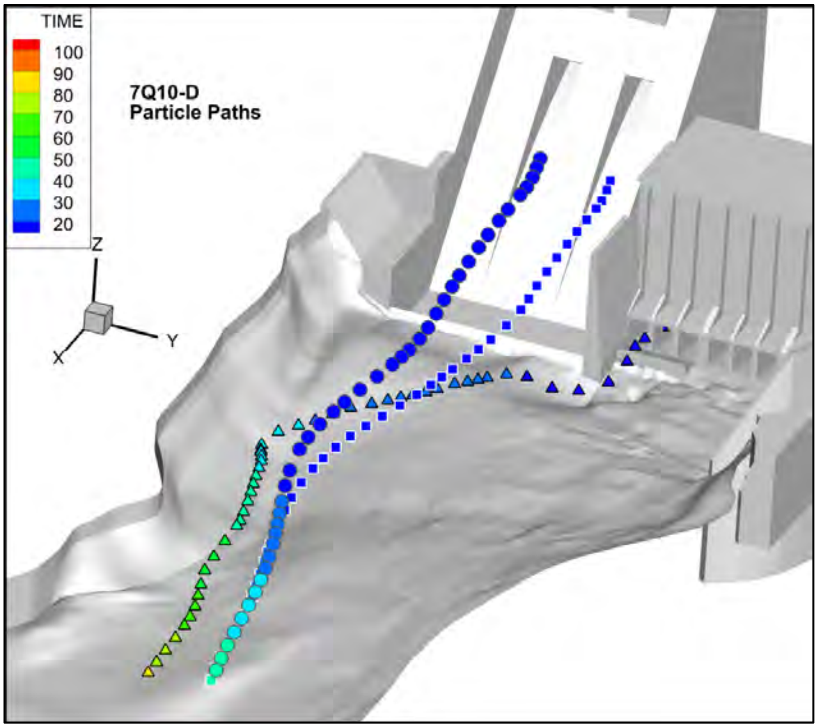


Figure 6-54. Path of a particle from each injection site colored by time (sec) for a 7Q10 flow with deflectors

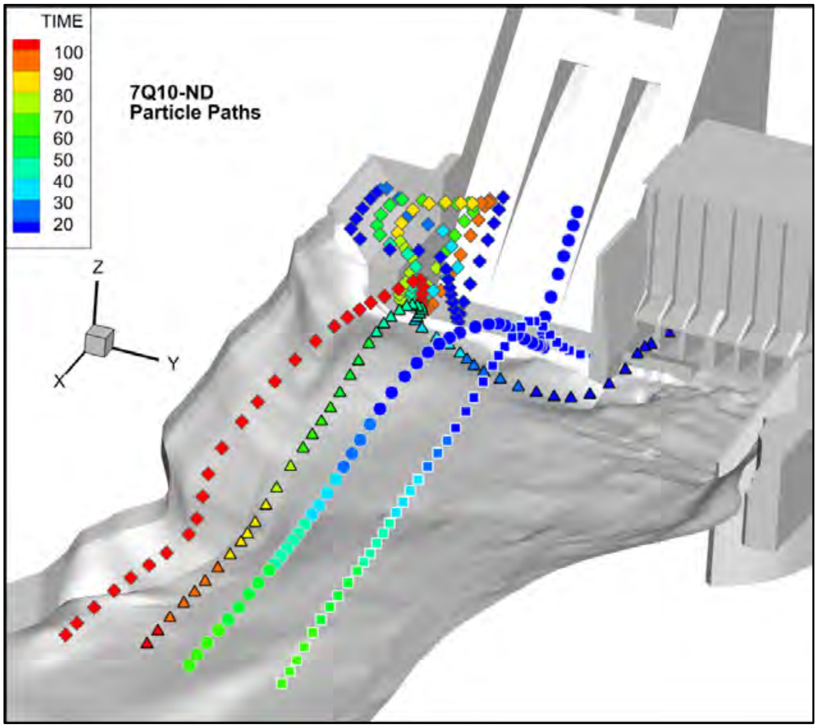


Figure 6-55. Path of a particle from each injection site colored by time (sec) for a 7Q10 flow without deflectors

Water Surface Elevation near the Fish Trap

Water surface elevations for 37 kcfs and the 7Q10 simulations are shown in Figure 6-56. For the 37 kcfs simulation, water surface elevation was extracted only near the lower fish entrance. As observed earlier for 25 kcfs and 45 kcfs, predicted water surface fluctuations are negligible for a 37 kcfs flow. The amplitude of the waves for the high and low fish entrances in a 7Q10 flow is similar. According to the model, deflectors reduce the generation of high frequency surface waves.

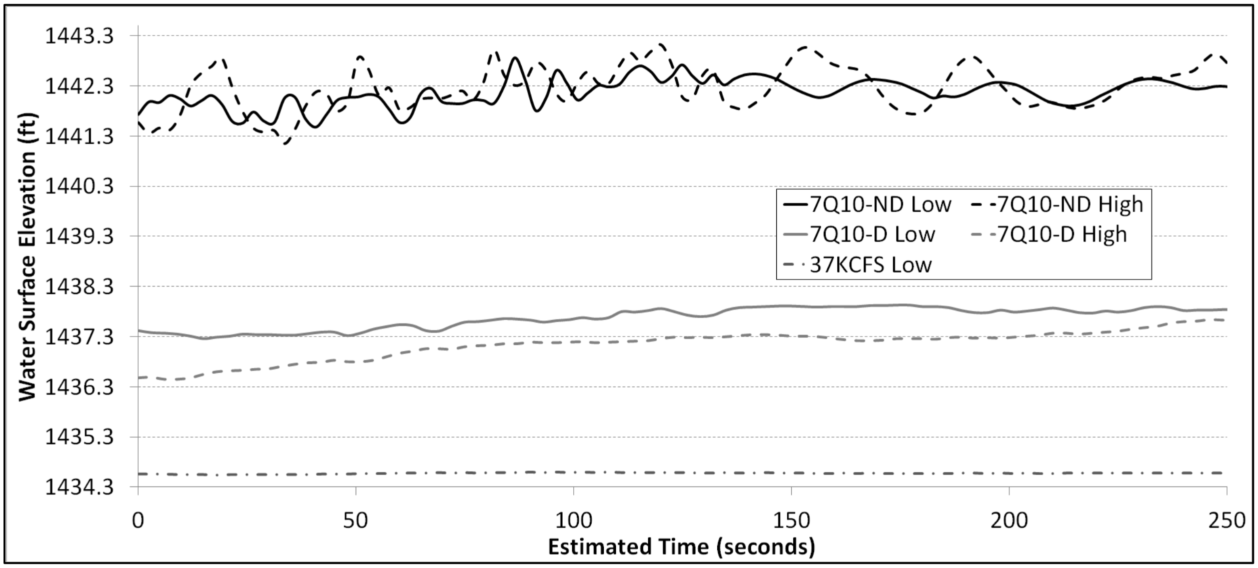


Figure 6-56. Water surface elevation al the low and high fish trap entrances for a 7Q10 flow

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Exhibit 7.3-4

Hydraulic modeling for Brownlee Dam spillway deflector design: Phase one – two-dimensional model

HYDRAULIC MODELING FOR BROWNLEE DAM SPILLWAY DEFLECTOR DESIGN: PHASE ONE – TWO-DIMENSIONAL MODEL

by

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Submitted to
Idaho Power Company
Boise, Idaho 83702

Limited Distribution Report No. 327

IIHR – Hydroscience & Engineering
College of Engineering
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Iowa City, Iowa 52242-1585

September 2005

Executive Summary

This report documents hydraulic model studies at IIHR – Hydroscience & Engineering (IIHR) supporting spillway deflector designs to reduce TDG (total dissolved gas) below Brownlee Dam. This is the first part of a two-phase project sponsored by Idaho Power Company (IPC) and documents design and construction of a laboratory model replicating the spillway and a two-dimensional tailrace. This phase develops the preliminary design of the spillway flow deflector.

Acknowledgements

This hydraulic model study was conducted for and sponsored by IPC. The authors are grateful to Mr. Pete Newton, Mr. Ralph Meyers, and Mr. Scott Larrondo of IPC for their support and cooperation throughout the project.

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1. INTRODUCTION AND BACKGROUND

Brownlee Dam is on the Snake River spanning the Idaho and Oregon borders. It is operated for hydropower production by Idaho Power Company (IPC).

Figure 1-1. Location of Brownlee Dam

This report documents design, construction, and testing of a 1:48 scale laboratory model of the Brownlee Dam spillway. This includes background on scaling laws, model design and construction, and the experimental equipment used. The report focuses on hydraulic design of a spillway flow deflector to potentially reduce TDG (total dissolved gas) below Brownlee Dam. The design considers river flowrates up to 7Q10[1] or 67,898 cfs and assumes a fully loaded powerhouse flowrate of 35,000 cfs. Project team members included Dr. Larry Weber and Mr. Troy Lyons of IIHR and Mr. Pete Newton, Mr. Ralph Myers, and Mr. Scott Larrondo of IPC.

---

[1] The 7Q10 flowrate is defined as the average peak annual flow for seven consecutive days with a recurrence interval of ten years.

2. EXPERIMENTAL APPROACH

2.1. Model Design and Construction

The 1:48 scale laboratory model was completed in February 2004. The model included a headbox, spillway structure, and a rectangular tail basin with an adjustable tailgate weir. The stilling basin, and adjacent left and right training walls were included.

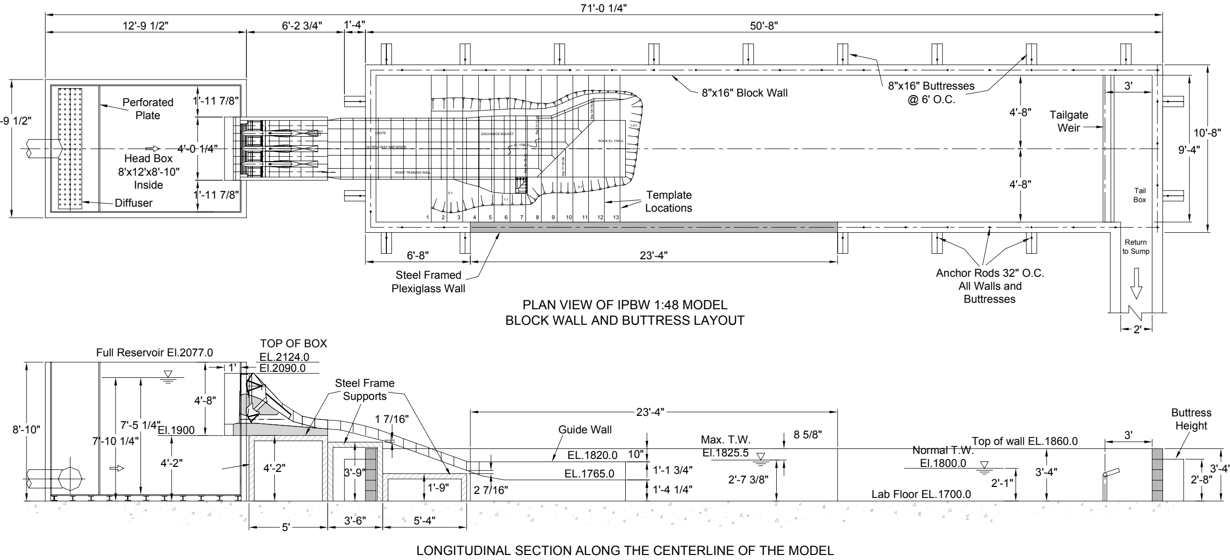


Figure 2-1. General layout of Brownlee Dam 1:48 scale two-dimensional model

<u>Similitude Criteria</u>

Froude scaling relationships were used to calculate expressions relating model and prototype values. The Froude number is the ratio of inertial and gravitational forces and represents the dominant parameter in free-surface flows. Froude scaling provides geometric and dynamic similitude, enabling direct velocity and discharge computation from a geometric model ratio. Based on spillway geometry modeling requirements and the phase two PMF (probable maximum flood) flowrates, the project team selected an undistorted Froude length scale of 48. Relationships determining model to prototype conversions are given in Equation 2-1. Subscript m refers to model and p refers to prototype.

$$\frac{Froude_m}{Froude_p} = \frac{V_m\sqrt{gL_p}}{V_p\sqrt{gL_m}} = \frac{Q_m L_p^2\sqrt{gL_p}}{Q_p L_m^2\sqrt{gL_m}} = \frac{Q_m}{Q_p}\left(\frac{L_p}{L_m}\right)^{2.5} = \frac{Q_m}{Q_p}(48)^{2.5} = 1 \qquad (2\text{-}1)$$

Where V_m = model velocity (ft/s)
V_p = prototype velocity (ft/s)
G = gravitational constant (32.17 ft/s^2)
L_m = model length parameter (ft)
L_p = prototype length parameter (ft)
Q_m = model flow rate (ft^3/s)
Q_p = prototype flow rate (ft^3/s)
48 = geometric scale factor (L_p/L_m)

Although Reynolds number criteria between model and prototype conditions are violated, the model Reynolds number is considered high enough to assure turbulent flow. Table 2-1 lists Froude scale relationships based on the selected length scale.

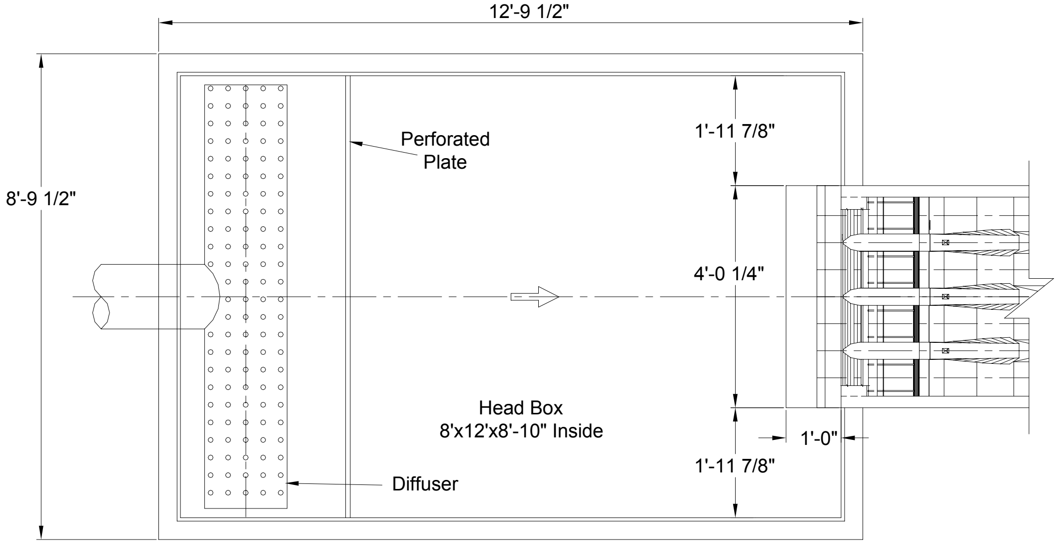
Variable	**Relationship**	**Model Scaling Factor**
Length	L_r = Length Ratio	0.020833
Slope	$S_r = L_r/L_r = 1$	1
Velocity	$V_r = L_r^{1/2}$	0.1443376
Time	$T_r = L_r^{1/2}$	0.1443376
Acceleration	$A_r = V_r/T_r = 1$	1
Discharge	$Q_r = V_r{*}A_r = L_r^{5/2}$	6.2647E-05
Force	$Fr = r_r{*}L_r^3 = L_r^3$	9.04225E-06
Pressure	$P_r = r_r{*}L_r = L_r$	0.020833
Reynolds Number	$Re_r = L_r^{3/2}$	0.003007

Table 2-1. Model similitude criteria

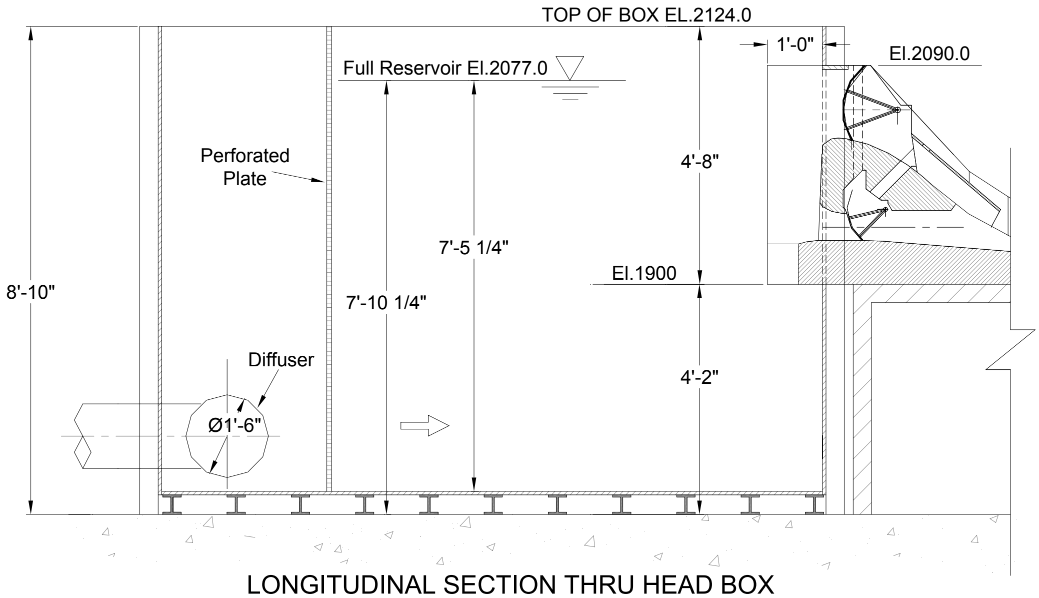
Headbox

The headbox was a 12 by 8 by 8 foot steel-framed tank. The floor and walls were ¾-inch marine grade plywood and Plexiglas sheeting. Construction joints were sealed with silicone. Water was conveyed to the upstream end of the headbox through a 12-inch steel pipe, terminating in a diffuser fabricated from ABS corrugated drainage pipe, capped on the ends, with uniformly spaced outlet holes. This helped create uniform flow distribution over the headbox width. An 8 foot high timber-framed wall enclosing the diffuser created a 3 foot long settling chamber at the upstream end of the tank. Two layers of 48% porosity perforated plate fastened to the timber framework helped dampen surface fluctuations and distribute flow evenly from the settling chamber. Figure 2-2 is a photograph of the headbox. Figure 2-3 displays plan and sectional views.

Figure 2-2. Photograph of the headbox and inflow pipe



PLAN VIEW OF HEAD BOX



LONGITUDINAL SECTION THRU HEAD BOX

Figure 2-3. Plan and section views of the headbox

Spillway

A welded stainless steel framework of 2-inch angle iron supports the spillway structure. After location and elevation were set using a total station and a laser level, the frame was bolted to the floor with ½-inch concrete anchors.

Model spillway dimensions were scaled from IPC drawings. Spillway details replicate as closely as possible prototype features including upstream face, ogee crest, piers, tainter gates, air vents and hoods, spillway apron, and training walls. The spillway structure was fabricated from marine grade plywood, Plexiglas, PVC, and stainless steel. Spillway piers were constructed of high density overlay (HDO) plywood templates skinned with galvanized steel sheeting which was smoothed with auto body filler, and then sanded and painted. Tainter gates were made of stainless steel with rubber strips sealing the edges. The chute sidewalls were formed with sheet metal templates and concrete. The concrete was given a smooth finish with water-proof auto body filler and painted. Figure 2-4 shows spillway plan and section views; Figure 2-5 is two photographs of the spillway during construction; and Figure 2-6 is a photograph looking upstream at the completed spillway.

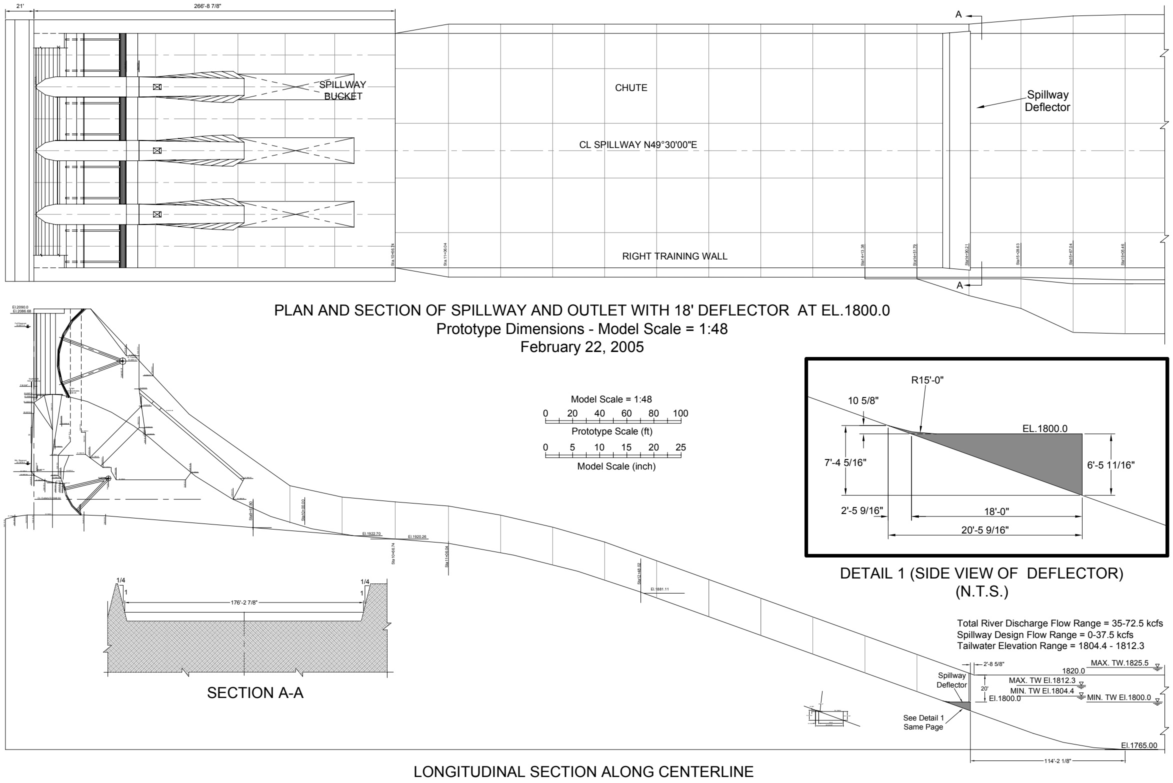


Figure 2-4. Plan and section views of the spillway and 18-foot deflector

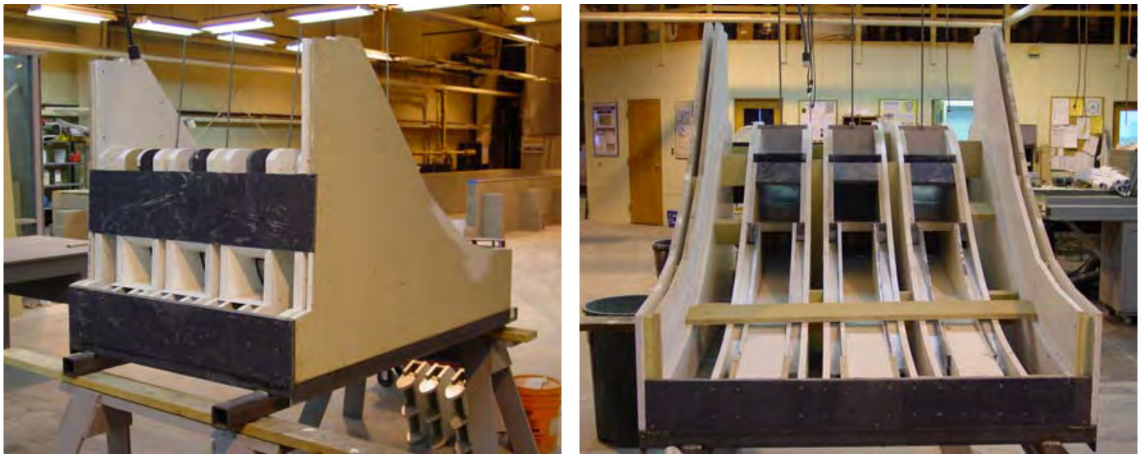


Figure 2-5. Photographs of the spillway during construction

Figure 2-6. Photograph of the completed spillway

Each spillway gate was raised or lowered turning a threaded lead screw fastened to the gate. A stainless steel ruler marked gate openings. Precision milled gate setting blocks were used to calibrate the rulers. Gate setting blocks are illustrated in Figure 2-7. A close-up photograph of the spillway gates is shown in Figure 2-8.

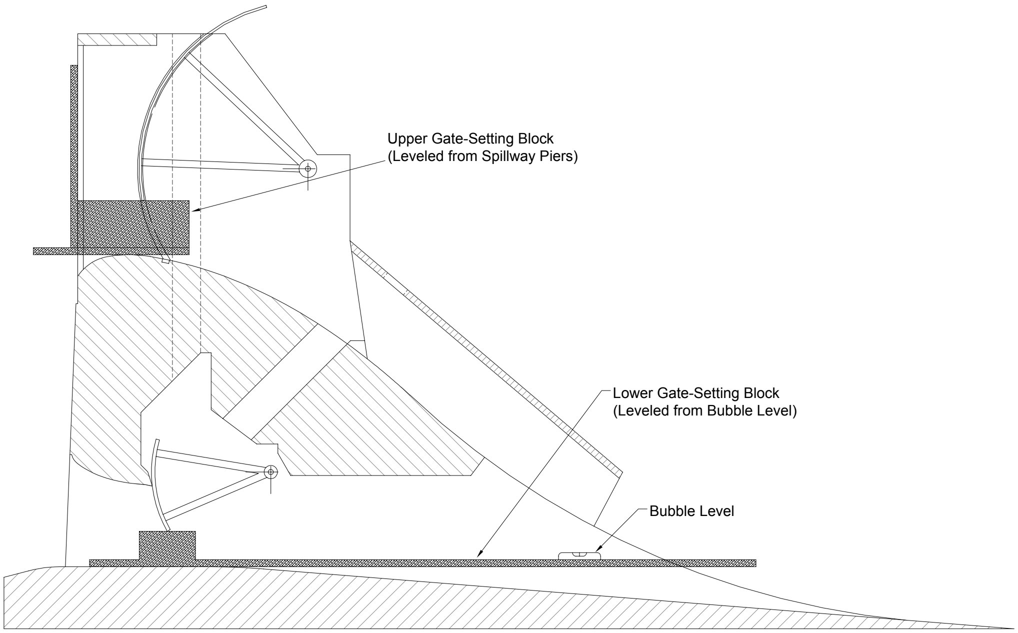


Figure 2-7. Gate operating and measurement mechanisms

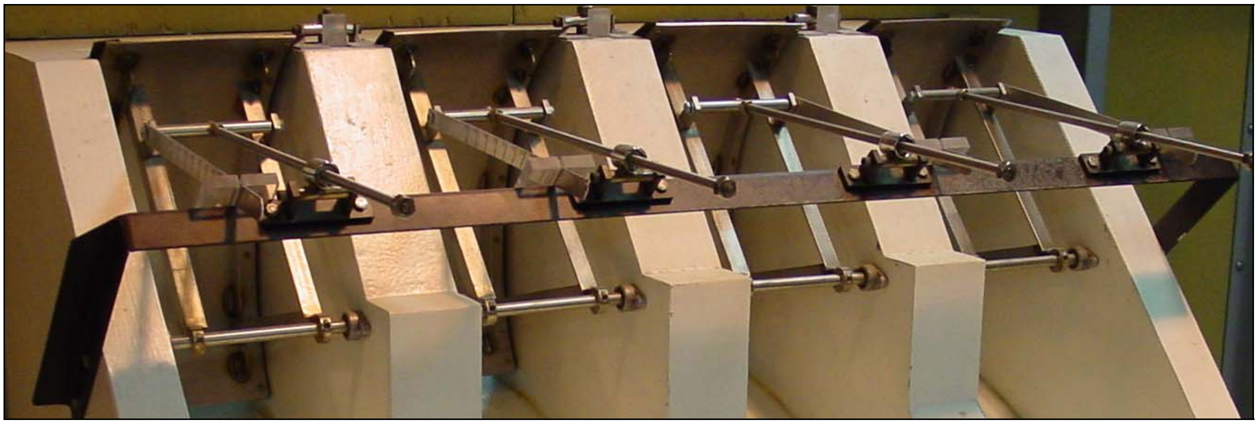


Figure 2-8. Photograph of the upper spillway gates

Model Walls

Construction joints in the floor beneath the model were cleaned with compressed air and sealed with Vulkem® 116 prior to construction to prevent leakage. Wall construction was contracted to Hall Masonry Inc. of Iowa City, Iowa. The 40-inch walls were constructed using 8 by 16-inch masonry blocks. Walls were anchored every 32 inches with ½-inch diameter threaded steel rod and buttressed every 8 feet with 32-inch columns of masonry blocks slugged with concrete. The threaded rods were bolted through a 2 by 8-inch wooden plate on top of the walls. Vulkem sealer was applied to prevent leakage between wall and floor. The wall interior was sealed with two coats of Acryl® 60 to prevent seepage. A 23-foot wall section near the spillway was timber-framed and covered with Plexiglas sheeting to provide views beneath the water surface. Wall layout is shown previously in Figure 2-1. Photographs of the completed model are in Figures 2-9 through 2-11.

Figure 2-9. Photograph looking upstream at the completed model

Figure 2-10. Photograph of the completed model basin

Figure 2-11. Photograph showing the downstream geometry

2.2. Experimental Equipment

Model Inflow Configuration and Measurement

The Model Annex is built above a 97,000 gallon underground sump providing water storage for models. Water circulation is provided by a 75 hp single stage, mixed flow pump equipped with a variable frequency drive (VFD) controller. The pump conveys water from the sump pit to the model headbox through a 12-inch steel pipe. Water is discharged from the headbox through the spillway and over the adjustable tailgate weir into a rectangular channel back to the sump.

Flowrates through the 12-inch supply line are measured with a calibrated annular ring orifice meter conforming to ASME standards.[2] Head differential across the orifice meter is measured with a precision 2-tube manometer equipped with a Vernier scale accurate to +/- 0.0005 model feet. Equation 2-2 calculated model flowrates, where Q is cubic feet per second discharge, C_d is the orifice discharge coefficient, and ΔH is pressure differential in feet of water.

$$Q = C_d \cdot \Delta H^{0.5} \qquad (2\text{-}2)$$

To convert flowrates to prototype values, model flowrates were multiplied by the Froude-scale factor ($48^{2.5} = 15,963$).

Headwater Gage

Headwater elevations were measured with a hook-type point gage, accurate to +/- 0.0005 model feet, mounted in a 6-inch diameter acrylic stilling pot. The stilling pot was mounted vertically to the headbox exterior, the top open to the atmosphere and the bottom sealed. A 3/8-inch tube connected the stilling pot to the headbox by a hole drilled through the headbox wall. The stilling pot served to dampen surface wave effects from the headbox. The headwater gage was referenced to average spillway crest elevation, determined using the total station. Equation 2-3 converted model vernier-scaled *gage* readings to prototype headwater elevations *HW*.

---

[2] American Society of Mechanical Engineers, "Measurement of Fluid Flow in Pipes Using Orifice, Nozzle, and Venturi." ASME MFC-3M-1989, page 15

$$HW = 48.00 \cdot gage + 0.511 \pm 0.05 \qquad (2\text{-}3)$$

Tailwater Gage

At Brownlee Dam, tailwater elevation is measured near powerhouse unit 1 and on the right bank downstream of the bridge. The model does not include these locations and tailwater was measured at the right bank wall corresponding to the channel center at the confluence of the powerhouse channels. Tailwater elevation was measured with a point gage, accurate to +/- 0.024 prototype feet, mounted inside a 6-inch diameter stilling pot. A 3/8-inch flexible tube connected the stilling pot to an opening in the model wall.

Tailwater elevation was set using an adjustable tailgate weir. Tailwater elevation for a given river flow and Oxbow reservoir elevation was determined with the tailwater rating curves for Brownlee Dam provided by IPC. Tailwater rating curves are illustrated in Figure 2-12 and show an approximate design tailwater elevation range of 1804.5 to 1812 feet.

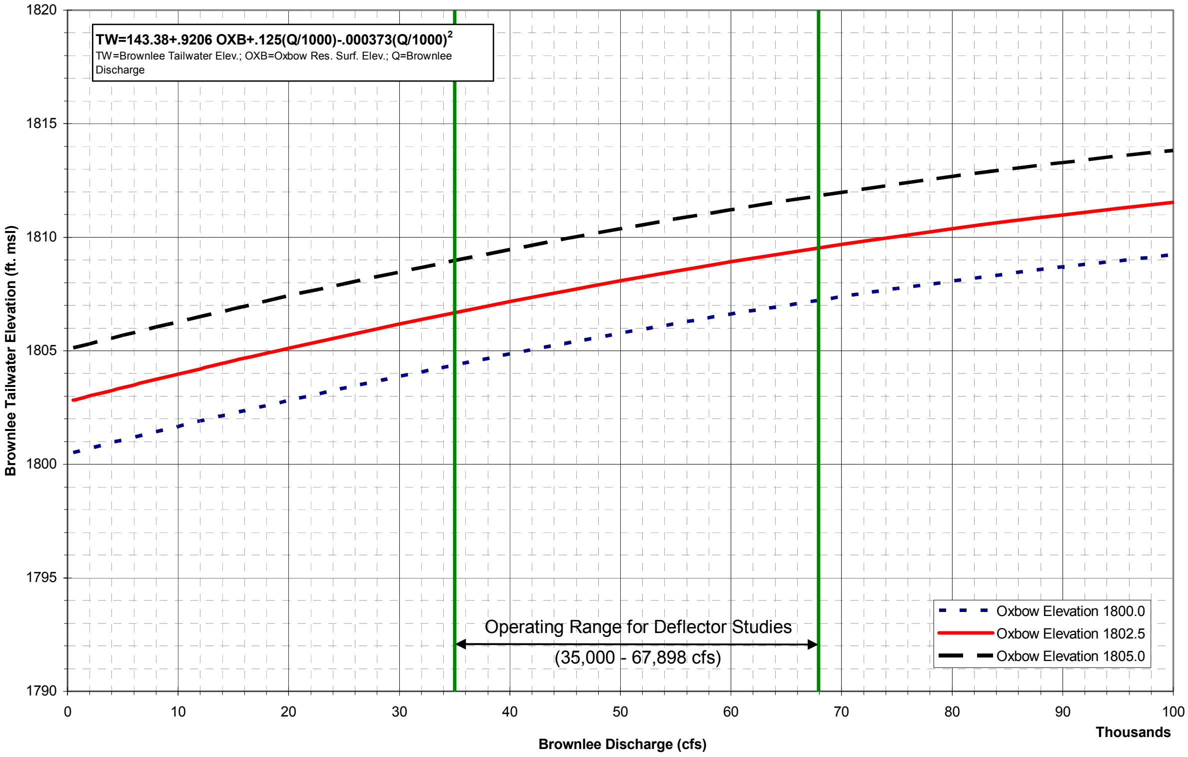


Figure 2-12. Tailwater rating curves up to 100,000 cfs for Brownlee Dam

3. SPILLWAY DEFLECTOR TESTING

3.1. Flow Conditions

Spillway deflector design was based on a Snake River 7Q10 flowrate of 67,898 cfs at Brownlee Dam. The 7Q10 is frequently applied for dissolved gas standards on the Columbia and Snake Rivers. In the model, the powerhouse was operated at full capacity, 35,000 cfs. The spillway operated between 0 and 32,898 cfs. The upper spillway gates passed spillway flows during deflector testing corresponding to probable field conditions. The lower sluiceways remained closed.

Due to spillway bay elevations relative to design tailwater elevations, deflectors could not be designed for individual spillway bays. Instead, a single deflector was designed spanning the spillway chute near the tailwater surface. Using the 7Q10 flowrate and 173-foot chute width, the maximum unit spillway discharge was 190.2 cfs/ft.

3.2. Design Parameters

Design parameters affecting deflector hydraulic performance were length, angle, and lip elevation or submergence. To decrease TDG production potential, a surface jet or skimming flow is most desirable for deflector operation. This minimizes tailrace bubble entrainment depth. Deflector design parameters are shown in Figure 3-1.

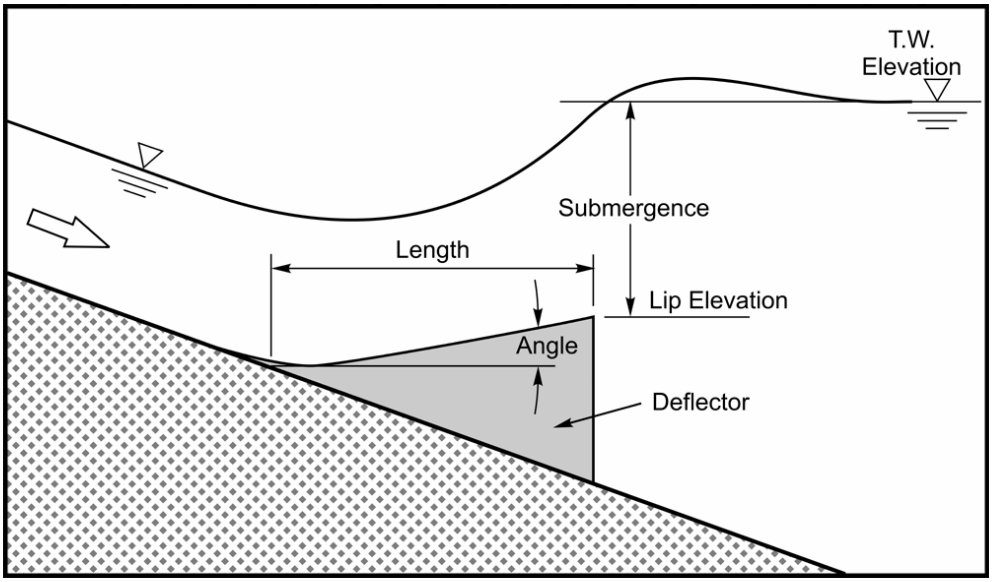


Figure 3-1. Spillway deflector design parameter schematic

Initial lip elevation was determined from spillway deflector performance curves derived from previous IIHR projects.[3, 4, 5, 6] For Wanapum Dam, a skimming surface jet was observed for a deflector submergence of approximately 14 to 18 feet at a unit discharge of 190 cfs/ft. For Hells Canyon Dam, a surface jet was observed for a deflector submergence of approximately 1.5 to 11 feet at a unit discharge of 190 cfs/ft. A lip elevation of 1790 feet was selected for initial testing based on this data. Deflector submergence depths of 14.5 to 22.0 feet for the design flow range resulted.

A deflector length of 7 feet was employed in the final design for Wanapum Dam and 16 feet for the Hells Canyon Dam project. Predicting the Brownlee Dam spillway deflector would fall in the same range as previous projects, an initial 9-foot deflector length was chosen.

3.3. Flow Regime Definition

Five distinct flow regimes defined spillway jet hydraulics entering the tailrace. These are described and illustrated below.

- Submerged surface jet: This occurs when the deflector is deeply submerged, with flow rolling back onto the jet. Very few bubbles are in the stilling basin at depth. The downstream water surface is relatively horizontal and smooth.

---

[3] Mannheim, C. O. M., and Weber, L. J. Hydraulic Model Studies for Fish Diversion at Wanapum/Priest Rapids Development Part XI: Spillway Deflector Design. IIHR Limited Distribution Report No. 264. University of Iowa, Iowa Institute of Hydraulic Research: Iowa City, Iowa, November 1997.

[4] Nielson, K. D., Weber, L. J., and Haug, P. E. Hydraulic Model Studies for Fish Diversion at Wanapum/Priest Rapids Development Part XVI: 1:32.5 Scale Sectional Model of Wanapum Dam Spillway Deflectors. IIHR Limited Distribution Report 284. University of Iowa, Iowa Institute of Hydraulic Research: Iowa City, Iowa, March 2000.

[5] Dierking, P. B., and Weber, L. J. Hydraulic Modeling of Hells Canyon Dam for Spillway Deflector Design: Phase One – Deflector Design. IIHR Limited Distribution Report No. 303. University of Iowa, Iowa Institute of Hydraulic Research: Iowa City, Iowa, March 2002.

[6] Haug, P. E., and Weber, L. J. Hydraulic Modeling for Hells Canyon Dam for Spillway Deflector Design: Phase Two – Three-dimensional Model. IIHR Limited Distribution Report No. 304. University of Iowa, Iowa Institute of Hydraulic Research: Iowa City, Iowa, March 2002.

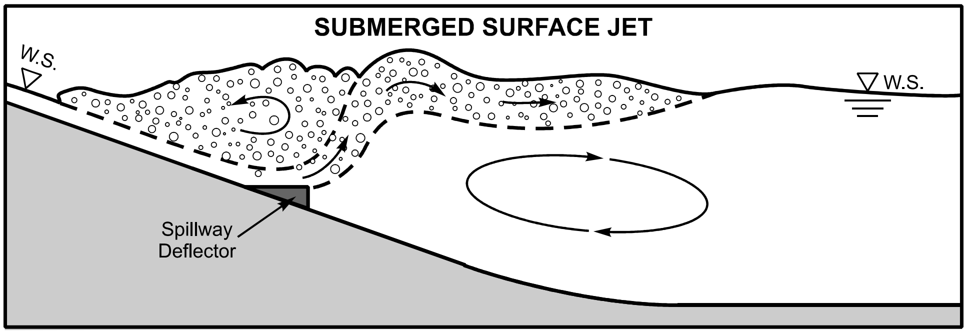


Figure 3-2. Submerged surface jet flow regime

- Ramped surface jet: This regime begins when the jet sweeps out and no flow rolls back onto the jet or deflector. Flow is deflected upward at an angle greater than 10 degrees. Air bubbles penetrate deeply at a secondary plunge point in the stilling basin.

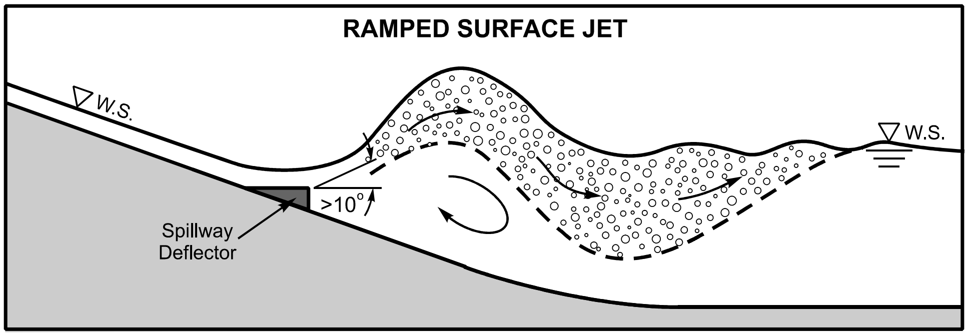


Figure 3-3. Ramped surface jet flow regime

- Skimming surface jet: This regime occurs when the deflected angle is 10 degrees or less. The entire jet is surface-oriented and relatively horizontal. There is no secondary plunge point. Very few bubbles are drawn to depth in the stilling basin. This regime produces the least air entrainment.

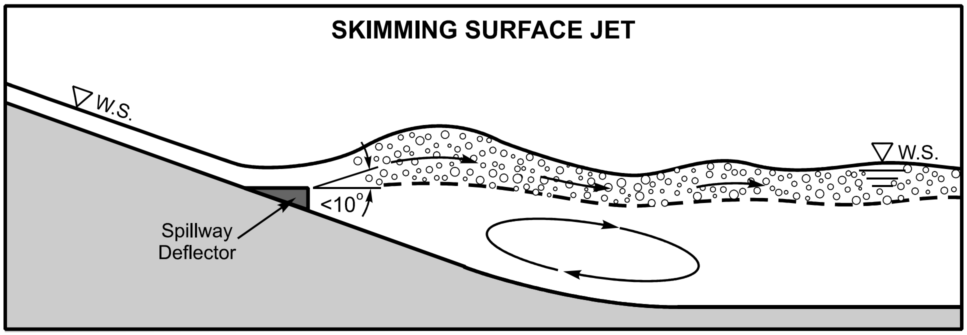


Figure 3-4. Skimming surface jet flow regime

- Unstable surface jet: This regime occurs when deflector submergence is lowered to the point where pockets of air bubbles are observed to intermittently burst to the bed. This regime occurs at submergence levels just above plunging flows.

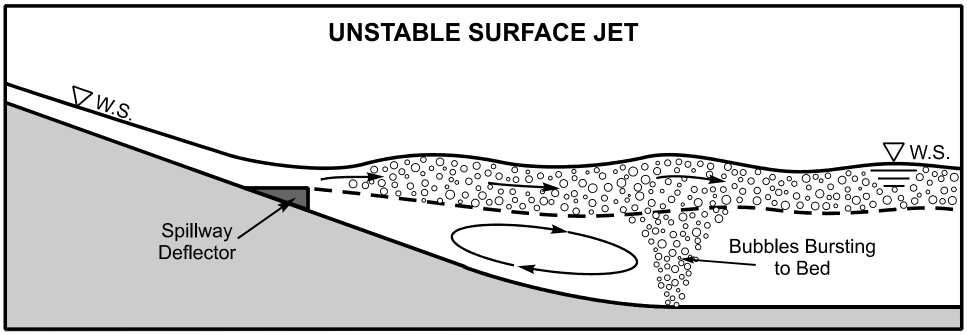


Figure 3-5. Unstable surface jet flow regime

- Plunging jet: This regime occurs when deflector submergence is lowered until the jet intermittently aerates at the deflector downstream edge. The jet, no longer supported by the tailwater, plunges downward from the deflector to the bed consistently carrying air bubbles to depth in the stilling basin.

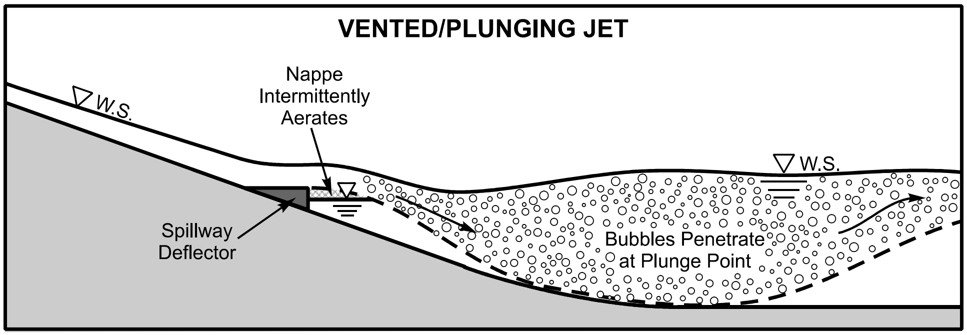


Figure 3-6. Plunging jet flow regime

3.4. Spillway Deflector Design

Initial model runs soon revealed that a 9-foot deflector was too short and would not change the jet direction enough to initiate a surface or a ramped surface jet flow regime. Subsequently, 15-, 18-, and 21-foot deflectors were tested. The 18-foot deflector, the shortest that adequately induced the desired flow regimes, was chosen for further testing. A photograph of the initial 18-foot deflector is shown in Figure 3-7.

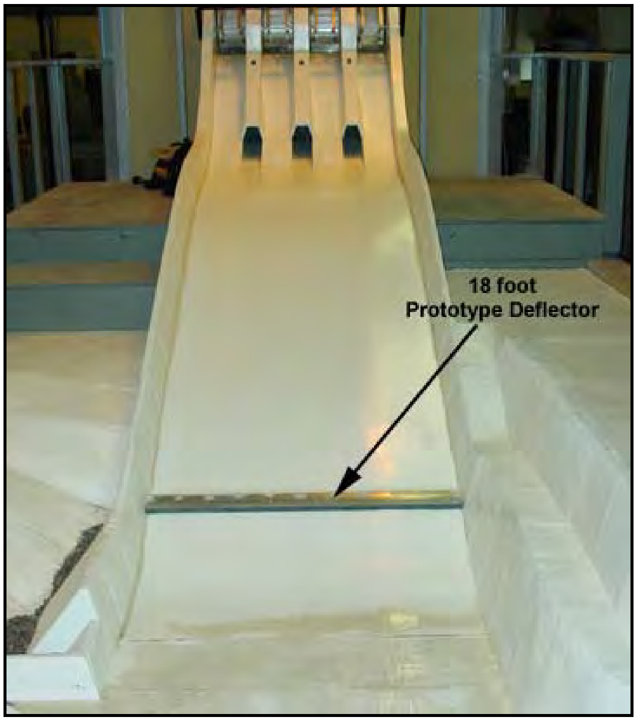
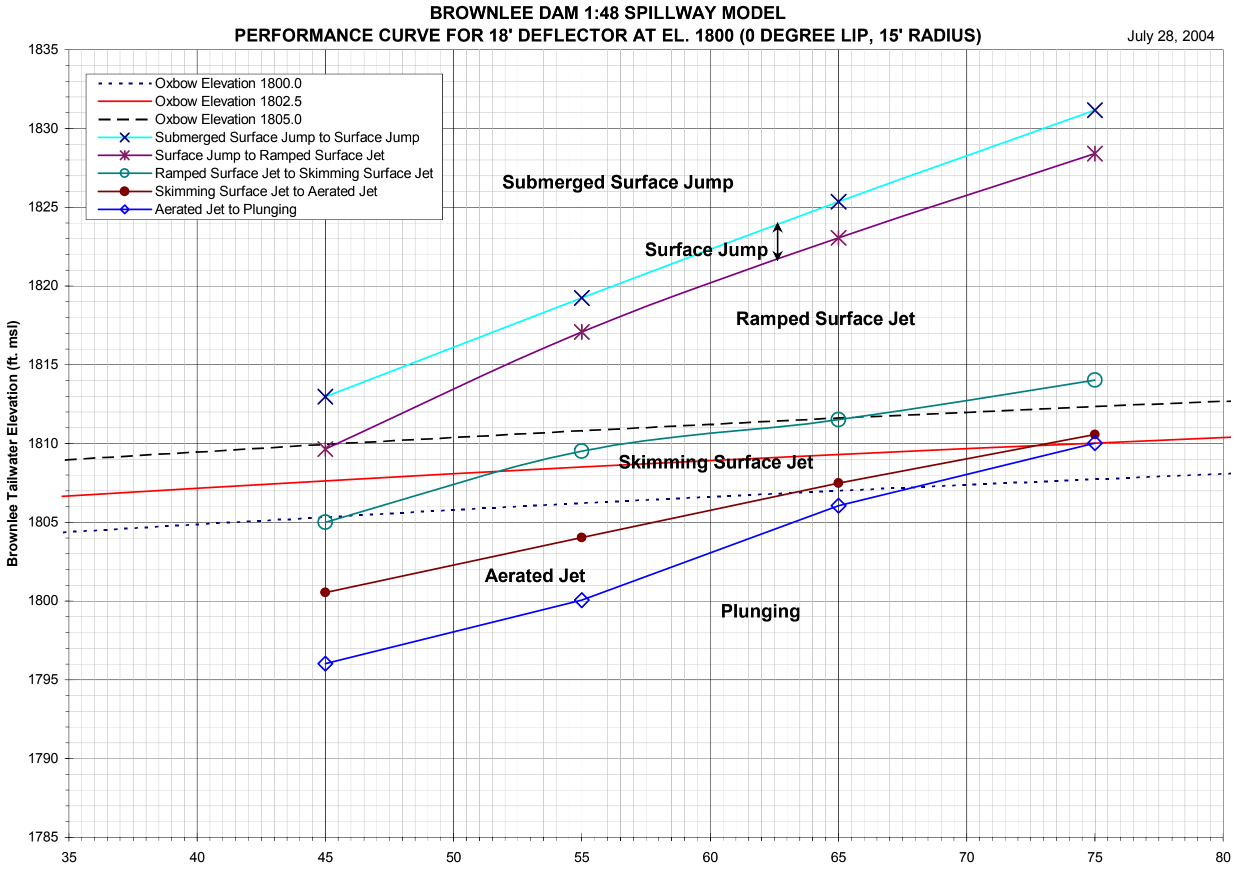


Figure 3-7. Photograph of the 18-foot deflector at elevation 1790 with 0^{o} lip

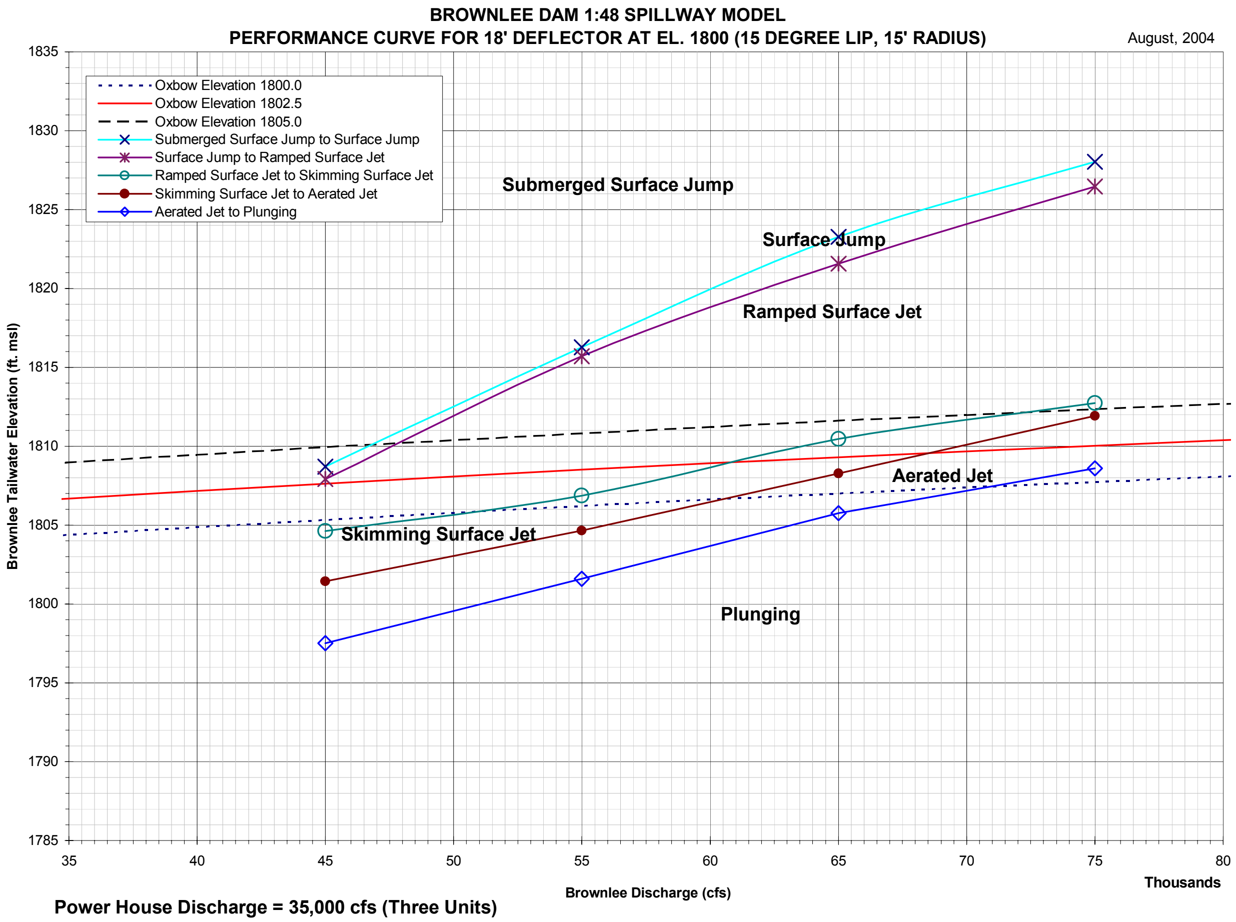
Upon developing performance curves for the 18-foot deflector, the deflector was raised 10 feet to elevation 1800 feet, maximizing the skimming/surface jet flow regime overlap with the most likely operating flow range. The resulting deflector performance curves are illustrated in Figure 3-8.



Power House Discharge = 35,000 cfs (Three Units)
Forebay Elevation = 2,077 ft-msl

Figure 3-8. Performance curves for the 18-foot deflector at elevation 1800 with 0^{o} lip

The skimming/surface jet flow regime shows good overlap with tailwater rating curves between 55 and 65 kcfs. It is below the operating range at low flows and above it at higher ones. At low design flows this causes a ramped surface jet. At high design flows it causes an aerated jet or plunging flow. Neither is good for minimizing TDG production. To "flatten out" or decrease the flow regime boundary slopes and better match the operating curves, a 15-degree lip was added to the deflector. A new performance curve was developed and is illustrated in Figure 3-9.



Power House Discharge = 35,000 cfs (Three Units)
Forebay Elevation = 2,077 ft-msl

Figure 3-9. Performance curves for the 18-foot deflector at elevation 1800 with 15^{o} lip

There was little improvement to the performance curve after adding the 15^{o} deflector lip. The main change was a slight downward shift of the upper boundary of the skimming/surface jet flow regime. This increased the extent of the ramped surface jet flow regime. The 15^{o} angle was considered an extreme condition. Since it did not improve on the horizontal deflector, further angled spillway deflector tests were not pursued.

The spillway deflector geometry that performed best up to the 7Q10 flowrate was a horizontal deflector with an 18-foot overall length and a lip elevation of 1800 feet. Figure 3-10 is a detailed sectional drawing of this deflector geometry.

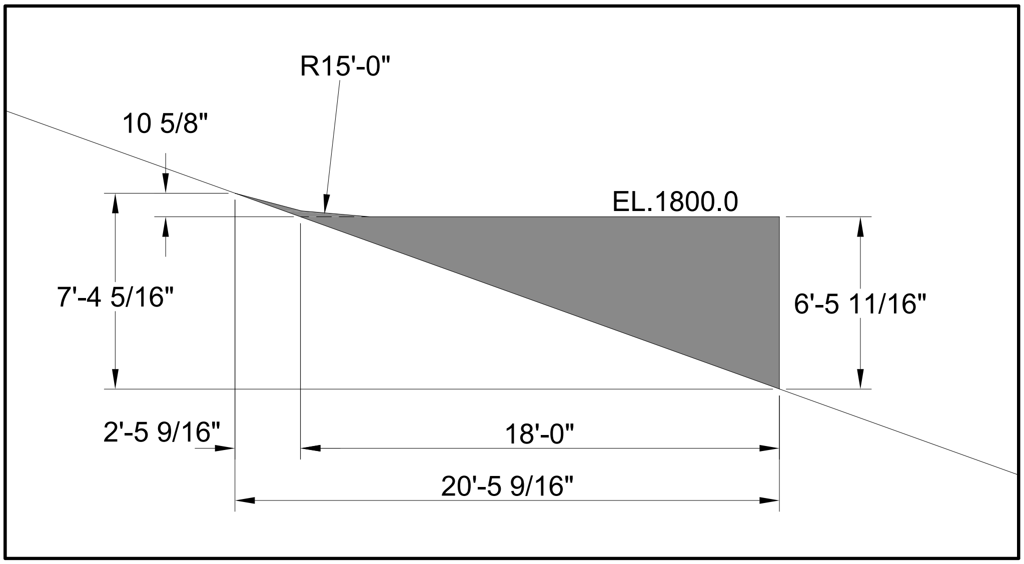


Figure 3-10. Geometry of the 18-foot horizontal deflector (prototype dimensions)

3.5. Training Wall Extension

The top horizontal edge of the training wall on the right bank of the chute is at elevation 1800 feet and is submerged at design tailwater elevations. Tailwater elevations varied between 1804.5 - 1812 feet. Re-entrant flows impacted the right side of the spillway jet just downstream of the deflector. This caused non-uniform flow patterns as the jet entered the pool. For example, with tailwater elevation set to 1805.9 feet at maximum design flow, the right side of the deflector becomes submerged due to additional flow over the training wall, and a ramped surface jet occurs to the left side of the deflector. This is illustrated in Figure 3-11.

Figure 3-11. Example of a non-uniform jet due to re-entrant flow over the right bank training wall

To eliminate the non-uniform jet, a clear Plexiglas wall was added to the existing training wall raising it to elevation 1830 feet. This allows unusually high tailwater elevations to be tested with no re-entrant flow over the wall. In the field, the wall would likely need be effective up to the 7Q10 design flow, corresponding to an 1812.5 foot tailwater elevation. Figure 3-12 is a photograph of the wall extension.

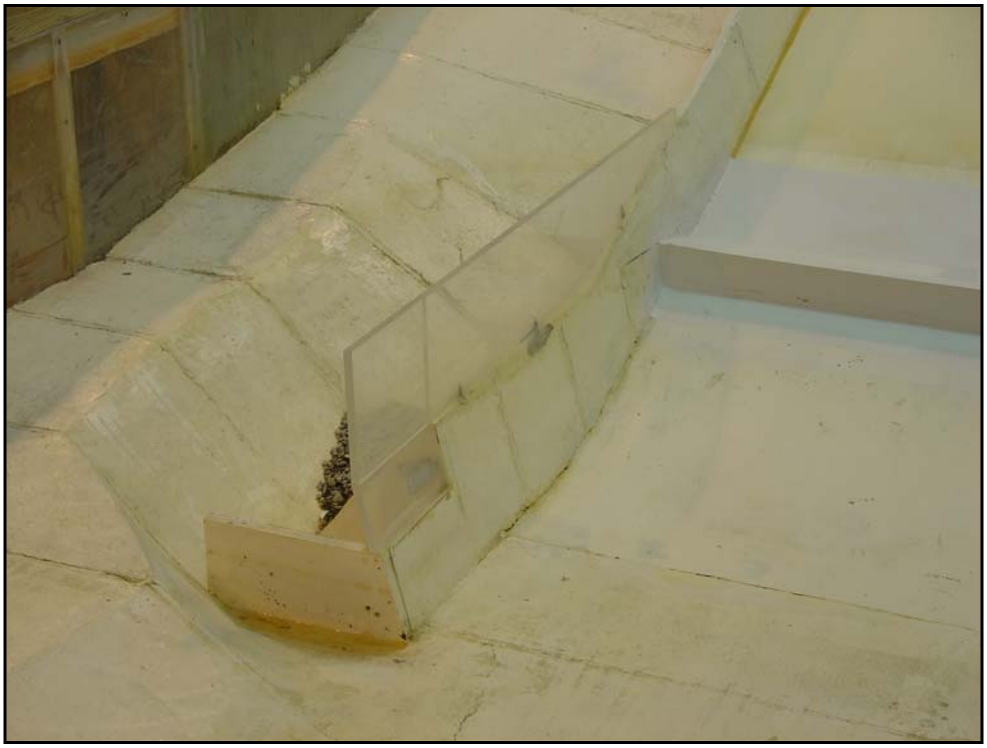


Figure 3-12. Photograph of the right bank training wall extension

The wall extension eliminated jet non-uniformity. A limiting factor in the training wall extension design was the narrow tailrace channel inhibiting three-dimensional flow patterns. The training wall extension may cause different flow patterns in a fully three-dimensional model from those observed in the phase one model. The phase one model lacks important characteristics including replication of river velocities, approach flow angle, powerhouse flows, and tailrace eddies. Further training wall design was not pursued in phase one due to these shortcomings but will be examined more closely in phase two.

4. SUMMARY AND CONCLUSIONS

A two-dimensional laboratory model of the Brownlee Dam spillway was built and tested to develop an initial spillway deflector design. Performance curves defining spillway jet hydraulic characteristics were used to determine appropriate spillway deflector geometry and location. An 18-foot horizontal deflector installed at an 1800-foot elevation was chosen for the final design. This configuration exhibited the best flow characteristics for reducing TDG. Spillway deflector performance will be validated with a fully three-dimensional tailrace model in phase two.

A training wall extension was tested on the spillway chute right wall to alleviate jet non-uniformity caused by re-entrant flow. The wall succeeded but needs further validation and refinement. The phase one two-dimensional tailrace did not replicate highly three-dimensional tailrace flow characteristics. The validity of the observations will be pursued in phase two.

Exhibit 7.3-5

Hydraulic modeling for Brownlee Dam spillway deflector design: Phase two – three-dimensional model

HYDRAULIC MODELING FOR BROWNLEE DAM SPILLWAY DEFLECTOR DESIGN: PHASE TWO – THREE-DIMENSIONAL MODEL

by

Troy C. Lyons and Larry J. Weber

Submitted to
Idaho Power Company
Boise, Idaho 83702

Limited Distribution Report No. 328

IIHR – Hydroscience & Engineering
College of Engineering
The University of Iowa
Iowa City, Iowa 52242-1585

September 2005

Executive Summary

This report documents hydraulic model studies at IIHR – Hydroscience & Engineering (IIHR) investigating spillway deflector designs to reduce total dissolved gas (TDG) below Brownlee Dam. This is phase two of a project sponsored by Idaho Power Company (IPC). Phase one determined the initial spillway deflector design using a two-dimensional model.[1] This report documents the two-dimensional model expansion to include the powerhouse units, powerhouse channels, and a fully three-dimensional erodable tailrace. The purpose of phase two is to verify the deflector performance data from phase one, document downstream flow conditions, and investigate potential tailrace erosion.

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[1] Lyons, T. C., and Weber, L. J. Hydraulic Modeling for Brownlee Dam Spillway Deflector Design: Phase One – Two-dimensional Model. IIHR Limited Distribution Report No. 327. University of Iowa IIHR – Hydroscience & Engineering: Iowa City, Iowa, September 2005.

Acknowledgements

This hydraulic model study was conducted for, and sponsored by Idaho Power Company (IPC) of Boise, Idaho. The authors are grateful to Mr. Pete Newton, Mr. Ralph Myers, and Mr. Scott Larrondo of IPC for their support and cooperation throughout the project.

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1. INTRODUCTION AND BACKGROUND

Brownlee Dam is on the Snake River spanning the Idaho and Oregon border. It is operated for hydropower production by Idaho Power Company (IPC).

Figure 1-1. Project location map

This report documents the design, construction, and testing of an expanded 1:48 scale Brownlee Dam laboratory model. It includes an explanation of scaling laws and descriptions of model design, construction, and experimental equipment. The focus is on verification of spillway flow deflector hydraulic design for TDG (total dissolved gas) reduction downstream of the spillway and the potential for tailrace erosion resulting from deflector installation. The deflector design is based on flowrates up to 7Q10 or 67,898 cfs. It assumes a fully loaded powerhouse flowrate of 35,000 cfs. Erosion potential and downstream flow conditions were investigated at the 7Q10 flowrate, an intermediate flow of 120,000 cfs, and the probable maximum flood (PMF) flowrate of 300,000 cfs. Project team members included Dr. Larry Weber and Mr. Troy Lyons of IIHR and Mr. Pete Newton, Mr. Ralph Myers, and Mr. Scott Larrondo of IPC.

2. EXPERIMENTAL APPROACH

2.1. Model Design and Construction

The 1:48 scale comprehensive tailrace model construction was completed in February 2005. Headbox and spillway structures used for phase one were moved and rotated. Tailrace bathymetry and powerhouse structures were incorporated as shown in Figure 2-1. Spillway and headbox construction details are discussed in the phase one report.[2] The spillway section, powerhouse units 1-4, powerhouse unit 5, the training walls, earthen embankment, and 2,900 prototype feet of downstream tailrace bathymetry were included in the expanded model. Powerhouse and spillway flowrates were individually set and measured with calibrated flow meters.

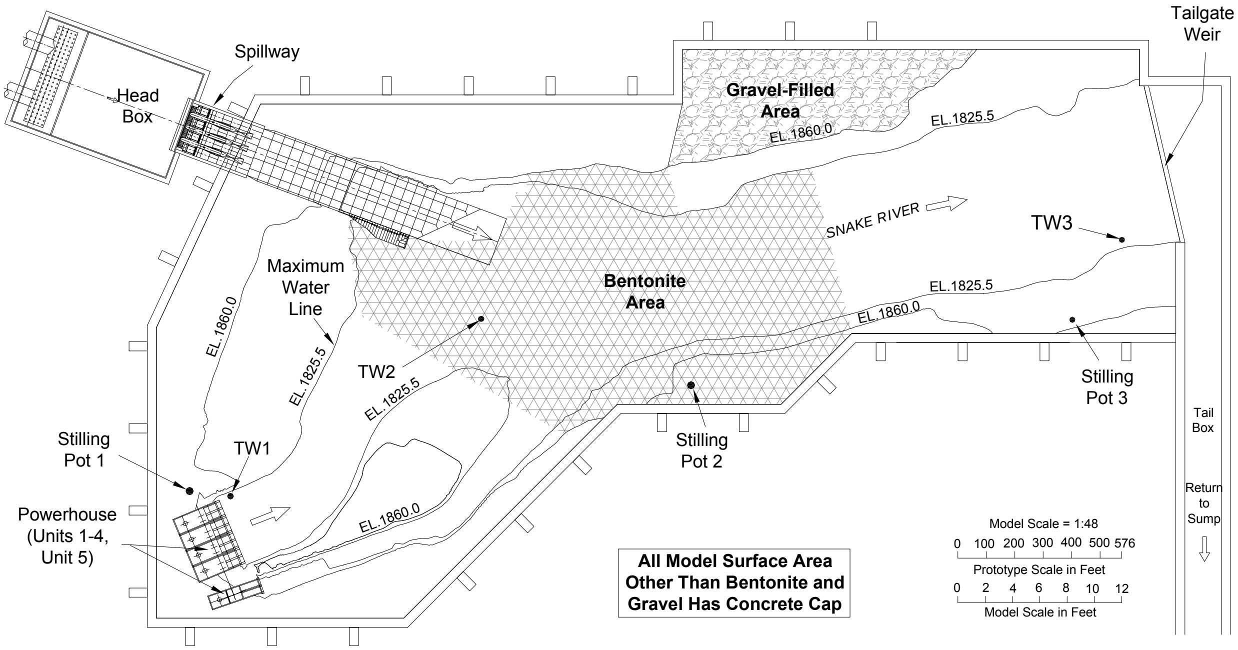

Figure 2-1. Laboratory model plan view

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[2] Lyons, T. C., and Weber, L. J. Hydraulic Modeling for Brownlee Dam Spillway Deflector Design: Phase 1 – Two-dimensional Model. Draft IIHR Limited Distribution Report. University of Iowa IIHR – Hydroscience & Engineering: Iowa City, Iowa, September 2005, pages 4-7.

Similitude Criteria

Froude scaling was used to calculate expressions relating model and prototype values. The Froude number is the ratio of inertial and gravitational forces. It represents the dominant parameter in free-surface flows. Froude scaling provides geometric and dynamic similitude, enabling direct velocity and discharge computation from a geometric model ratio. The 1:48 Froude length scale used for phase one was retained for phase two. Although Reynolds number criteria between model and prototype conditions are violated, the model Reynolds number is considered high enough to assure turbulent flow. A Froude length scale of 48 allows accurate modeling of the spillway structure, individual powerhouse units, and tailrace channels. Froude scale relationships for the 1:48 scale model are summarized in Table 2-1.

Variable	Relationship	Model Scaling Factor
Length	L_r = Length Ratio	0.020833
Slope	$S_r = L_r/L_r = 1$	1
Velocity	$V_r = L_r^{1/2}$	0.1443376
Time	$T_r = L_r^{1/2}$	0.1443376
Acceleration	$A_r = V_r/T_r = 1$	1
Discharge	$Q_r = V_r{*}A_r = L_r^{5/2}$	6.2647E-05
Force	$Fr = r_r{*}L_r^3 = L_r^3$	9.04225E-06
Pressure	$P_r = r_r{*}L_r = L_r$	0.020833
Reynolds Number	$Re_r = L_r^{3/2}$	0.003007

Table 2-1. Model similitude criteria

Limited information is available documenting model-prototype rock scour. Based on historical data up to 1988, Hay[3] concludes that "…model-prototype correlation of rock scour downstream of spillways has generally been poor." Where rock scour tests are undertaken as part of design development, Hay recommends matching the prototype size of fractured bedrock material to the model, and using a binding agent such as bentonite clay. Model tests have been conducted at IIHR implementing Hay's recommendation.[4] Generally, these studies are

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[3] Hay, Duncan, Model-Prototype Correlation of Hydraulic Structures: Proceedings of the International Symposium. Keynote paper: "Model-Prototype Correlation: Hydraulic Structures." ASCE, 1998. Pages 17-18.

[4] Haug, P. E., Weber, L. J. Hydraulic Model Studies for Fish Diversion at Wanapum/Priest Rapids Development Part XXV: Probable Maximum Flood Scour Studies with the 1:52 Scale Wanapum Dam Comprehensive Tailrace Model. Draft Limited Distribution Report. IIHR – Hydroscience & Engineering, the University of Iowa. May 2005.

conducted to compare scour resulting from a geometric spillway change, such as adding a spillway flow deflector, rather than prediction of "ultimate" scour. While neither scour test necessarily replicates field results, the comparison is useful in showing a worsening or lessening of scour and is accepted as the best predictor available.

Spillway

After removing the two-dimensional tailrace basin used in phase one, the spillway was rotated and moved to accommodate an expanded tailrace and powerhouse structures. Care was taken to minimize strain on the steel support structure during the move. The headbox and spillway were re-leveled and their alignment checked using the total station. The 16-inch inflow pipe was re-routed from the sump and a supplemental 12-inch inflow pipe was added to provide spillway flowrates up to the PMF (300,000 cfs). Spillway plan and section views are shown in Figure 2-2. Figure 2-3 is a photograph of the spillway during model construction.

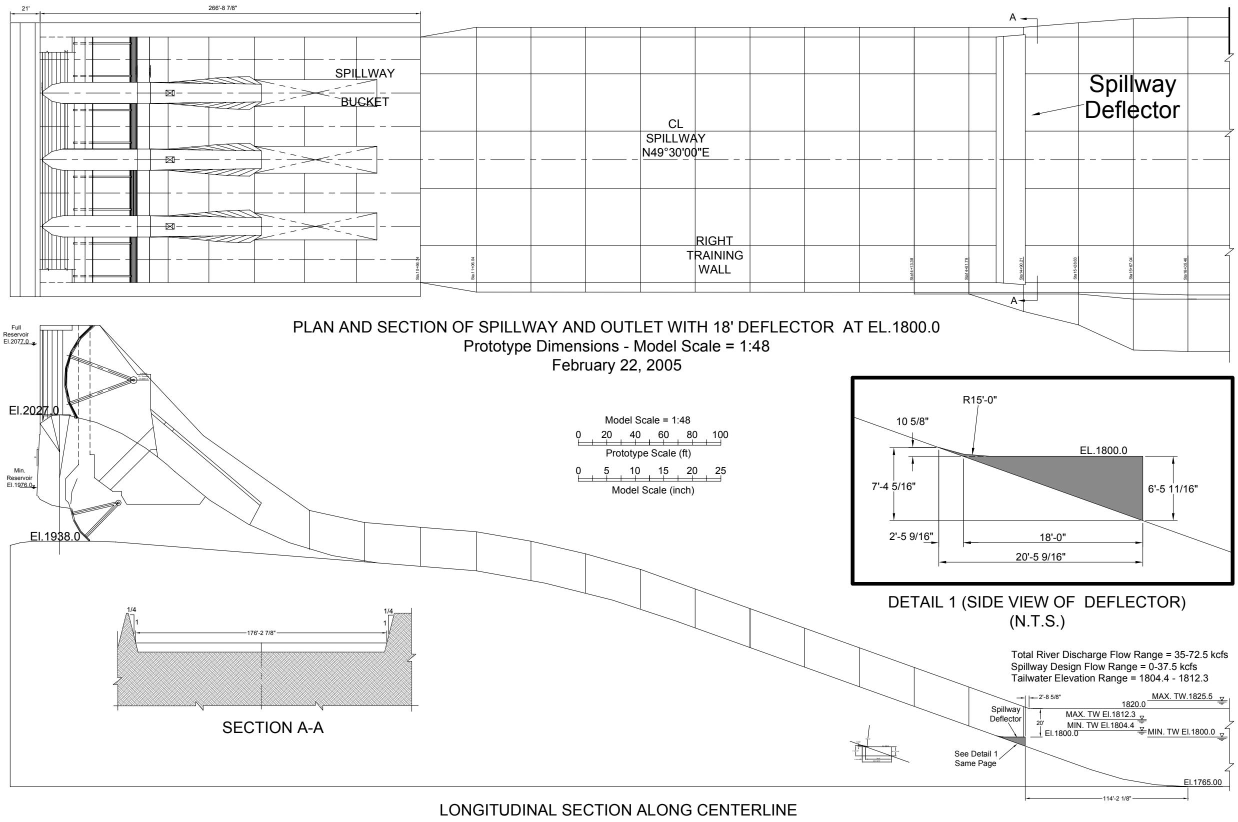

Figure 2-2. Spillway plan and section views

Figure 2-3. Photograph of spillway during model construction

Powerhouse Units

Welded stainless steel frameworks of 2-inch angle iron were built to support the powerhouse structures. Frame location and elevation were set using the total station and a laser level and bolted to the floor with ½-inch concrete anchors.

Model powerhouse dimensions were scaled from IPC drawings. Powerhouse surfaces were built using ¾-inch thick PVC sheeting. Upper and lower draft tube exit profiles were skinned with 18-gage galvanized metal. Units were set into place and bolted to the steel framework with stainless steel fasteners. A sharp-crested overflow weir upstream of the draft tube outlets was incorporated to maintain powerhouse flow independent of tailwater elevation. Prototype features were not built upstream of the draft tubes because the draft tubes alone would sufficiently replicate prototype flow discharge characteristics. Figure 2-4 is a plan view of the powerhouse. Figure 2-5 is a downstream elevation view of the powerhouse. Figure 2-6 is a typical powerhouse unit section view. Figure 2-7 is an isometric view of a single powerhouse unit. Figure 2-8 is a photograph looking upstream at the completed powerhouse structures.

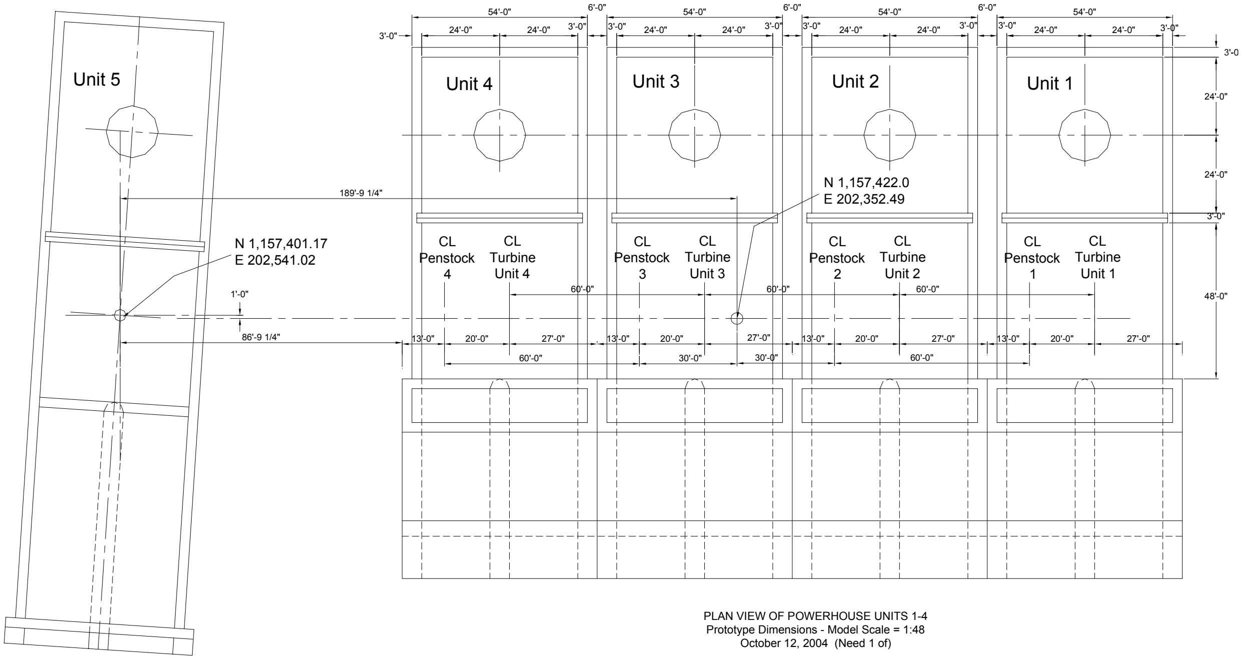

Figure 2-4. Plan view of powerhouse units 1-5

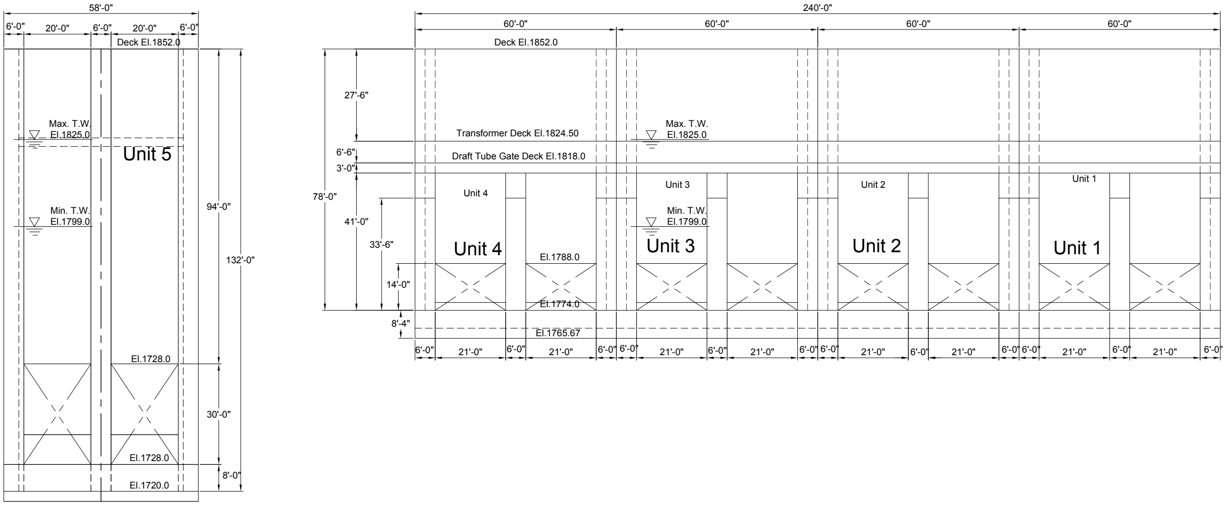

Figure 2-5. Downstream elevation view of powerhouse units 1-5

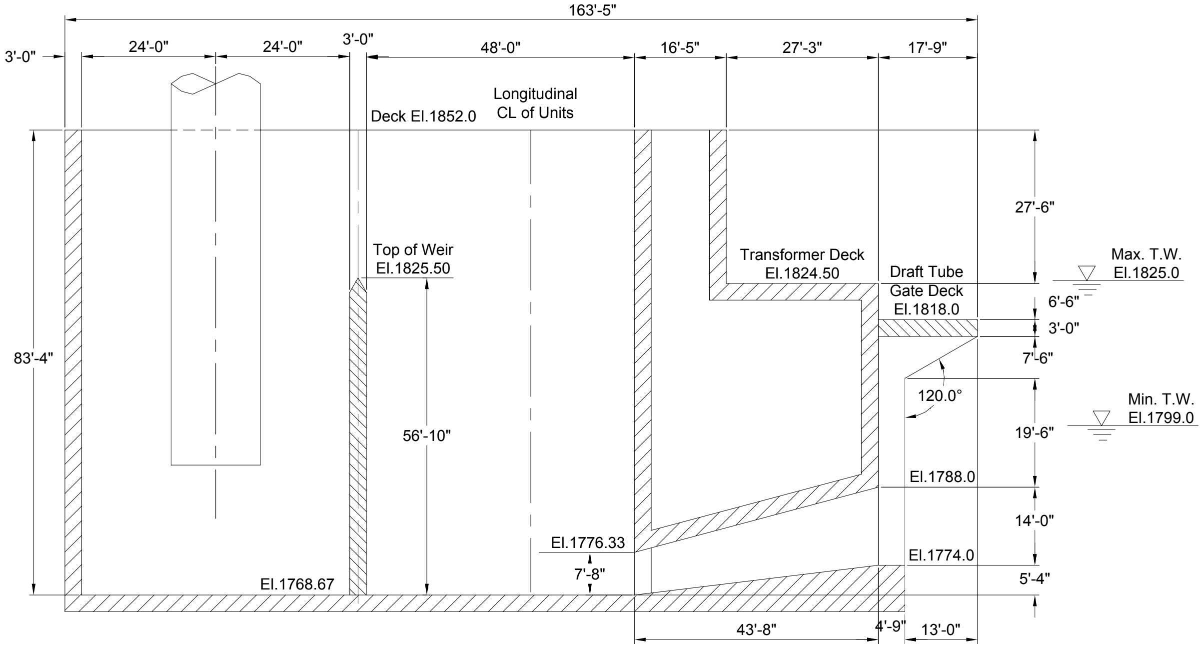

Figure 2-6. Typical section through powerhouse units 1-4

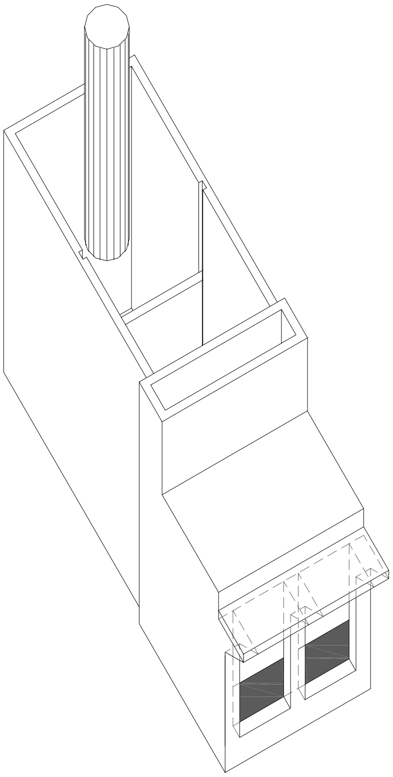

Figure 2-7. Isometric view of powerhouse units 1-4 (not to scale)

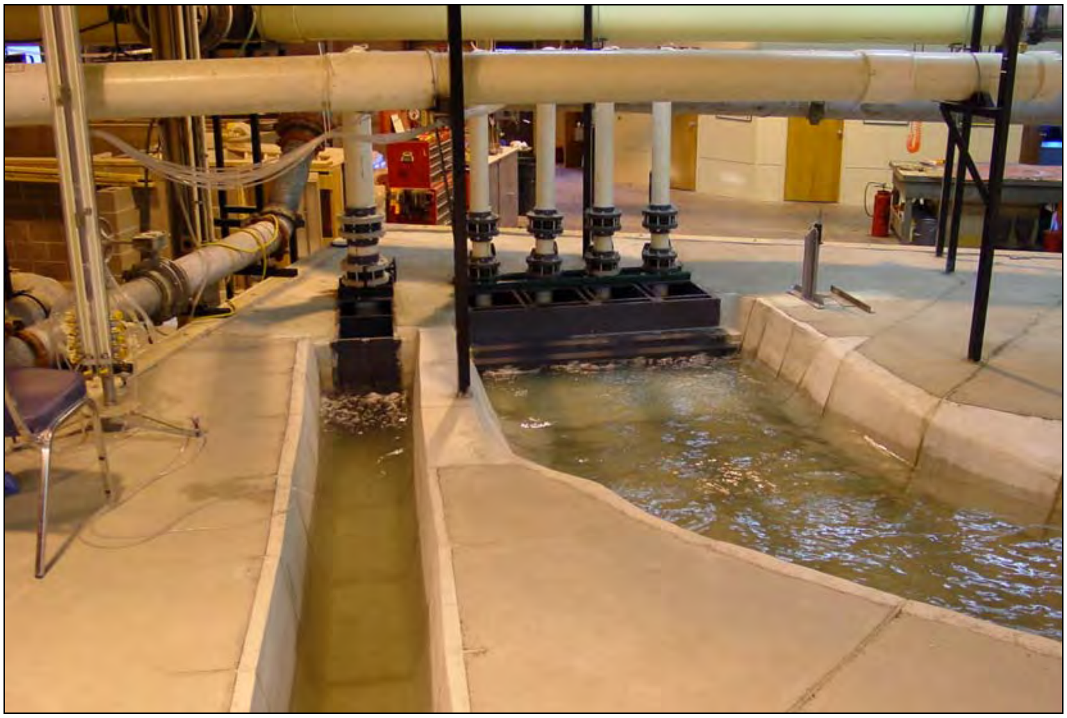

Figure 2-8. Photograph of the completed powerhouse

Tailrace Basin

Phase one basin walls were removed except for one portion on the left bank reused for phase two. New wall construction was contracted to Yoder Masonry Inc. of Riverside, Iowa. The walls were made from 8x16-inch masonry blocks rising to 40 inches at the right and left banks of the tailrace and return trough. The walls were internally anchored to the floor at 16-inch intervals by alternating ½-inch diameter rebar and threaded steel rods. Rebar openings were slugged with concrete. A 2x8-inch timber plate was installed on the masonry walls, with threaded steel rods bolted through the plate providing rod tension and wall strength. Steel plates were bolted to the timber plates at joints and corners. The walls were buttressed on the exterior at 8-foot intervals with 32-inch high masonry block columns slugged with concrete. Expansion gaps were incorporated at 25-foot intervals to minimize cracking. Wall expansion gaps and floor-to-wall transitions were treated with Vulkem sealer. Block wall interiors were sealed with a self-adhering waterproof membrane.[5] An adjustable tailgate weir installed downstream of the basin provided tailwater elevation control. A wall layout showing buttress locations is illustrated in Figure 2-9.

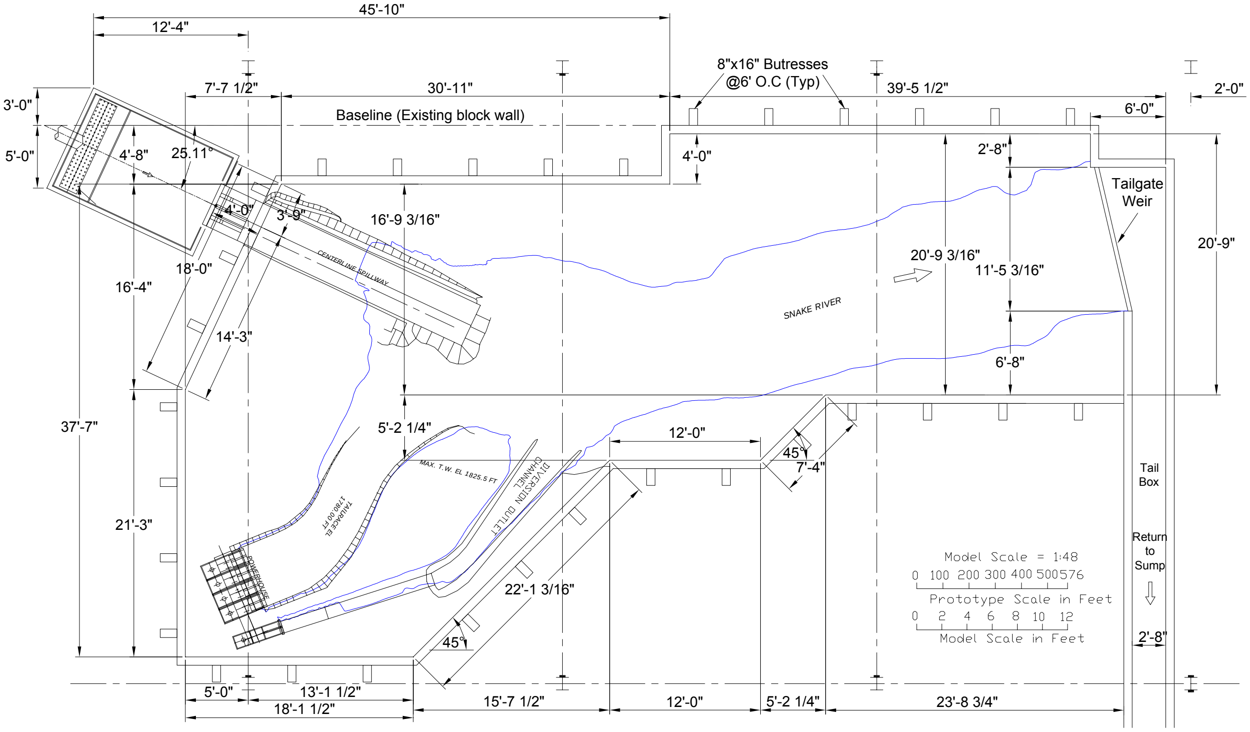

Figure 2-9. Model wall layout

Bathymetric Templates and Grade Stakes

Hydrographic, land survey, and aerial photogrammetry data define tailrace bathymetry. A three-dimensional representation of bathymetry was created using AutoCAD Land Development Desktop 2i. Transects extracted from the resulting topographic surface defined the powerhouse channels, spillway bank lines, and river transects near the tailgate. Single points were replicated using steel grade stakes anchored in the concrete floor and these defined the tailrace downstream of the powerhouse channel confluence. Grade stakes were surveyed using the total station and cut to scaled prototype elevation. Additional grade stakes were placed to refine complex bed surface details. Figure 2-10 is a bathymetric contour map illustrating model template (transect) and grade stake locations.

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[5] CCW MiraDRI 860 manufactured by Carlisle Coatings and Waterproofing

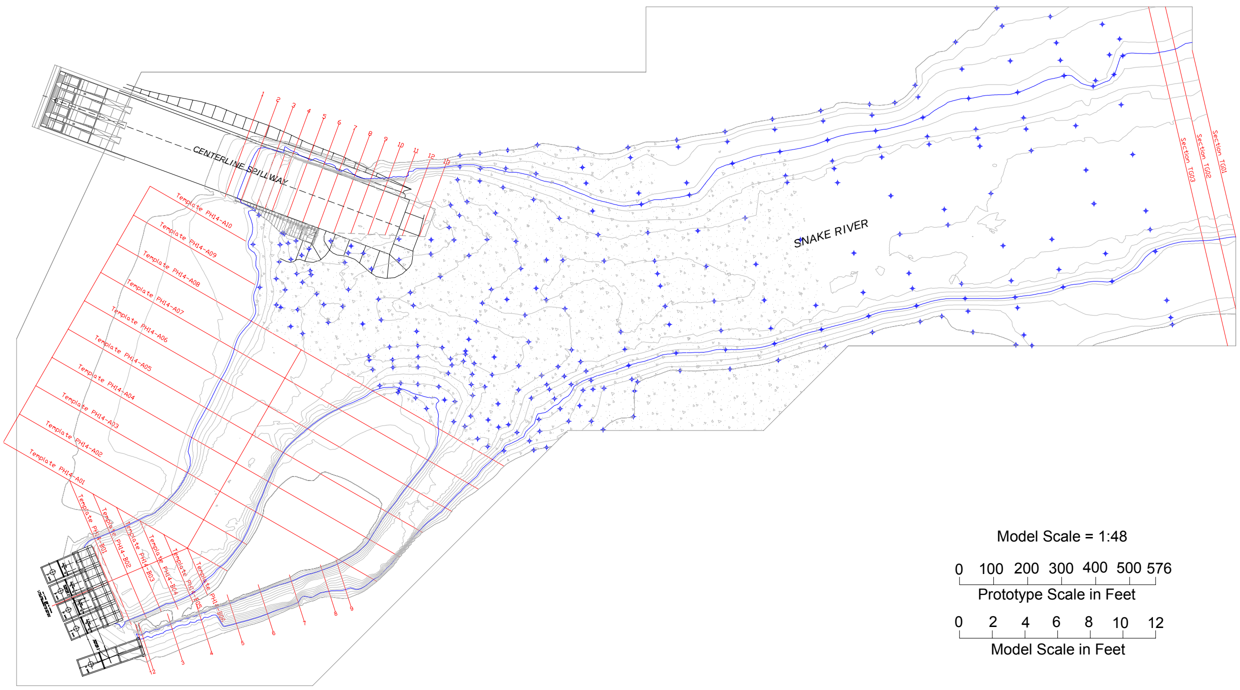

Figure 2-10. Model template and grade stake locations

To produce model scale bathymetric templates, extracted transects were scaled and printed on 36-inch wide roll-fed drafting paper. Printed transects were transferred to ½-inch thick 4x8-foot OSB plywood sheets and jig-sawed to form templates. The bottom of each template was set to a prototype elevation of 1700 feet by inserting the lower edge into a rectangular groove cut in a wooden block so set. The wooden blocks were adjusted with shims and fastened to the floor with concrete anchors. Prototype elevations were set using a LaserMark® LMH laser level. The manufacturer's stated accuracy is +/- 1/16-inch at 100 feet. Template block elevation uncertainty set using the laser level was +/- 0.12 prototype feet. Template locations (prototype Northings and Eastings) and elevations were verified using a Topcon GTS 226 total station. The total station uncertainty was ±0.32 prototype feet. Figure 2-11 is a photograph of bathymetric templates and grade stakes during construction. Figures 2-12 and 2-13 are photographs of completed bathymetry near the powerhouse and spillway.

Figure 2-11. Photograph of bathymetric templates and grade stakes during construction

Figure 2-12. Photograph of completed bathymetry near the powerhouse

Figure 2-13. Photograph of completed bathymetry near the spillway

Bathymetric Material Selection

Three materials formed the tailrace bed; a concrete cap over fill material, an erodable 3/8-inch washed limestone gravel, and an erodable bentonite clay and gravel mixture. Figure 2-1 shows materials used in each area. The area downstream of the bentonite was initially gravel, but was capped with concrete to inhibit erosion during the PMF scour test.

In areas not likely to erode, such as powerhouse channels, washed limestone gravel was placed between templates and firmed with a walk-behind plate compactor. A 1-½ inch thick concrete cap placed over the gravel provided a non-erodable bed.

For prediction of scour hole development, a clay binding agent was mixed with 3/8-inch (nominal diameter) washed limestone gravel to reduce void space and increase cohesion. Finely ground Aldenite[6] (sodium bentonite) was mixed in a volumetric ratio of three gravel to one water

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[6] Aldenite is packaged by Iowa Limestone Company (Des Moines, Iowa). The following information was obtained by Richard Bristol, Director of Nutrition and Technical Services at ILC. Aldenite (sodium bentonite) is primarily composed of the expansive clay montmorillonite (92% by x-ray analysis). The material used was labeled as "Granular Feed Grade" and

to one bentonite in a rotary mixing drum. The bentonite was slowly added after water had coated the gravel. The final product was softball sized gravel clumps, bound with clay. The bentonite and gravel mixture was placed and compacted from the floor to the bedrock surface. The surface was smoothed to match surveyed grade stakes and adjoining concrete bedrock. The grain size distribution for the washed limestone gravel in the bentonite and gravel mixture is shown in Figure 2-14. The specific gravity was 2.70 ± 0.06.

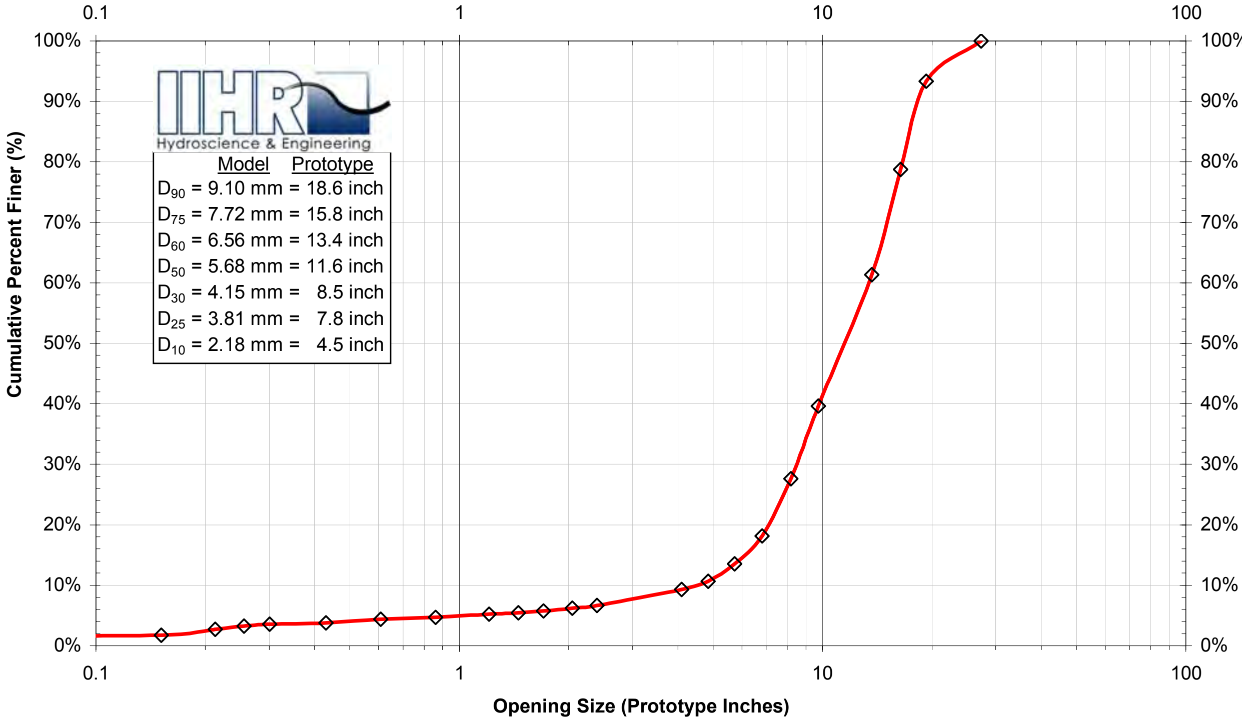

Figure 2-14. Grain size distribution of angular gravel used to model fractured bedrock particles

An independent[7] hydrometer / pipet test (ASTM Test Designation D-422) indicates that about 1.75% of angular gravel particles pass through a 200 sieve. Sieve data for the angular gravel is summarized in Table 2-2.

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distributed as the "#3" granulation (85% passing 0.833mm, 40% passing 0.420mm, and 15% passing 0.075mm sieves). The specific gravity of Aldenite is between 2.75 and 2.80.

[7] United States Geological Survey. Particle-Size Summary Sheet IA2000.0. File bc-2002-37-ia. Laboratory test completed on September 11, 2002.

Sieve Number	Opening mm	Percent Retained	Cumulative Percent Passing	Sieve Opening Prototype Inches
	13.330	0.0%	100.0%	27.3
	9.423	6.6%	93.4%	19.3
	8.000	21.3%	78.7%	16.4
	6.680	38.6%	61.4%	13.7
4	4.760	60.4%	39.6%	9.7
5	4.000	72.4%	27.6%	8.2
6	3.327	81.8%	18.2%	6.8
7	2.800	86.5%	13.5%	5.7
8	2.362	89.3%	10.7%	4.8
10	2.000	90.7%	9.3%	4.1
14	1.168	93.3%	6.7%	2.4
18	1.000	93.8%	6.2%	2.0
20	0.833	94.2%	5.8%	1.7
25	0.710	94.5%	5.5%	1.5
30	0.590	94.8%	5.2%	1.2
40	0.420	95.3%	4.7%	0.9
50	0.297	95.6%	4.4%	0.6
70	0.210	96.3%	3.7%	0.4
100	0.147	96.4%	3.6%	0.3
120	0.125	96.7%	3.3%	0.3
140	0.104	97.3%	2.7%	0.2
200	0.075	98.2%	1.8%	0.2
	0.031	98.5%	1.5%	0.1
	0.016	98.8%	1.2%	0.0
	0.008	99.2%	0.8%	0.0
	0.004	99.4%	0.6%	0.0
	0.002	99.5%	0.5%	0.0

Table 2-2. Angular gravel sieve data

2.2. Experimental Equipment

Model Inflow Configuration and Measurement

The Model Annex is built above a 97,000 gallon sump providing water storage for models. Two single-stage, mixed flow pumps, 75 and 60 HP, with variable frequency drive (VFD) controllers provide flow. Model inflow capacity, approximately 300,000 cfs (prototype), corresponds to the probable maximum flood (PMF) predicted for the Snake River at Brownlee Dam.[8] The 75 and 60 HP pumps convey water to the model through 16- and 12-inch pipes. Calibrated flow meters in each pipe measure flowrates. Figure 2-15 shows sump, pumps, pipe network, and flow meter locations.

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[8] 300,000 cfs PMF value provided by IPC.

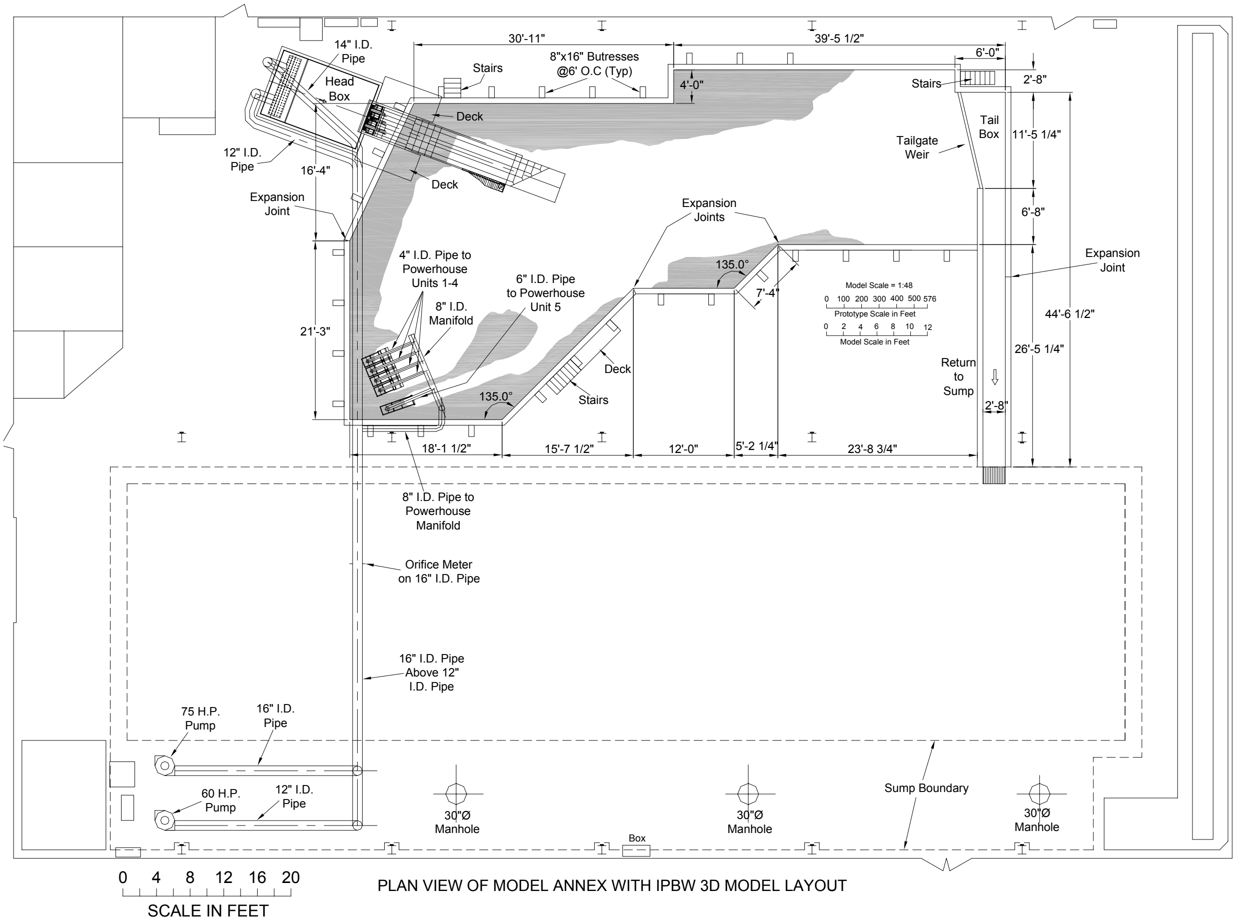

Figure 2-15. Sump, pumps, pipe network, and flow meter locations

The 16-inch pipe conveys water from the sump to the spillway headbox and is equipped with interchangeable annular ring orifice flow meters. The 12-inch pipe conveys water from the sump to the spillway headbox and is equipped with an electronic MagFLO flow meter. Typically, the 16-inch pipe provides spillway flows and the 12-inch pipe provides powerhouse flows. Both pumps convey water to the headbox for PMF flow simulations. When powerhouse flows are needed, a valve is closed on the 12-inch pipe and the water is diverted through an 8-inch steel pipe to four 4-inch and one 5-inch PVC pipe discharging water to individual powerhouse units. Each powerhouse pipe has an elbow flow meter.

Pressure differentials across the flow meters were measured with a vernier-scaled precision 2-tube multi-port manometer accurate to +/- 0.0005 model feet. Equation 2-1 calculated model flowrate, where Q is cubic foot per second discharge, C_d is the discharge coefficient (listed in Table 2-3), and ΔH is pressure differential measured in feet of water. Discharge coefficients were developed from a statistical regression of the calibration data.

$$Q = C_d \cdot \Delta H^{0.5} \tag{2-1}$$

The orifice flowrate was calculated and multiplied by the Froude-scale factor $48^{2.5} \cong 15{,}963$, to convert model values to prototype.

Elbow and orifice meters were manufactured in the IIHR machine shop. Orifice meters were calibrated independently at Utah Water Research Laboratory (UWRL). Elbow meters were calibrated in IIHR's weigh tank facilities. Table 2-3 is a summary of model flow meter details including discharge coefficients.

Location on Model	*Flow Meter Type*	C_d	*Pipe Dia. (in)*	*Orifice I.D. (in)*	*IIHR Serial Number*
Headbox Inflow	Orifice	1.7762	16.00	8.00	051804-16-08
Headbox Inflow	Orifice	3.9025	16.00	11.00	051804-16-11
Headbox Inflow	Orifice	5.9733	16.00	12.50	051804-16-12.5
Headbox/Powerhouse Supply	ElectroMagnetic	---	14.00	---	UI 567131
Powerhouse Unit 1	Elbow	0.440	4.00	---	040105-04-A
Powerhouse Unit 2	Elbow	0.440	4.00	---	040105-04-B
Powerhouse Unit 3	Elbow	0.440	4.00	---	040105-04-C
Powerhouse Unit 4	Elbow	0.440	4.00	---	040105-04-D
Powerhouse Unit 5	Elbow	0.876	6.00	---	040105-05-A

Table 2-3. Flow meter details

Headwater Gage

Headwater elevations were measured with a hook-type point gage, accurate to +/- 0.0005 model feet, mounted in a 6-inch diameter acrylic stilling pot on the headbox wall exterior near the spillway. The stilling pot was mounted vertically, the top open to the atmosphere and the bottom sealed. A 3/8-inch tube connected the stilling pot to the headbox by a hole drilled through the wall dampening surface wave effects in the headbox. The headwater gage was referenced to average spillway crest elevation, determined using the total station. Equation 2-2 converted the model vernier-scaled *gage* reading to a prototype headwater elevations *HW*.

$$HW = 48.00 \cdot gage + 0.561 \pm 0.05 \tag{2-2}$$

Tailwater Gages

At Brownlee Dam, the tailwater elevation is measured near powerhouse unit 1 and near the right bank downstream of the bridge. In the model, tailwater was measured near powerhouse unit 1, approximately corresponding to field location, at the confluence of the two powerhouse channels, corresponding to the phase one location, and approximately three model feet upstream of the tailgate approximately corresponding to the near bridge field location. These locations are labeled TW1, TW2, and TW3 in Figure 2-1. Tailwater elevation was measured with a point gage, accurate to +/- 0.024 prototype feet, mounted inside a 6-inch diameter stilling pot. Buried 3/8-inch flexible tubing connected the stilling pot to a pan-type water surface gage emerging from the bed at each location. The powerhouse gage (TW1) determined tailwater elevations for the model, set with the adjustable tailgate weir. Tailwater elevations for given river flowrates and Oxbow reservoir elevations were determined from the Brownlee Dam tailwater rating curves provided by IPC, shown in Figures 2-16 and 2-17. Based on Figure 2-16, the tailwater operating range for the deflector studies was 1804.5 to 1812 feet.

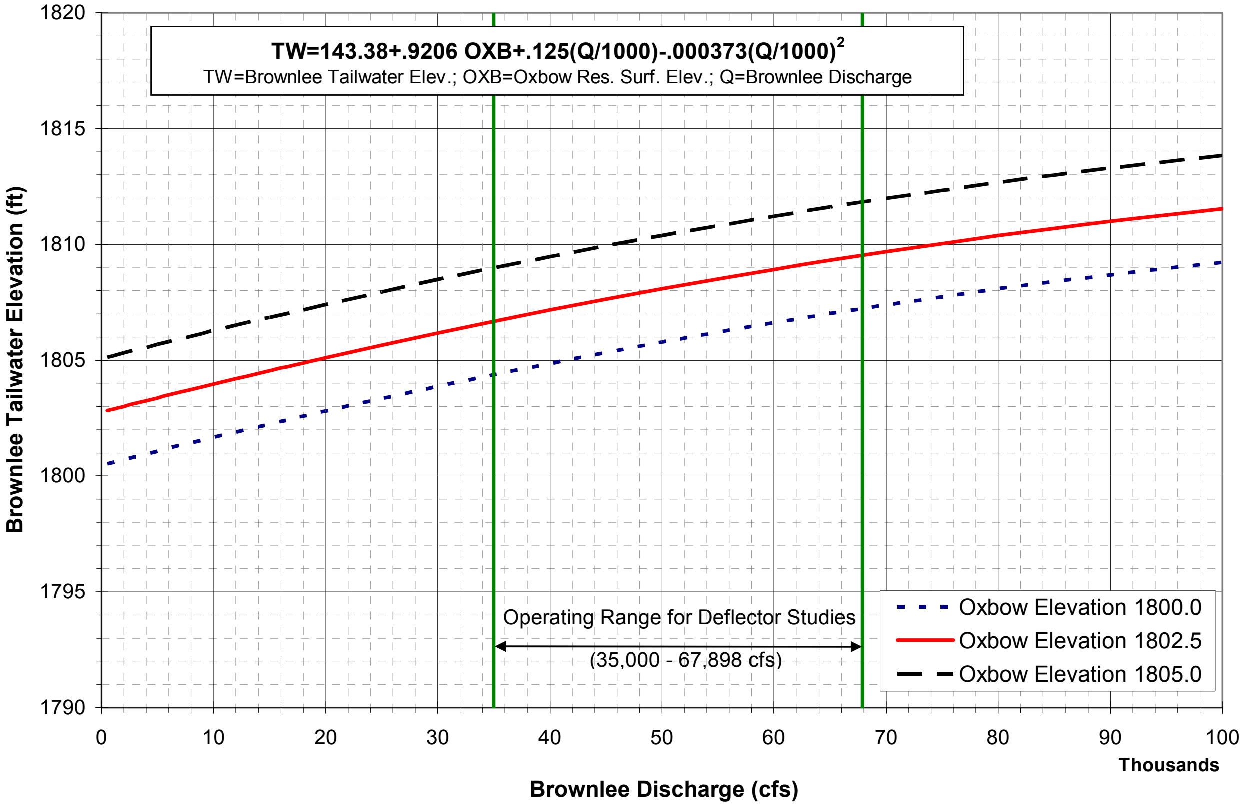

Figure 2-16. Tailwater rating curves for Brownlee Dam up to 100,000 cfs

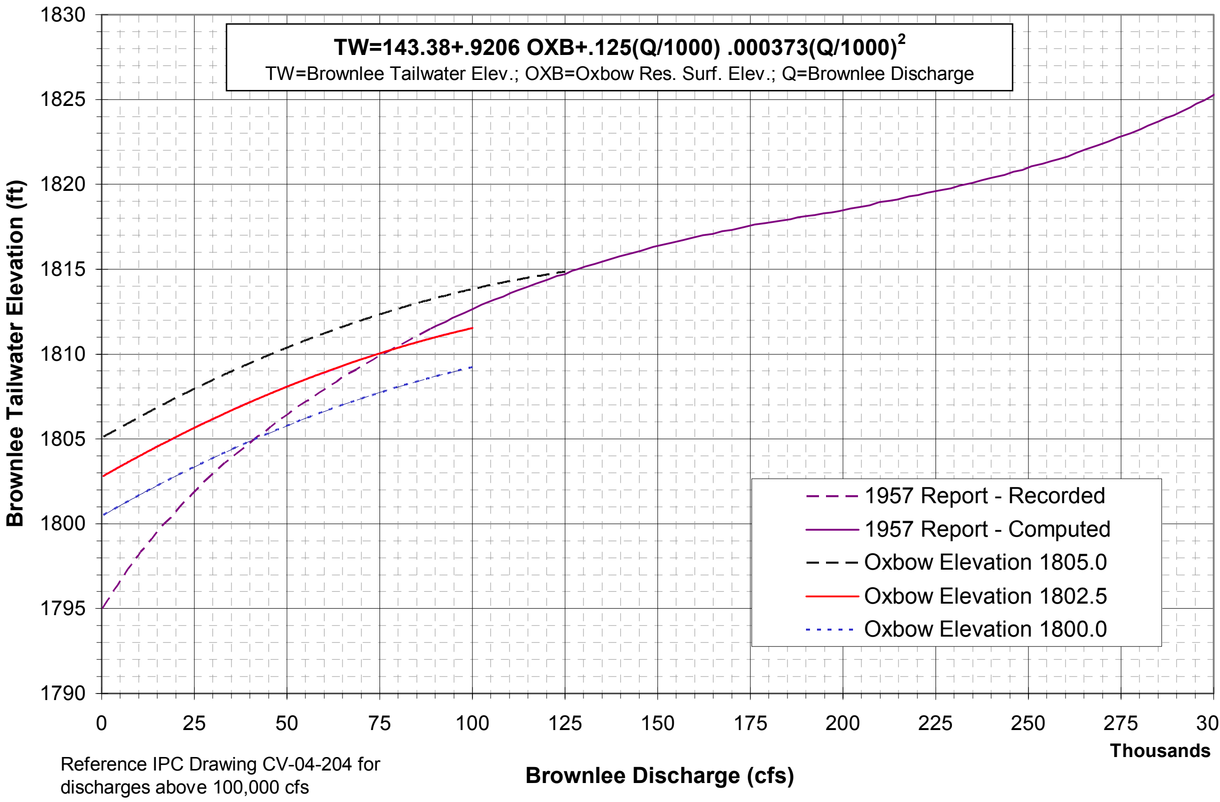

Figure 2-17. Tailwater rating curves for Brownlee Dam up to the PMF

Velocity Measurement

In-river model velocities were measured by a SonTek/YSI Acoustic Doppler Velocimeter (ADV) equipped with a 3D down-looking probe tip. This instrument measures point velocities from approximately half an inch below the surface to half an inch above the bed. The ADV was installed on a motorized traverse with a manual tri-axial leveling bracket and mounted on an aluminum beam suspended over the model. A bubble level on the mounting bracket facilitated vertical alignment. The motorized traverse provided remote vertical positioning of the probe tip through an encoder and digital position display accurate to +/- 0.0005 feet (model). The ADV probe velocity azimuth was calibrated in one-dimensional flow prior model use.

Wave Height Measurements

In-river wave heights were measured with calibrated Teflon capacitance probes to obtain a time series of vertical wave positions. A Visual Basic macro program was written[9] to process

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[9] Provided by Pete Haug at IIHR

and normalize data to a zero position. Waves were separated by downward zero crossings sorted from highest to lowest. For *n* waves, Equations 2-3 through 2-5 calculated wave height statistics:

$$\text{Maximum wave height} = H_m = H_1 \qquad (2\text{-}3)$$

$$\text{Significant wave height} = H_s = \frac{3}{n}\cdot\sum_{i=1}^{n/3} H_i \qquad (2\text{-}4)$$

$$\text{Root mean squared wave height} = H_{rms} = \sqrt{\frac{1}{n}\cdot\sum_{i=1}^{n} H_i^2}\,. \qquad (2\text{-}5)$$

The Corps of Engineers defines[10] significant wave period, T_s, as the average of waves whose troughs are below and crests above the mean water level. The separator between waves is defined as a zero crossing of the position series. Wave height, H_i, is defined as the maximum crest position minus the minimum trough position. Significant wave height, H_s, is defined[11] by Munk (1944) as the average height of the highest one-third of the waves.

Bed Surveys and Model Layout

Bed profiles, contour map survey data, and civil structures placement were set using a Topcon GTS-226 total station. This instrument was collimated and inspected for alignment in December 2004. The total station has a stated accuracy of two millimeters plus 2 parts per million of the total range. The maximum uncertainty for surveyed measurements is ±0.31 prototype feet. The total station also documented wave height and velocity probe locations.

3. DEFLECTOR PERFORMANCE VERIFICATION

3.1. Deflector Design

The deflector design studied here is the final deflector design from phase one, an 18-foot long horizontal deflector with the lip 1800 foot above mean sea level. Figure 3-1 is a detailed section view. Figure 3-2 is a photograph of the deflector as constructed on the model.

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[10] Shore Protection Manual. Department of the Army, Waterways Experiment Station, Corps of Engineers. Volume I. 1984. pp 3-1 to 3-19.

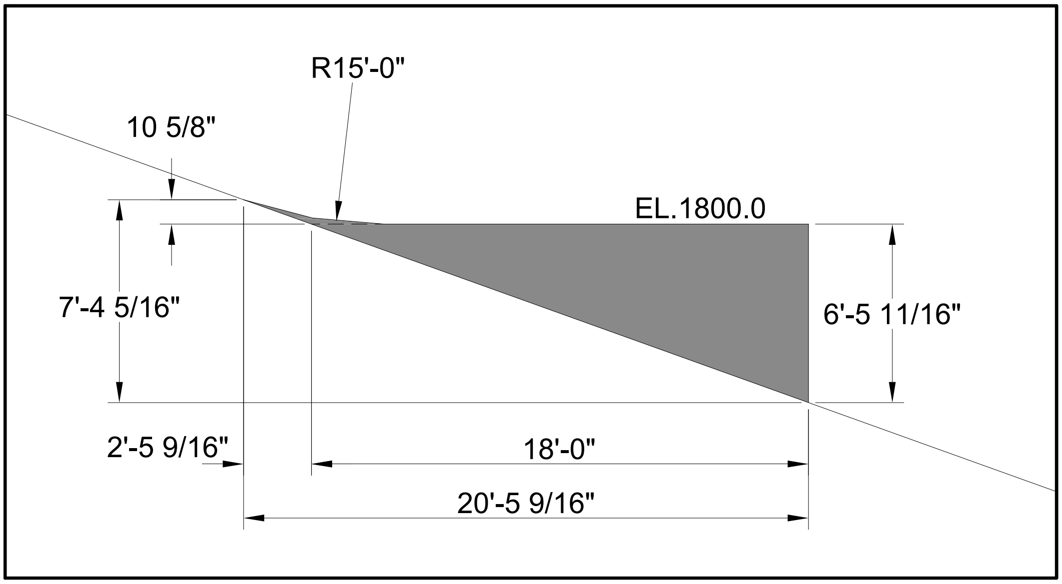

Figure 3-1. Spillway deflector details

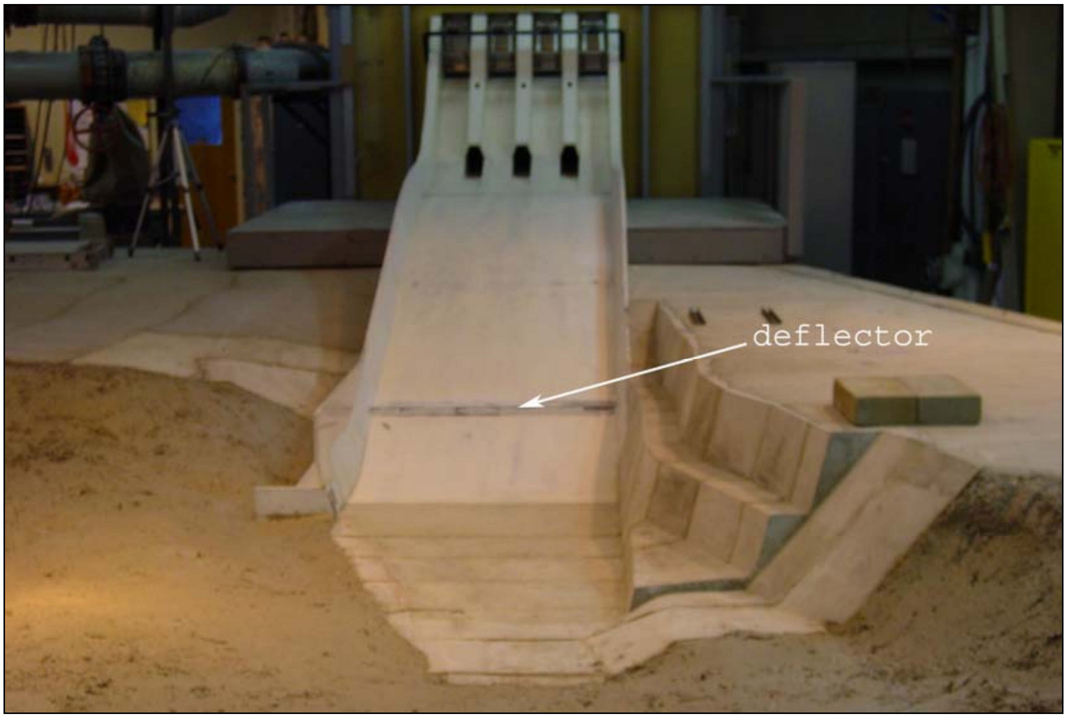

Figure 3-2. Photograph of the spillway deflector on the model

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[11] Schiereck, Gerrit J. Introduction to Bed, Bank and Shore Protection. Delft University Press: Delft (Netherlands), 2001. pp 169-173.

3.2. Flow Regime Definitions

Five distinct flow regimes defined spillway jet transition hydraulics entering the tailrace. These are described and illustrated below.

- Submerged surface jet: This occurs when the deflector is deeply submerged, with flow rolling back onto the jet. Very few bubbles are in the stilling basin at depth. The downstream water surface is relatively horizontal and smooth.

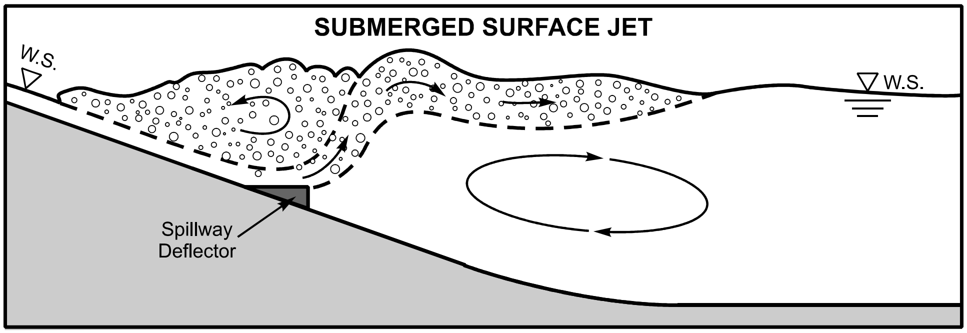


Figure 3-3. Submerged surface jet flow regime

- Ramped surface jet: This regime begins when the jet sweeps out and no flow rolls back onto the jet or deflector. Flow is deflected upward at an angle greater than 10 degrees. Air bubbles penetrate deeply at a secondary plunge point in the stilling basin.

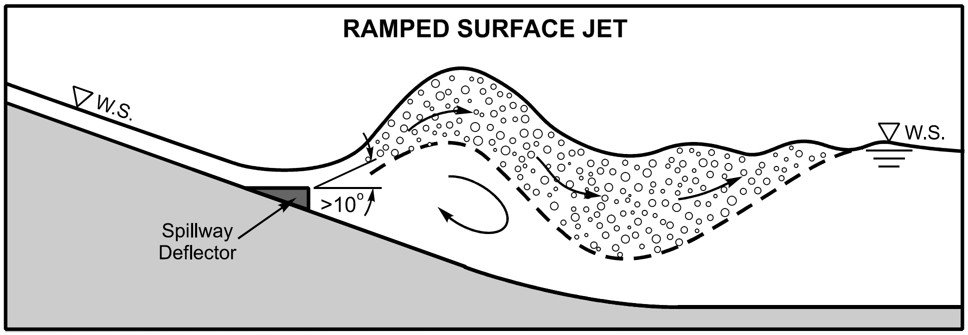


Figure 3-4. Ramped surface jet flow regime

- Skimming surface jet: This regime occurs when the deflected angle is 10 degrees or less. The entire jet is surface-oriented and relatively horizontal. There is no secondary plunge point. Very few bubbles are drawn to depth in the stilling basin. This regime produces the least air entrainment.

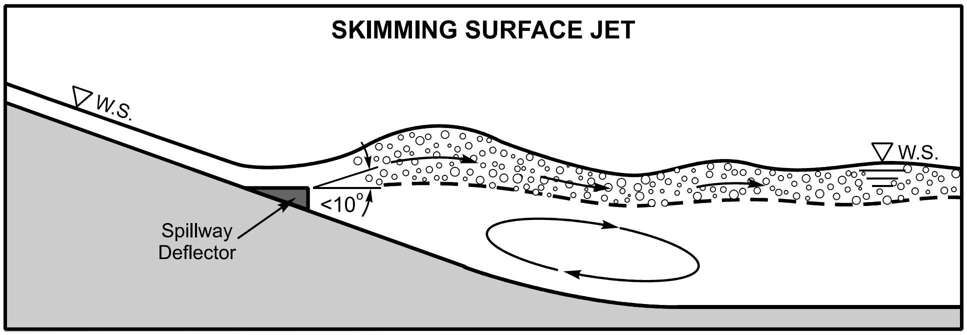


Figure 3-5. Skimming surface jet flow regime

- Unstable surface jet: This regime occurs when deflector submergence is lowered to the point where pockets of air bubbles are observed to intermittently burst to the bed. This regime occurs at submergence levels just above plunging flows.

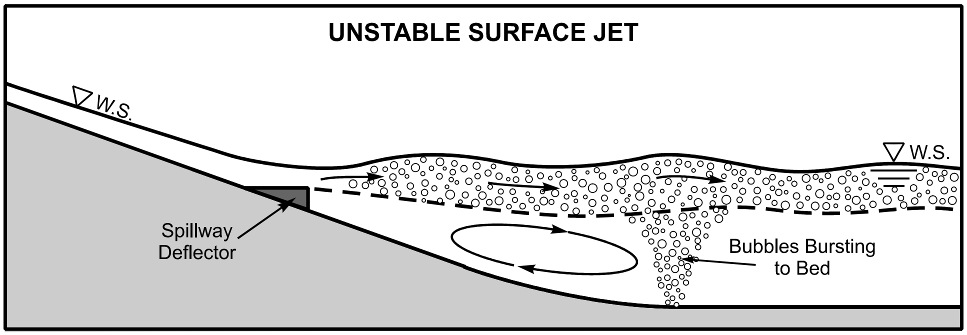


Figure 3-6. Unstable surface jet flow regime

- Plunging jet: This regime occurs when deflector submergence is lowered until the jet intermittently aerates at the deflector downstream edge. The jet, no longer supported by the tailwater, plunges downward from the deflector to the bed consistently carrying air bubbles to depth in the stilling basin.

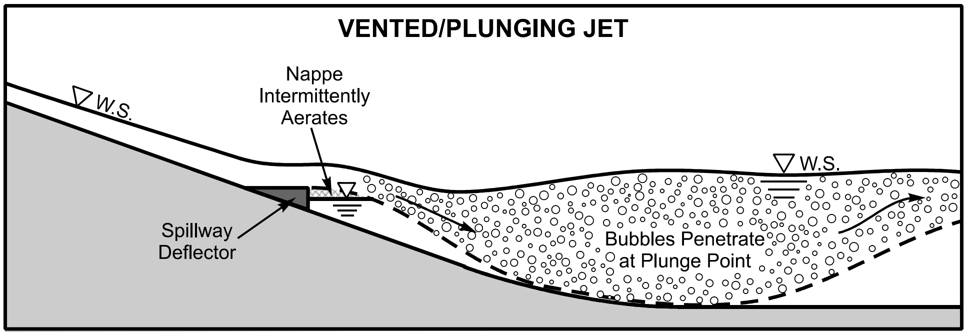


Figure 3-7. Plunging jet flow regime

3.3. Performance Curve Data

Transition points between flow regimes defined in Section 3.2 were determined by setting the spillway flowrate, varying the tailwater elevation, and documenting tailwater elevations when regime transitions were observed. This exercise was performed for spillway flows at 10, 20, 30, and 40 kcfs while 35 kcfs was discharged through the powerhouses. Tailwater elevations were set using gage TW2 (Figure 2-1), corresponding to the location that set phase one tailwater elevations allowing valid comparisons between the two models. Flow regime transitions are illustrated in Figure 3-8 by plotting tailwater elevation against total river flow. Dashed lines represent the phase one and solid lines the phase two model.

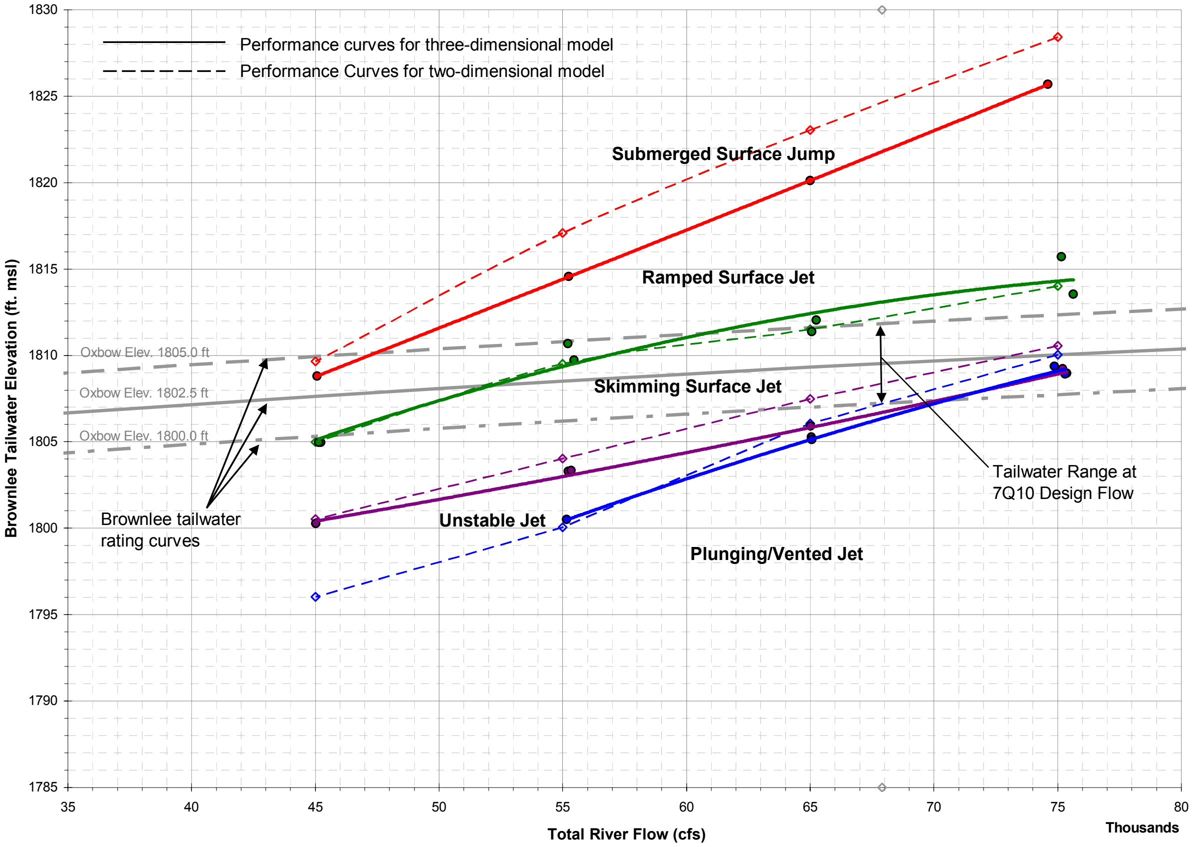


Figure 3-8. Performance curves for phases one and two

Figure 3-8 shows spillway jet performance changes for three-dimensional flow characteristics in phase two. Most notable is a downward shift for the transition between submerged surface jump and ramped surface jet flow regimes, diminishing the ramped surface jet flow regime for phase two. A probable cause is additional spillway jet flow entrainment enabled by the three-dimensional model. This is not a concern since the transition occurs at tailwater elevations above those observed for the design flowrate. The transition between ramped and skimming surface jets increased slightly for the design flow (67,898 cfs), resulting in the desired larger skimming surface jet flow regime. The transition between skimming surface and unstable jets decreased approximately 1.5 feet (prototype) at the design flow, lowering maximum depth for the former. This increase in skimming surface flow regime range is also good. The transition between unstable and vented/plunging flows decreased by approximately 0.8 feet (prototype). This is also good considering the disadvantages of plunging flows.

Performance curve changes in phase two showed good deflector performance at the design total river flowrate of 67,898 cfs (32,898 cfs spillway). For maximum deflector design flow (32,898 cfs), with Oxbow reservoir elevations from 1800 – 1805 feet, the flow regime was observed as a skimming surface jet, which should reduce TDG at the project.

4. TAILRACE EROSION POTENTIAL

Tailrace erosion test scenarios are given in Table 4-1. Each was carefully set up and monitored. Tailwater gage TW3 (Figure 2-1) set tailwater elevation. "Baseline" tests were performed without the deflector.

Test	Deflector		Spillway Q	Powerhouse Q	River Q	Tailwater Elevation	Test Duration
Number	length (feet)	elevation (feet)	(cfs)	(cfs)	(cfs)	(feet above msl)	(hours - model)
IP-3D-01	none	none	32,898	35,000	67,898	1811.9	48
IP-3D-06	none	none	300,000	0	300,000	1825.5	24
IP-3D-09	18	1800	32,898	35,000	67,898	1811.9	48
IP-3D-14	18	1800	300,000	0	300,000	1825.5	24

Table 4-1. Erosion test scenarios

4.1. Erosion Tests for the 7Q10 Design Flowrate

Tests IP-3D-01 and IP-3D-09 (Table 4-1) were completed at the 7Q10 design flow, with and without the deflector. After 48 hours (13.9 days prototype) of continuous model operation, no scour had occurred in the erodable bentonite/gravel layer (defined in Figure 2-1) at any location. Scour should not be a concern for flows up to the 7Q10.

4.2. Erosion Tests for the Probable Maximum Flood (PMF) Flowrate

Tests IP-3D-06 and IP-3D-14 were conducted at the probable maximum flood (PMF) flowrate with and without the deflector to observe deflector impact on scour depth or pattern. Both tests resulted in significant scour of the erodable bentonite/gravel layer downstream of the spillway and the formation of gravel bars in the tailrace. A survey completed after each test accurately recorded the eroded bed surface. Contours from tests IP-3D-06 and IP-3D-14 are plotted in Figures 4-1 and 4-2 and present 2 foot prototype elevation increments.

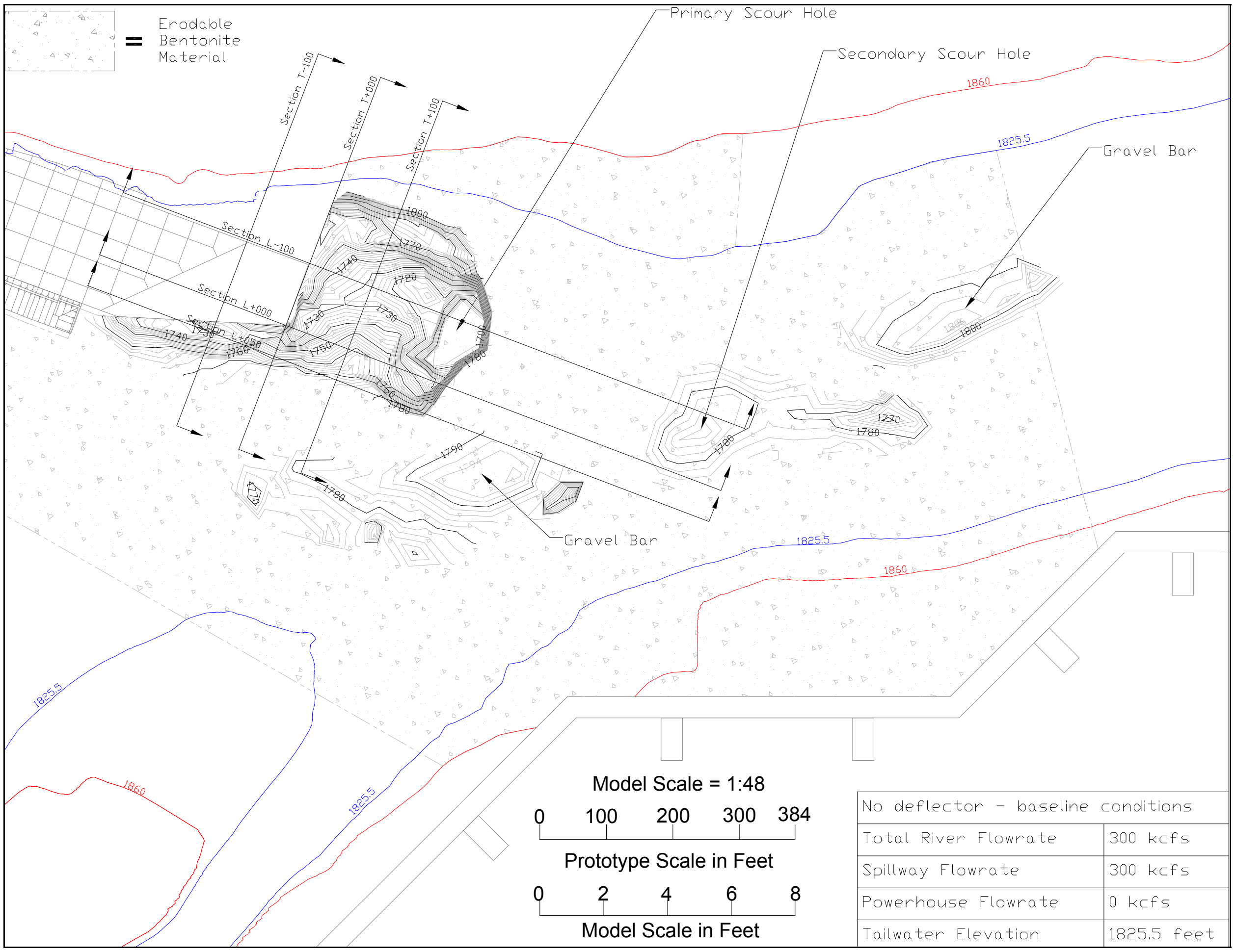


Figure 4-1. Bathymetric contour plan view without deflector (baseline) after PMF scour test (test IP-3D-06, 300,000 cfs)

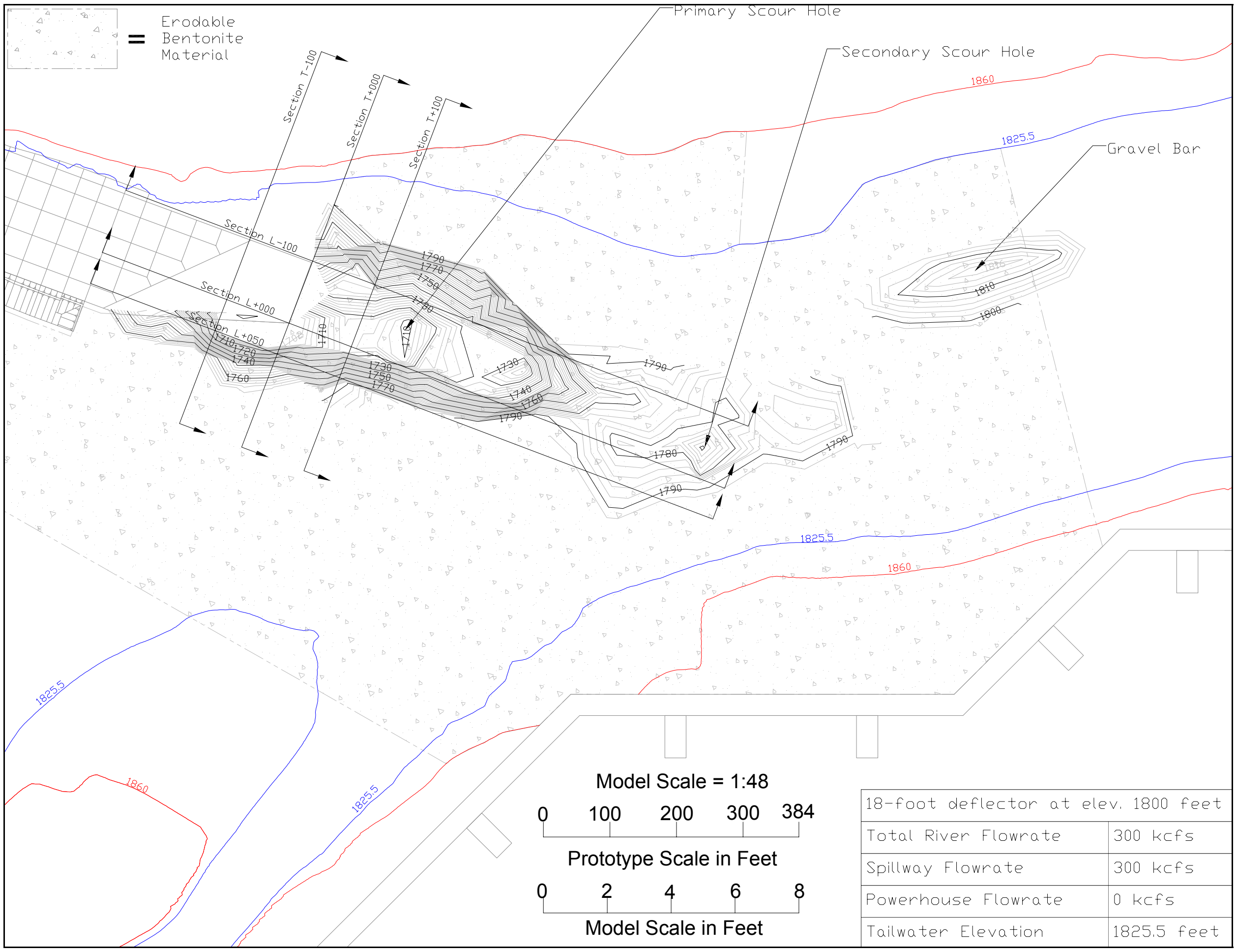
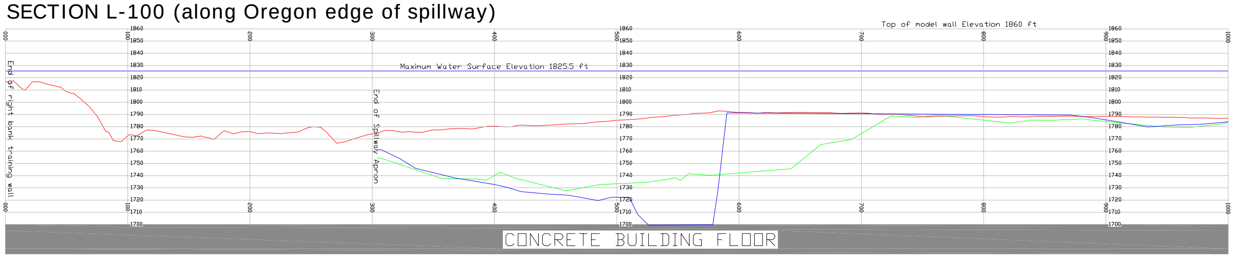


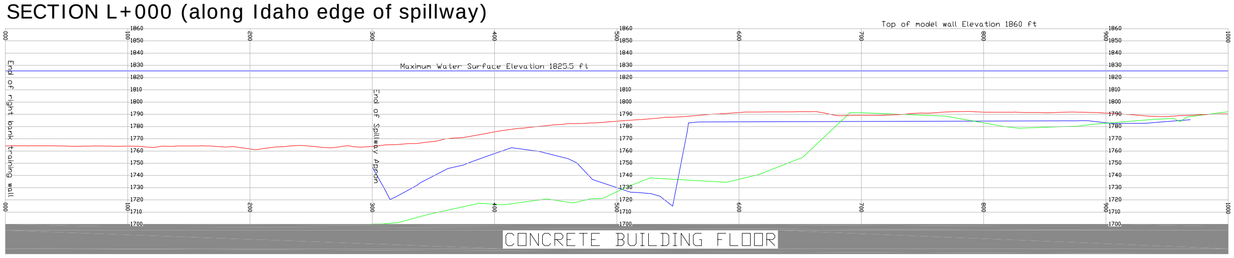
Figure 4-2. Bathymetric contour plan view with deflector after PMF scour test (test IP-3D-14, 300,000 cfs)

Cross-sections cut through the scour holes both stream-wise and transversely are shown in plan view in Figures 4-1 and 4-2, the locations of which were identical in each test. The cross-sections are plotted in Figures 4-3 and 4-4. Red lines represent the bed surface before the scour test. Green lines represent the bed surface after test IP-3D-06, without the deflector. Blue lines represent the bed surface after test IP-3D-14, with the deflector.

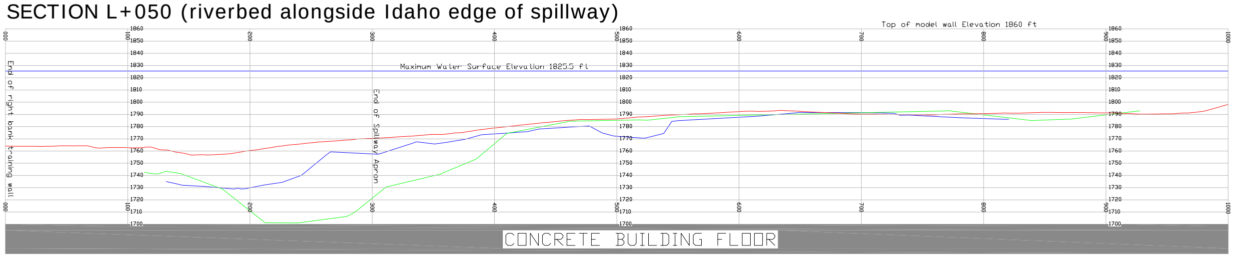
SECTION L-100 (along Oregon edge of spillway)



SECTION L+000 (along Idaho edge of spillway)



SECTION L+050 (riverbed alongside Idaho edge of spillway)



🟥 original bed
🟩 scour without deflector
🟦 scour with deflector

Figure 4-3. Longitudinal bed profiles for tests IP-3D-06 and IP-3D-14 (300,000 cfs)

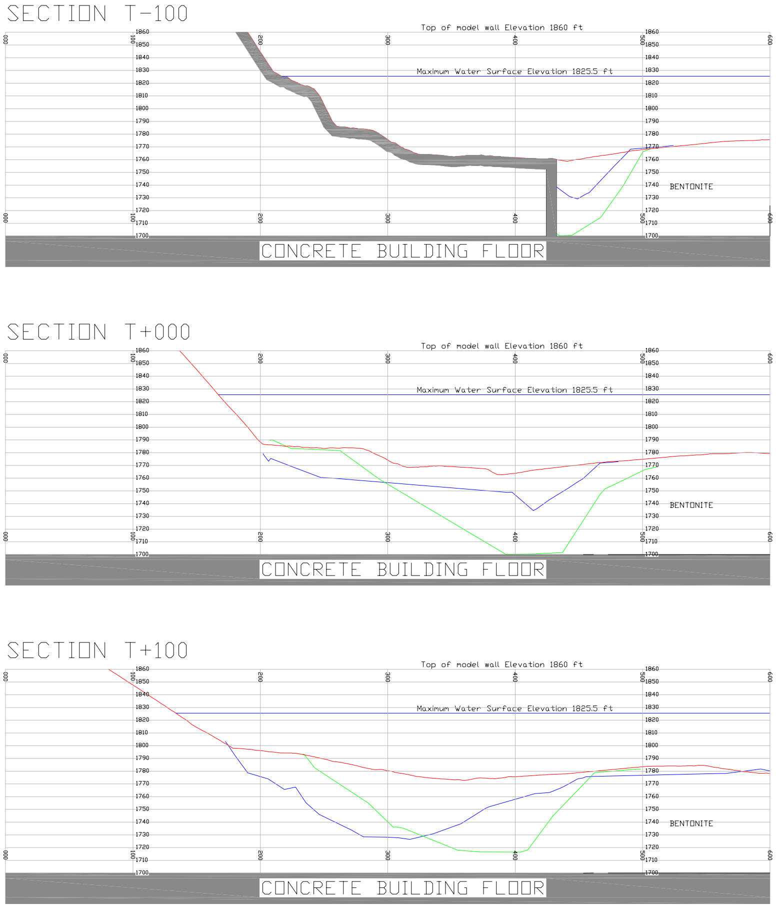


Figure 4-4. Transverse bed profiles looking downstream for tests IP-3D-06 and IP-3D-14 (300,000 cfs)

With the exception of transect L-100, Figures 4-3 and 4-4 show that a deeper and more substantial scour hole results in the baseline scour test without the deflector. Significantly deeper scour was observed with the deflector removed, most notably near the apron and especially along the right side (section T-100). In section T-100, with the deflector removed, scour was to the lab floor, with a 60 foot (prototype) hole. With the deflector, section T-100 shows a 30 foot deep hole at this location. The deepest scour for test IP-3D-06, without a deflector, occurs at section L+050, approximately 210 feet downstream of the apron endsill. It is approximately 60 feet deep, 33 feet deeper than for the IP-3D-14 case at the same location. The deepest scour for test IP-3D-14, with deflector, occurs at section L-100, approximately 500 feet downstream of the apron endsill. It is approximately 90 feet deep.

Photos taken after completion of the no deflector baseline scour test are shown in Figures 4-5 and 4-6. Photos taken after the scour test with the deflector are shown in Figures 4-7 through 4-9.

Figure 4-5. Photograph of the bed after the scour test without deflector (IP-3D-06)

Figure 4-6. Primary scour hole looking upstream to apron after the scour test without deflector (IP-3D-06)

Figure 4-7. Photograph of the bed after the scour test with deflector (IP-3D-14)

Figure 4-8. Primary scour hole looking upstream to apron after the scour test with deflector (IP-3D-14)

Figure 4-9. Primary scour hole looking downstream from apron after the scour test with deflector (IP-3D-14)

Figures 4-10 and 4-11 are photos of the PMF flow taken during the scour test.

Figure 4-10. Photograph of the spillway chute during the PMF scour test

Figure 4-11. Photograph of the downstream reach during the PMF scour test

4.3. Discussion of Results

Erosion due to sustained PMF flows results in tremendous erosion downstream of the spillway with and without the deflector. At the PMF flowrate, the deflector was over-ridden by the jet. Jet re-direction, observed with smaller flows, did not occur at PMF. This is an important factor for the deflector design that causes the spillway jet to re-submerge, dissipating energy in the stilling basin rather than downstream. The deflector made no significant difference in tailrace erosion and does not significantly affect scour downstream of the spillway at PMF flows.

5. EVALUATION OF TAILRACE FLOW CONDITIONS

5.1. Tailrace Egress Flow Patterns

Flow lines defining tailrace egress patterns at the confluence were observed and recorded for a steady 35 kcfs powerhouse flowrate and varied spillway flowrates of 10, 20, and 32.9 kcfs for the following conditions:

1) baseline – no deflector, no sidewall
2) deflector – 18-foot deflector with lip elevation at 1800 feet above m.s.l., no sidewall
3) deflector with sidewall – 18-foot deflector with lip elevation at 1800 feet above m.s.l., with a vertical extension on the right training wall to an elevation of 1830 feet)

Consistent with normal field operation, upper spillway gates passed flow and lower sluiceway gates remained closed. Headwater elevation was set to 2077.0 feet for all tests. Flowrates were carefully set with calibrated flow meters. The test matrix is given in Table 5-1 and includes model flow settings for each condition.

Condition	***(1) Baseline***			***(2) Deflector***			***(3) Deflector and Sidewall***		
IIHR Test Number	***TE1***	***TE2***	***TE3***	***TE4***	***TE5***	***TE6***	***TE7***	***TE8***	***TE9***
Upper spillway (cfs)	10,000	20,000	32,898	10,000	20,000	32,898	10,000	20,000	32,898
Lower sluiceway (cfs)	0	0	0	0	0	0	0	0	0
Spillway Total (cfs)	*10,000*	*20,000*	*32,898*	*10,000*	*20,000*	*32,898*	*10,000*	*20,000*	*32,898*
Powerhouse 1 (cfs)	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
Powerhouse 2 (cfs)	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
Powerhouse 3 (cfs)	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
Powerhouse 4 (cfs)	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
Powerhouse 5 (cfs)	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000
Powerhouse Total (cfs)	*35,000*	*35,000*	*35,000*	*35,000*	*35,000*	*35,000*	*35,000*	*35,000*	*35,000*
River Total (cfs)	***45,000***	***55,000***	***67,898***	***45,000***	***55,000***	***67,898***	***45,000***	***55,000***	***67,898***

Table 5-1. Egress flow pattern test matrix

Flow lines were drawn over an aerial photo of the Brownlee project. Baseline conditions (condition 1) are illustrated in Figures 5-1 to 5-3. Deflector conditions (condition 2) are illustrated in Figures 5-4 to 5-6. Deflector with sidewall conditions (condition 3) are illustrated in Figures 5-7 to 5-9.

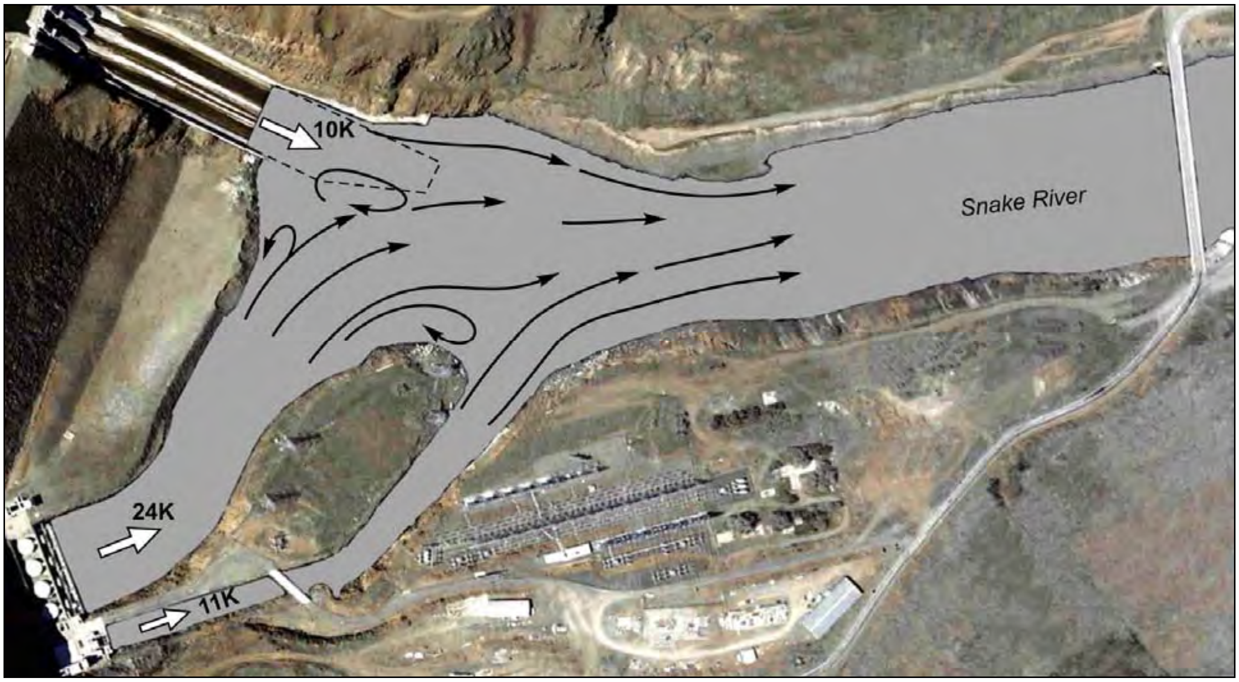


Figure 5-1. Test TE1: Spillway = 10,000 cfs, Powerhouse = 35,000 cfs, no deflector, no sidewall

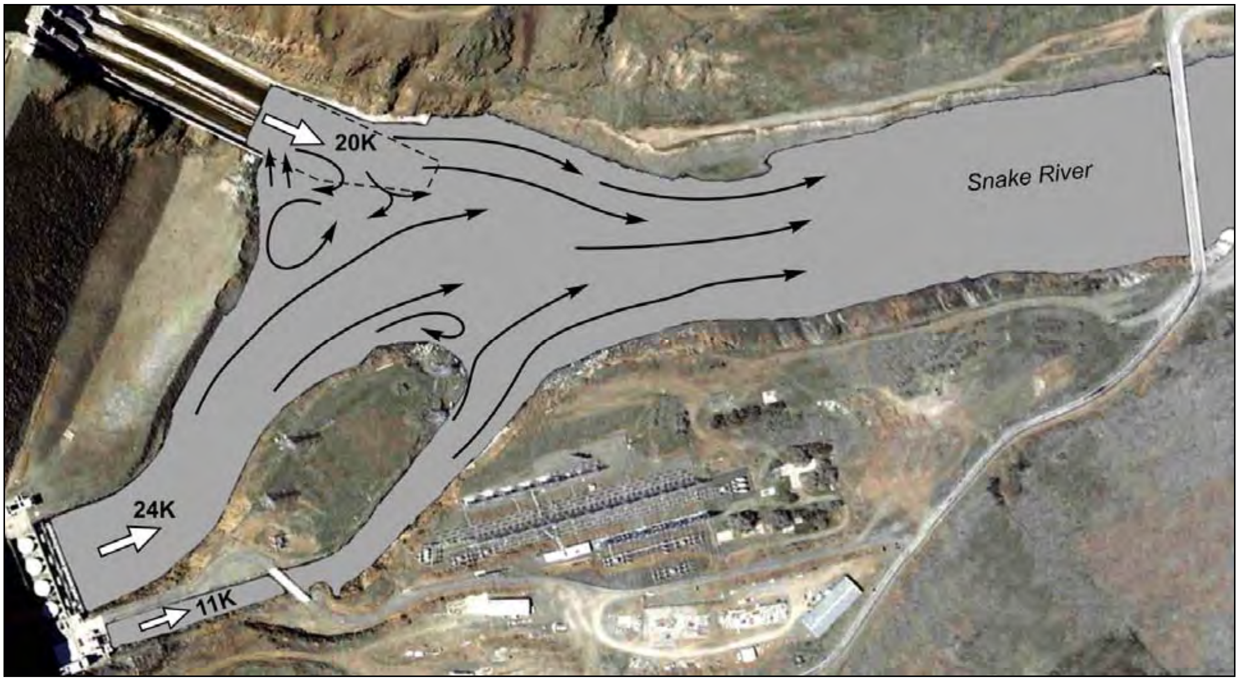


Figure 5-2. Test TE2: Spillway = 20,000 cfs, Powerhouse = 35,000 cfs, no deflector, no sidewall

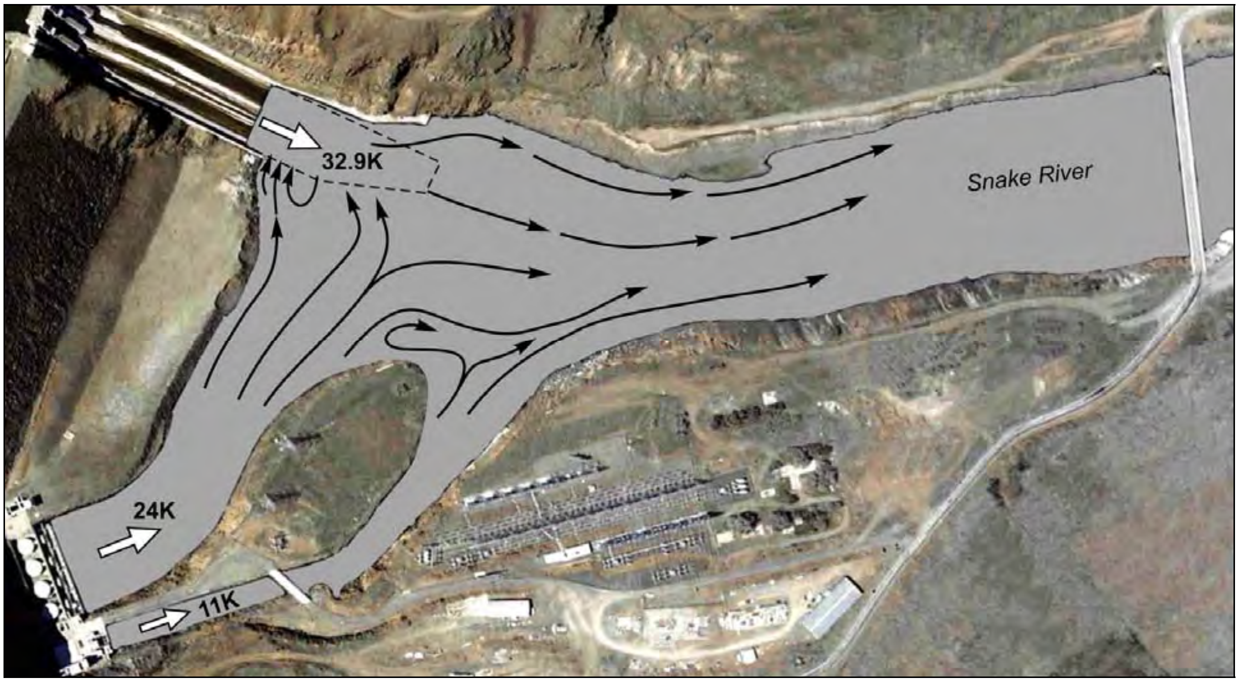


Figure 5-3. Test TE3: Spillway = 32,900 cfs, Powerhouse = 35,000 cfs, no deflector, no sidewall

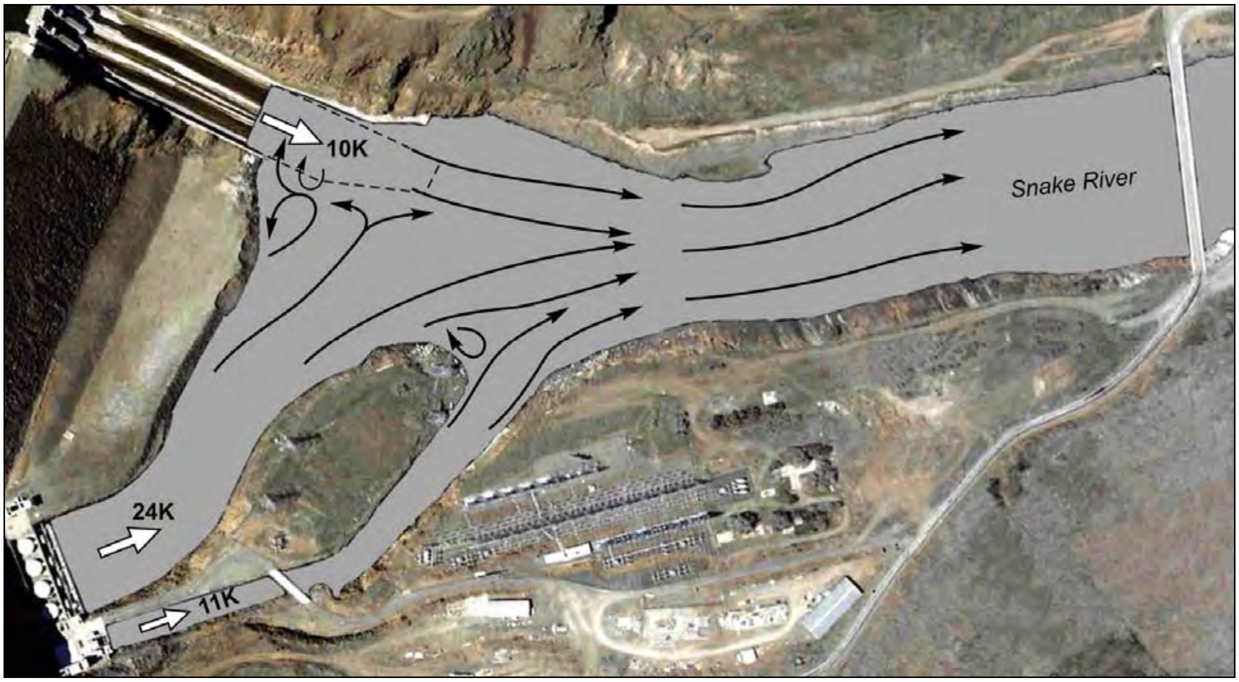


Figure 5-4. Test TE4: Spillway = 10,000 cfs, Powerhouse = 35,000 cfs, deflector, no sidewall

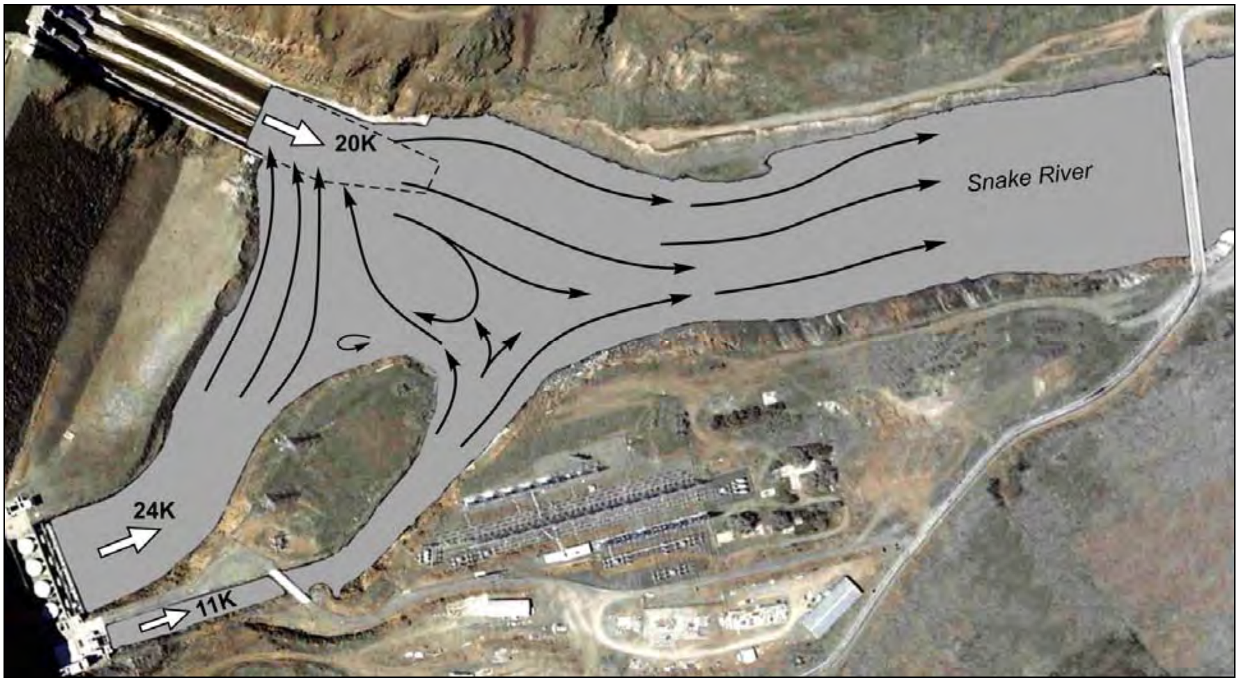


Figure 5-5. Test TE5: Spillway = 20,000 cfs, Powerhouse = 35,000 cfs, deflector, no sidewall

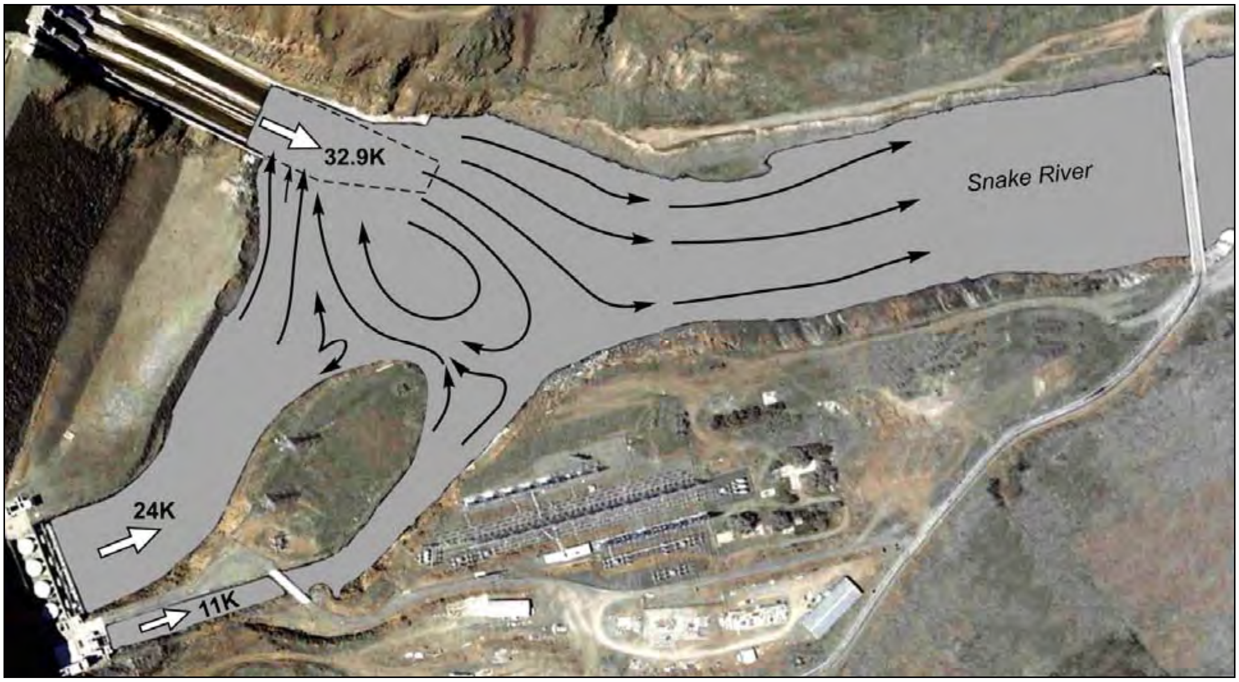


Figure 5-6. Test TE6: Spillway = 32,900 cfs, Powerhouse = 35,000 cfs, deflector, no sidewall

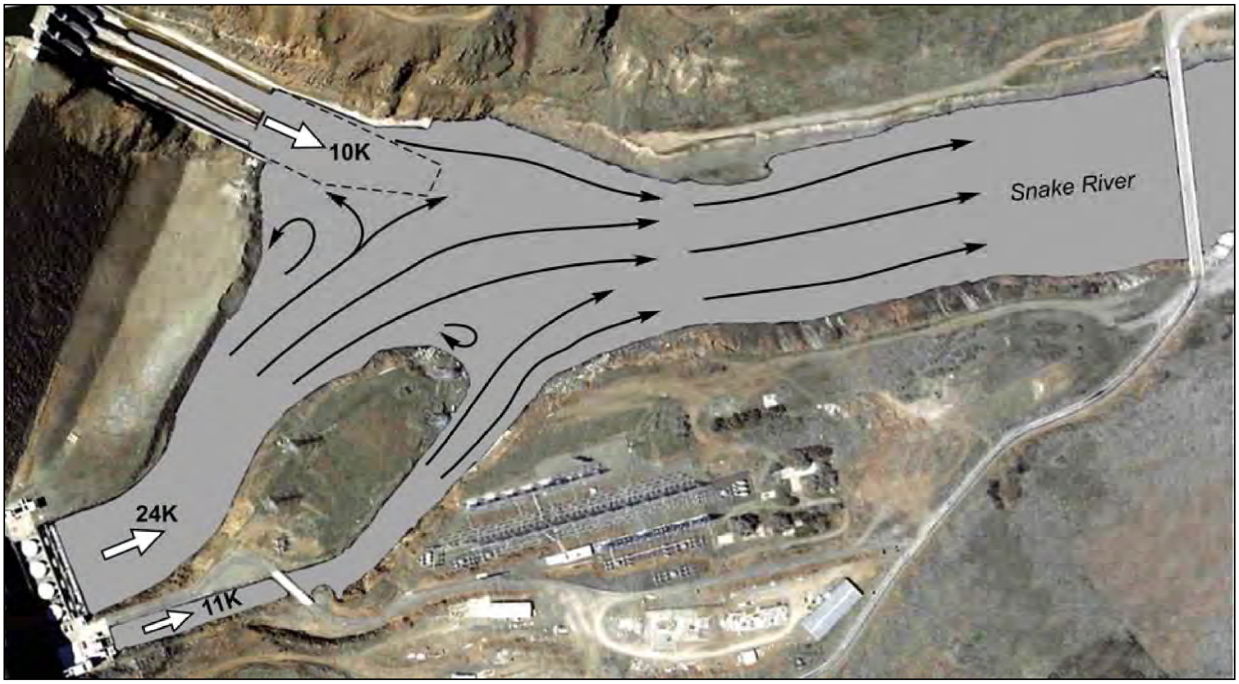


Figure 5-7. Test TE7: Spillway = 10,000 cfs, Powerhouse = 35,000 cfs, deflector, sidewall

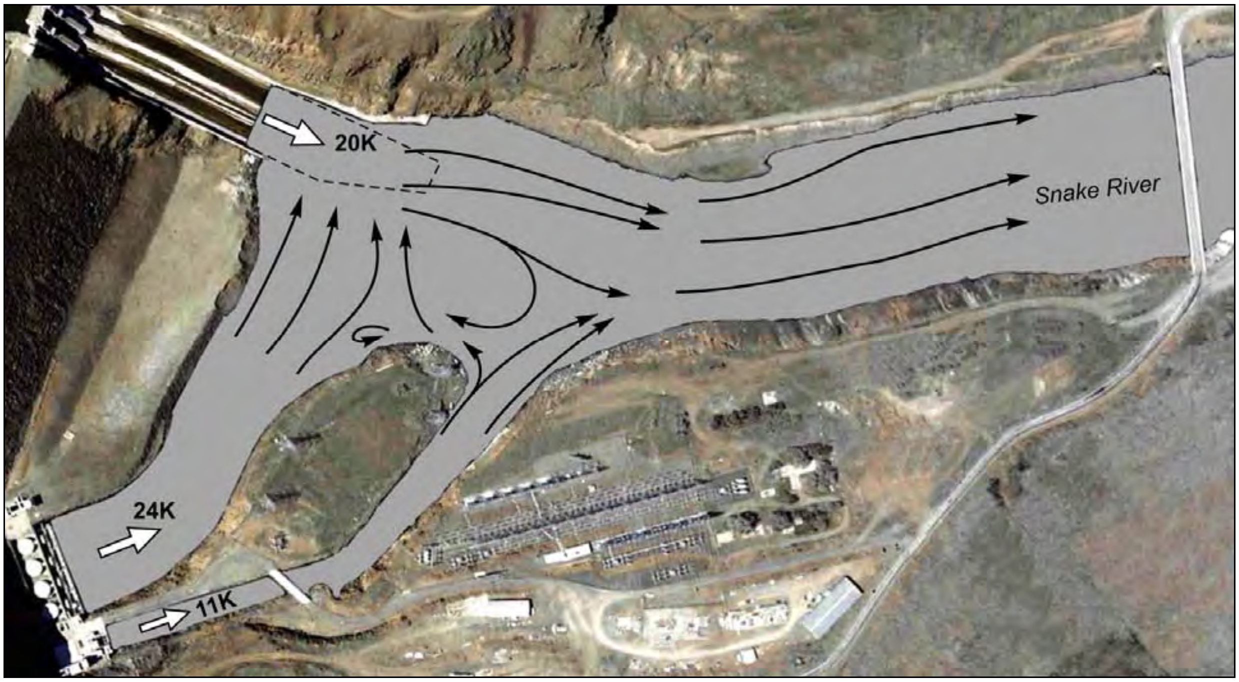


Figure 5-8. Test TE8: Spillway = 20,000 cfs, Powerhouse = 35,000 cfs, deflector, sidewall

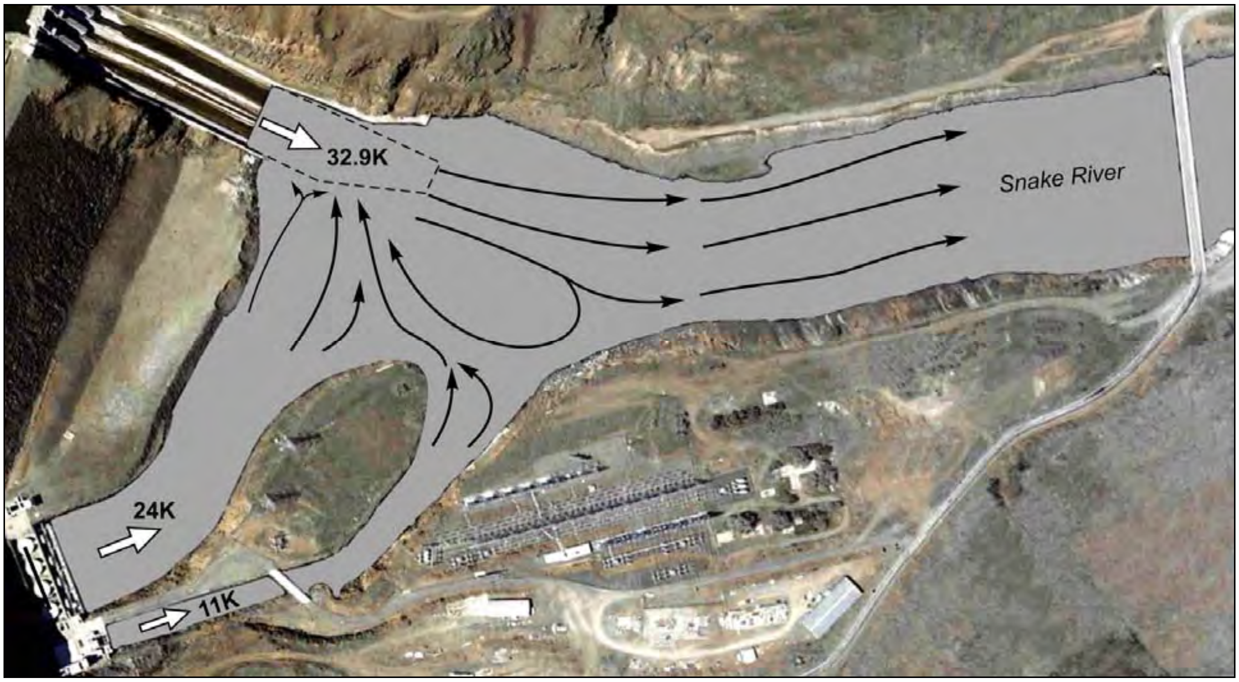


Figure 5-9. Test TE9: Spillway = 32,900 cfs, Powerhouse = 35,000 cfs, deflector, sidewall

Flow pattern analysis reveals that adding the deflector increases the spillway jet entrainment flow and expands the recirculation area at the spillway channel and the powerhouse discharge channels confluence. This increase is the greatest at the highest spillway flows, 20 and 32.9 kcfs.

For baseline conditions, tests TE1 and TE2, powerhouse unit 5 discharge flowed immediately downstream after exiting the bypass channel. For the 7Q10 flow, test TE3, a small flow amount was drawn into the eddy adjacent to the peninsula between powerhouse discharge channels before traveling downstream. At 20 kcfs, test TE5, adding the spillway deflector split unit 5 discharge, with approximately half going downstream and half entering the large recirculation zone and moving toward the spillway. Adding the deflector at the 7Q10 flow, test TE6, caused the entire unit 5 discharge plume to enter the recirculation zone and move toward the spillway before traveling downstream. Adding the vertical training wall extension slightly lessened the recirculation. It did not affect the unit 5 discharge plume for any flows tested.

Most of the discharge plume from powerhouse units 1-4 for baseline conditions at low flows moved directly downstream, tests TE1 and TE2. At the baseline condition 7Q10 most flow from units 1-4 was entrained into the spillway flow, while a small flow amount moved directly downstream, test TE3. The deflector increased flow entrainment at the low flow condition, test TE4, and entrained flow from units 1-4 in the spillway jet at higher flows, tests TE5 and TE6, Figures 5-5 and 5-6. The vertical training wall extension decreased the entrained flow at the spillway, most significantly for the 7Q10 design flow, test TE9.

5.2. Entrainment Flow

The existing training wall rises to an elevation of 1800 feet at the base of the spillway. In phase one, a vertical training wall extension rising to 1830 feet was added, tested, and observed to stabilize the spillway jet, especially for unusually high tailwaters. The training wall extension tested in the phase two model is shown in Figure 5-10.

Figure 5-10. Photograph of the training wall extension as tested in phase two

A large head differential exists across the wall at high tailwater elevations. As a result, flows entrain at the spillway jet surface. Under certain conditions, this causes ramped or skimming jets to partially submerge. In phase two tests for the 7Q10 design flow, entrainment flow over the training wall did not adversely affect the spillway jet. It was not clearly demonstrated that the sidewall extension significantly improved conditions for flowrates up to the design flow. The training wall did decrease entrained flow at the spillway, but entrainment without the extension was not considered a problem. The training wall extension was not tested for flows greater than the design flow. It may or may not improve hydraulic conditions for these flows. Tailrace flow pattern changes for design flow with sidewall are observed by comparing Figures 5-6 and 5-9 (Tests TE6 and TE9) in Section 5.1. Further testing at higher flows would be required to determine efficacy and the appropriate wall extension height for flows above 7Q10.

5.3. Velocity Measurements

Velocity measurements were collected at river transects for 67.9 (7Q10) and 120 kcfs river flows with and without the deflector. An attempt to measure velocity at the PMF condition was thwarted by highly aerated and turbulent flows. Table 5-2 displays the velocity measurement test matrix. Tables 5-3 and 5-4 summarize velocity data for the 7Q10 and 120 kcfs flowrates. Figure 5-11 shows the velocity data monitoring locations. Figures 5-12 through 5-15 are vector plots showing flow direction and magnitude at 4/10, 6/10, and 8/10 depths (fractions of the total water depth at a point, measured from the water surface).

IIHR Test Number	*Deflector*	*Spillway Flowrate*	*Powerhouse Flowrate*	*River Flowrate*
V1-7Q10	18-ft @ elev. 1800	32,898	35,000	67,898
V2-7Q10	none	32,898	35,000	67,898
V3-120K	18-ft @ elev. 1800	85,000	35,000	120,000
V4-120K	none	85,000	35,000	120,000

Table 5-2. Velocity measurement test matrix

--- = data not available

			Total River Flowrate = 67,898 cfs, TW Elevation = 1811.9 feet							
			without deflector				with deflector			
Beam	Northing (feet)	Easting (feet)	Flow Direction	Velocity (ft/sec)			Flow Direction	Velocity (ft/sec)		
				4/10	6/10	8/10		4/10	6/10	8/10
T0	1365577.75	1277325.92	NW	---	2.70	2.38	NW	---	---	2.01
T0	1365657.30	1277228.57	NW	---	3.25	2.73	NW	---	---	0.33
T1	1366288.33	1277297.72	NE	5.95	5.63	5.06	NE	---	3.32	3.22
T1	1366215.45	1277360.21	NE	5.01	4.58	4.05	NE	2.79	2.52	2.40
T1	1366142.57	1277422.69	NE	4.24	4.08	3.73	NE	8.98	8.40	7.91
T1	1366069.69	1277485.18	NE	2.21	2.19	2.32	NE	10.19	8.50	8.54
T1	1365996.82	1277547.67	NE	1.37	1.34	1.23	SW	3.63	3.84	5.19
T1	1365960.38	1277578.92	NE	1.02	1.24	1.05	SW	7.35	7.87	8.28
T1	1365923.94	1277610.16	NE	0.45	0.40	0.35	SW	1.77	5.76	6.21
T1	1365887.50	1277641.41	NE	0.46	0.25	0.07	NE	---	1.66	1.28
T2	1366597.26	1277605.34	NE	---	---	8.03	NE	---	---	0.09
T2	1366574.39	1277647.54	NE	---	9.99	8.87	NE	---	6.16	5.77
T2	1366551.52	1277689.75	NE	8.98	8.62	7.67	NE	---	5.87	5.51
T2	1366528.66	1277731.95	NE	8.64	8.19	7.78	NE	6.76	6.52	6.03
T2	1366505.79	1277774.15	NE	8.03	7.80	7.28	NE	9.10	8.93	7.21
T2	1366482.92	1277816.36	NE	7.19	7.03	6.75	NE	11.21	11.17	9.73
T2	1366460.05	1277858.56	NE	7.12	7.07	6.82	NE	10.88	11.16	9.28
T2	1366437.19	1277900.76	NE	---	7.31	6.33	NE	---	7.91	7.28
L1	1365663.61	1277150.39	NW	---	---	0.14	NW	---	---	0.01
L1	1365726.59	1277222.83	SW	2.94	2.74	2.55	NW	2.09	2.35	1.35
L1	1365789.58	1277295.28	SW	1.97	2.31	2.32	W	3.97	3.65	3.57
L1	1365852.57	1277367.73	NW	1.23	1.22	1.18	SW	4.44	4.48	3.92
L1	1365915.55	1277440.18	NW	1.13	1.09	0.77	SW	5.55	5.82	6.71
L1	1365947.04	1277476.40	NE	1.58	1.45	1.07	SW	6.43	5.68	6.62
L1	1366041.52	1277585.08	NE	2.85	3.12	3.06	SW	2.56	2.18	2.14
L1	1366104.51	1277657.52	NE	3.55	3.61	3.35	NW	3.27	1.77	2.41
L1	1366167.50	1277729.97	NE	3.77	3.85	3.58	NE	6.35	5.69	3.11
L1	1366230.48	1277802.42	NE	7.28	7.33	6.79	NE	6.39	5.14	3.16
L1	1366261.98	1277838.64	NE	---	8.27	7.53	NE	4.90	3.11	1.99
L1	1366293.47	1277874.87	SE	---	---	0.21	NE	---	2.30	1.93

Table 5-3. Velocity data summary table for 67,898 cfs (7Q10)

--- = data not available

			Total River Flowrate = 120,000 cfs, TW Elevation = 1815.0 feet							
			without deflector				with deflector			
Beam	Northing (feet)	Easting (feet)	Flow Direction	Velocity (ft/sec)			Flow Direction	Velocity (ft/sec)		
				4/10	6/10	8/10		4/10	6/10	8/10
T0	1365577.75	1277325.92	NW	---	1.39	0.89	NW	---	0.60	0.56
T0	1365657.30	1277228.57	NW	---	2.47	2.26	NW	---	3.17	2.64
T1	1366288.33	1277297.72	NE	16.17	15.44	13.11	NE	14.14	12.82	12.44
T1	1366215.45	1277360.21	NE		18.69	16.77	NE	---	15.31	14.36
T1	1366142.57	1277422.69	NE	12.01	11.63	10.58	NE	11.85	9.63	9.30
T1	1366069.69	1277485.18	SE	4.89	6.43	6.58	NE	3.09	3.39	2.67
T1	1365996.82	1277547.67	SW	10.36	12.45	13.20	SW	9.50	11.01	12.19
T1	1365960.38	1277578.92	SW	15.41	16.49	17.61	SW	13.08	13.34	13.65
T1	1365923.94	1277610.16	SW	14.69	15.66	13.40	SW	11.38	11.04	10.33
T1	1365887.50	1277641.41	NE	---	2.15	1.60	NE	1.74	2.25	2.18
T2	1366597.26	1277605.34	SW	---	---	1.91	SE	---	---	1.90
T2	1366574.39	1277647.54	SE	---	2.15	2.01	NE	---	---	12.74
T2	1366551.52	1277689.75	NE	---	20.07	16.69	NE	15.14	20.04	16.57
T2	1366528.66	1277731.95	NE	18.53	17.00	13.60	NE	18.05	15.10	11.97
T2	1366505.79	1277774.15	NE	16.52	14.22	12.91	NE	18.06	14.52	12.00
T2	1366482.92	1277816.36	NE	16.18	13.71	11.29	NE	16.00	13.42	10.26
T2	1366460.05	1277858.56	NE	12.39	10.61	7.05	NE	12.48	9.89	6.75
T2	1366437.19	1277900.76	NE	7.44	4.22	3.65	NE	8.13	5.23	3.68
L1	1365663.61	1277150.39	SW	---	---	0.41	NE	---	---	0.70
L1	1365726.59	1277222.83	SW	2.95	2.91	2.92	NW	1.62	1.32	0.87
L1	1365789.58	1277295.28	NW	4.83	3.52	3.81	NW	4.04	3.11	3.72
L1	1365852.57	1277367.73	SW	11.03	11.02	8.62	SW	8.59	7.96	7.68
L1	1365915.55	1277440.18	SW	15.19	15.79	15.62	SW	16.49	16.29	16.37
L1	1365947.04	1277476.40	SW	14.29	15.64	16.44	SW	16.47	15.57	16.86
L1	1366041.52	1277585.08	SW	6.92	8.67	9.17	SW	7.20	9.02	11.13
L1	1366104.51	1277657.52	SW	2.32	3.13	5.00	SW	1.24	2.18	5.43
L1	1366167.50	1277729.97	SW	1.67	1.04	2.37	NE	4.25	2.23	1.41
L1	1366230.48	1277802.42	SE	5.69	6.39	7.59	SE	6.31	5.16	6.49
L1	1366261.98	1277838.64	SE	8.12	7.93	10.12	SE	6.66	6.11	8.79
L1	1366293.47	1277874.87	SE	7.68	9.53	9.70	SE	6.98	8.08	8.99

Table 5-4. Velocity data summary table for 120,000 cfs

Figure 5-11. Velocity data monitoring points

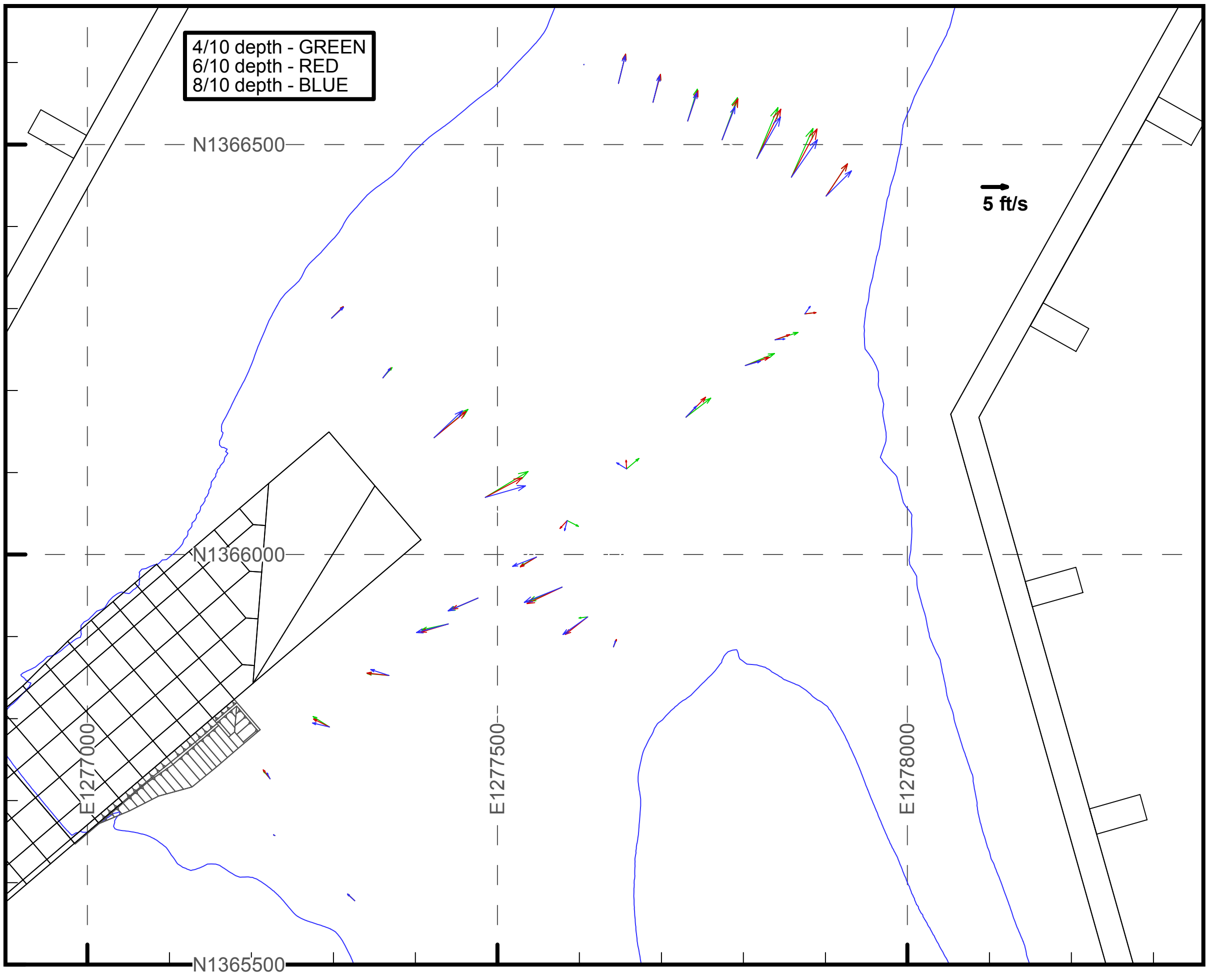


Figure 5-12. Velocity measurements with deflector at 7Q10 (test V1-7Q10)

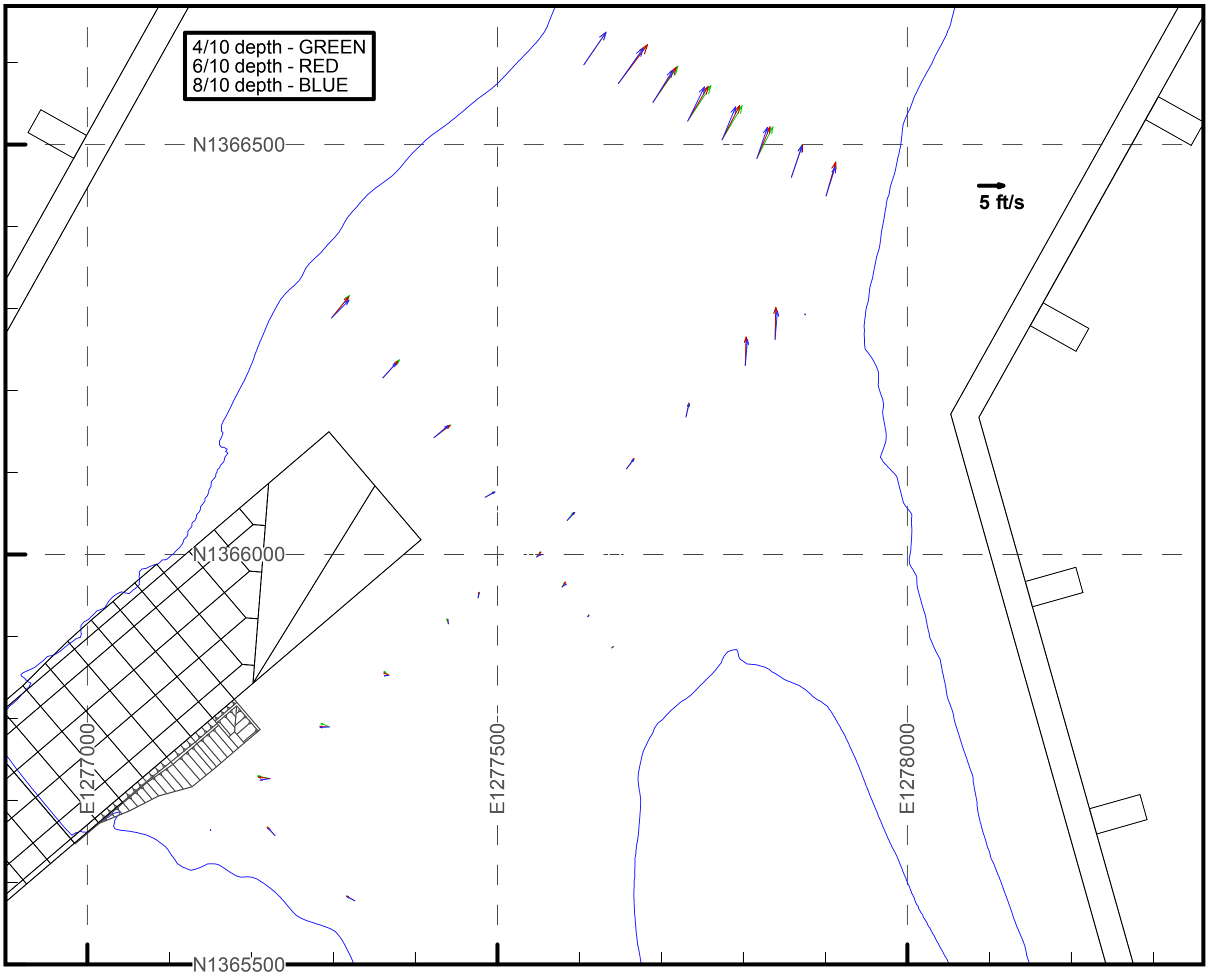


Figure 5-13. Velocity measurements without deflector at 7Q10 (test V2-7Q10)

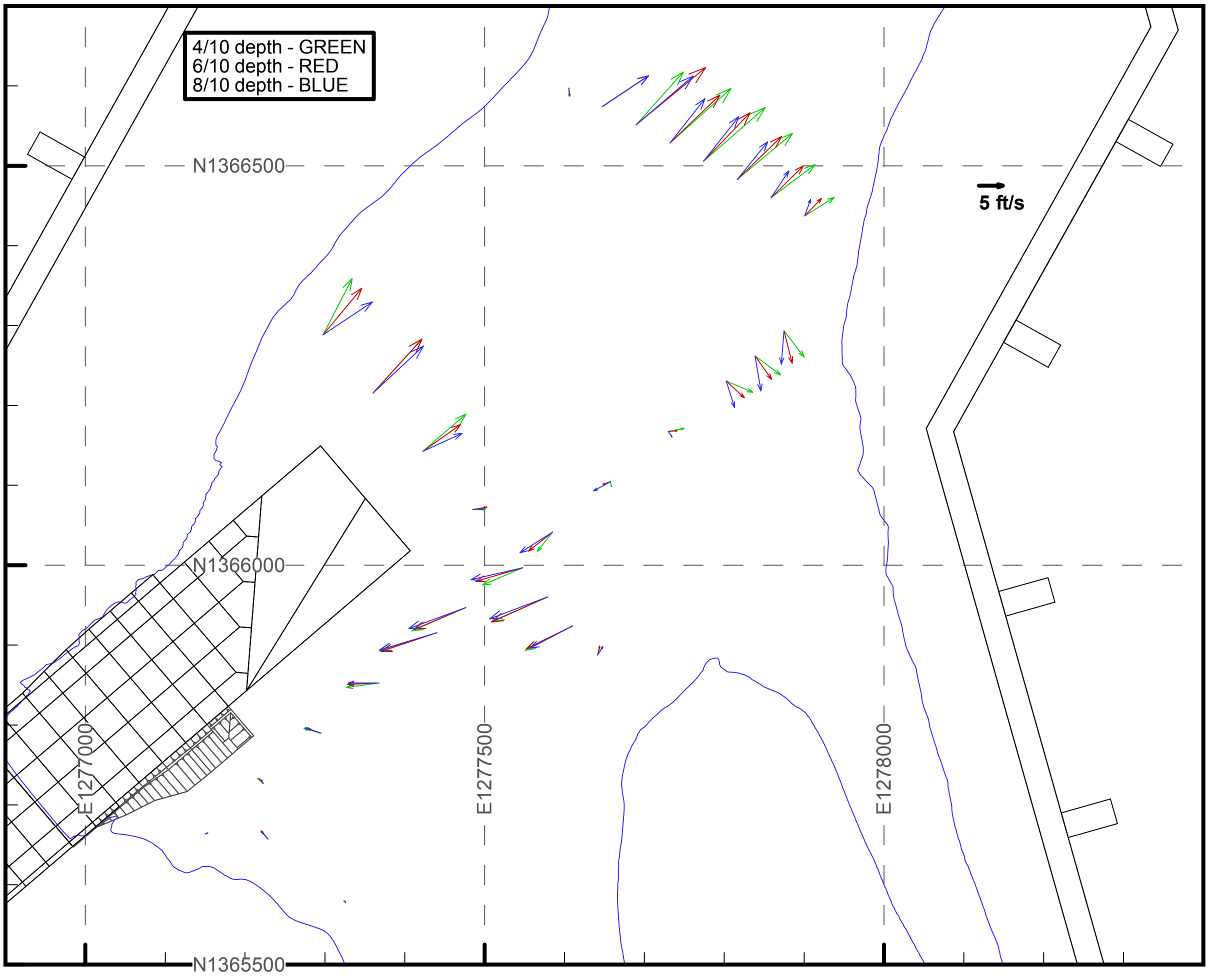


Figure 5-14. Velocity measurements with deflector at 120 kcfs (test V3-120K)

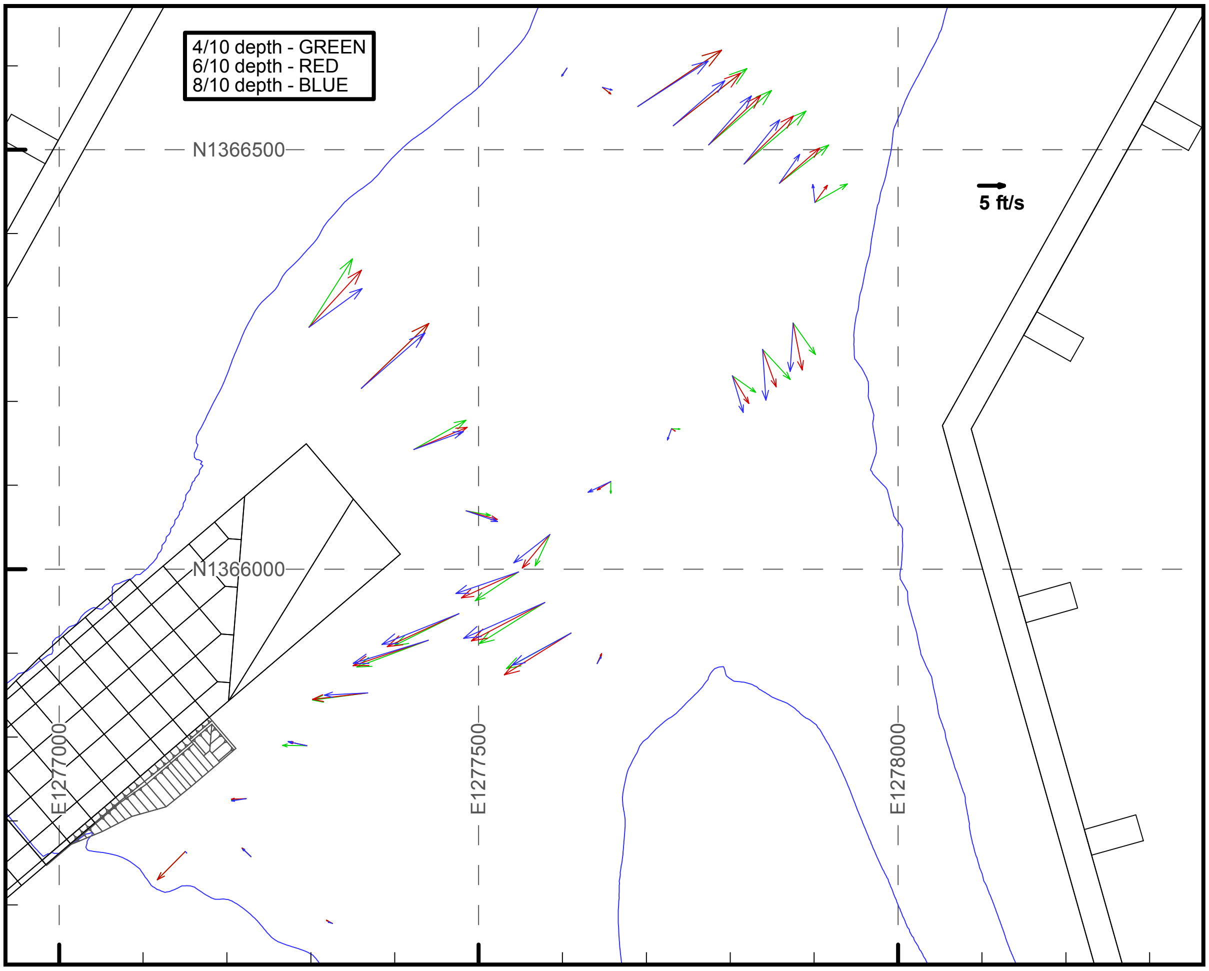


Figure 5-15. Velocity measurements without deflector at 120 kcfs (test V4-120K)

At the 7Q10 design flow, velocity increased, most significantly just downstream and to the right of the spillway. Velocity vectors confirmed egress patterns documented in Section 5.1 (Figures 5-3 and 5-6) showing a large clockwise circulation downstream of the spillway and entrainment of unit 5 flow with the deflector. Without the deflector, flows moved downstream uniformly with low velocities in the confluence area. Left bank velocity decreased slightly with the deflector, showing a less uniform flow distribution, with higher velocities near the channel centerline.

At a 120 kcfs flowrate, velocity vectors and recirculation patterns were nearly identical. Recirculation was slightly more dominant and persistent upstream without the deflector. Measured velocities were equal to or slightly higher without the deflector. The similarities indicate the deflector was essentially "over-ridden," with the jet entering deep into the pool both with and without the deflector.

5.4. Wave Height Measurements

Wave heights and periods were measured comparing conditions with and without the deflector. Using calibrated Teflon capacitance probes, a wave position time series was obtained. Initial tests determined the minimum expected wave frequency to be about 10 hertz (model). Position data was collected at twice this frequency. Position was recorded twenty times per second over seven minutes (model time). Froude similitude criteria were used to convert model to prototype time scales. The model data corresponded to about 3 Hz for 48 prototype minutes. Figure 5-16 shows the wave height probe during a typical model test. Figure 5-17 documents the wave height measurement locations.

Figure 5-16. Photograph of wave height instrumentation during model test

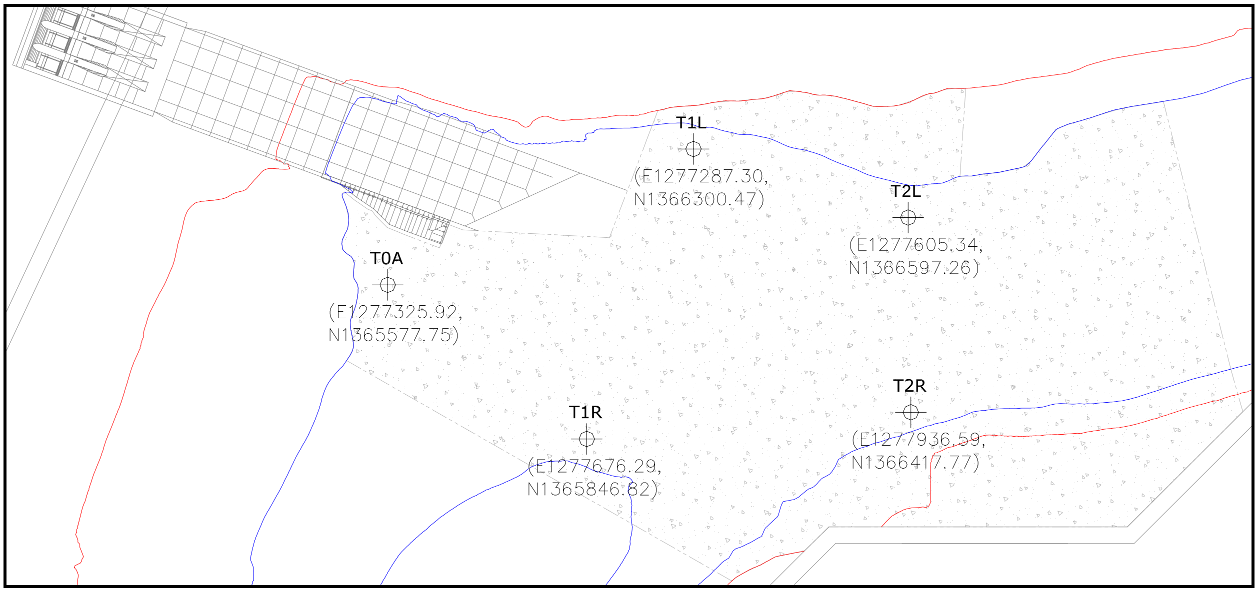


Figure 5-17. Locations of wave height measurements

As described in Section 2.2, wave position data was analyzed by a downward zero-crossing method. Wave height statistics presented here do not include effects generated by wind. Table 5-5 summarizes the wave height data.

--- = Data Not Available

		Total River Flowrate = 67,898 cfs, TW = 1811.9 ft		Total River Flowrate = 120,000 cfs, TW = 1815.0 ft		Total River Flowrate = 300,000 cfs, TW = 1825.5 ft	
		Without Deflector	With Deflector	Without Deflector	With Deflector	Without Deflector	With Deflector
At left bank gage T1L:							
Significant Wave Period, Ts	Seconds	4.49	3.13	3.13	3.13	3.56	---
Maximum Wave Height, Hm	Feet	4.09	6.11	12.91	9.03	6.54	---
Significant Wave Height, Hs	Feet	2.21	3.29	6.96	4.87	3.65	---
Root Mean Square Height, Hrms	Feet	1.57	2.37	5.01	3.51	2.67	---
At left bank gage T2L:							
Significant Wave Period, Ts	Seconds	4.32	3.13	3.56	3.13	3.13	3.13
Maximum Wave Height, Hm	Feet	2.15	6.11	9.36	8.24	9.03	7.71
Significant Wave Height, Hs	Feet	1.24	3.29	5.22	4.44	4.87	4.15
Root Mean Square Height, Hrms	Feet	0.86	2.37	3.81	3.20	3.51	2.99
At gage T0A:							
Significant Wave Period, Ts	Seconds	3.79	3.13	4.15	3.13	3.13	---
Maximum Wave Height, Hm	Feet	2.71	6.11	6.20	8.24	12.91	---
Significant Wave Height, Hs	Feet	1.70	3.29	3.76	4.44	6.96	---
Root Mean Square Height, Hrms	Feet	1.22	2.37	2.71	3.20	5.01	---
At right bank gage T1R:							
Significant Wave Period, Ts	Seconds	3.60	3.56	5.07	3.56	3.56	3.56
Maximum Wave Height, Hm	Feet	3.03	4.43	7.55	6.54	9.36	5.58
Significant Wave Height, Hs	Feet	1.89	2.47	4.34	3.65	5.22	3.12
Root Mean Square Height, Hrms	Feet	1.35	1.80	3.05	2.67	3.81	2.27
At right bank gage T2R:							
Significant Wave Period, Ts	Seconds	3.20	3.56	4.05	3.56	3.93	---
Maximum Wave Height, Hm	Feet	2.86	4.43	7.41	5.97	0.75	---
Significant Wave Height, Hs	Feet	1.43	2.47	4.13	3.33	0.32	---
Root Mean Square Height, Hrms	Feet	0.99	1.80	2.94	2.43	0.22	---

Table 5-5. Wave height data summary table (prototype values)

For the 7Q10 design flow, wave heights near the banks increased with the spillway deflector. The highest increase was measured at gage T2L, about 2 feet. At higher flows the wave heights decreased with the deflector. For a 120 kcfs total river flowrate, the deflector decreased significant wave height from about 6.96 feet to about 4.87 feet at gage T1L. Maximum wave height also decreased from 12.91 feet to 9.03 feet. The maximum measured wave height was 12.91 feet at gage T1L without the deflector for 120 kcfs river flow, and the same at gage T0A without the deflector for 300 kcfs river flow.

6. SUMMARY AND CONCLUSIONS

The 2D phase one model has been expanded to include the powerhouse and tailrace bathymetry, replicating 3D flow patterns downstream of the dam. Hydraulic performance of the 18-foot spillway deflector with a lip at an elevation of 1800 feet above m.s.l. was successfully validated exhibiting flow characteristics predicted to reduce TDG. Model flow patterns, wave heights, and velocities have been documented.

An examination of downstream flow conditions suggests that the vertical training wall extension proposed in phase one, would have limited usefulness up to the 7Q10 design flow. Further tests are required to demonstrate efficacy and specify wall extension height for flows greater than 7Q10.

At the 7Q10 design flow, the deflector increased tailrace velocities and wave heights. At higher flows, velocities continued to increase while wave heights subsided.

Model tests found that for flowrates up to 7Q10, tailrace erosion would not occur with or without the deflector. PMF erosion tests revealed that significant erosion occurs with or without the deflector. The deflector did not significantly increase erosion near the spillway or downstream along the right bank at PMF.

Deflector laboratory modeling cannot quantifiably predict or guarantee TDG reduction. It is reasonable to assume, however, based on observations, experience, and deflector hydraulic performance documented here, that installation of a spillway deflector will decrease TDG below Brownlee Dam.

Exhibit 7.3-6

Oxbow Spillway total dissolved gas reduction structure (TRS) hydraulic model study final report

OXBOW SPILLWAY TRS HYDRAULIC MODEL STUDY FINAL REPORT

Prepared for:

November 2007

Prepared by: Northwest Hydraulic Consultants

OXBOW DAM
TOTAL DISSOLVED GAS REDUCTION STRUCTURE
HYDRAULIC MODEL STUDY
FINAL REPORT

Prepared for:

IDAHO POWER CORPORATION
Boise, Idaho

Prepared by:

northwest hydraulic consultants
16300 Christensen Rd, Suite 350
Seattle, WA 98188-3422

November 21, 2007

EXECUTIVE SUMMARY

northwest hydraulic consultants (**nhc**) was retained by Idaho Power Corporation (IPC) to conduct conceptual design and physical model studies of total dissolved gas reduction structure (TRS) alternatives at the Oxbow Dam spillway. Oxbow Dam is part of Idaho Power's Hells Canyon Complex on the Snake River on the Idaho/Oregon state boundary. Field monitoring downstream from Oxbow Dam has shown there is a potential for elevated total dissolved gas (TDG) concentrations, which have been recorded as high as 127%, during periods of Oxbow Dam spillway operation. State standards mandate that the TDG downstream of projects must not exceed state standards of 110% when the flow rate is less than the 7Q10 flow for the project (where "7Q10" is the highest average seven consecutive day flow with an average recurrence frequency of once in ten years determined hydrologically). For the Oxbow project, the 7Q10 spillway discharge is 41,060 cfs. This corresponds to a total river discharge downstream of the Oxbow powerhouse of about 69,000 cfs with the maximum powerhouse capacity of 28,000 cfs.

The objectives of the present study were to develop hydraulic designs for up to three TRS alternatives that would reduce the plunge depth to which air is taken. Prototype work at other projects has shown that if plunging characteristics are reduced, then TDG levels downstream of the spillway will be reduced. The elements of the study included development of a numerical model to determine hydraulic characteristics (i.e., water surface elevation and velocity) downstream from the spillway for various discharges; develop conceptual designs for potential TRS alternatives; and evaluate up to three of the most promising alternatives in a physical model.

The eight TRS alternatives developed included a wide range of alternatives. Some of the alternatives included the addition of a stilling basin downstream of the existing high velocity chute and adding a flow deflector. Other alternatives included the addition of flip buckets at the downstream end of the chute to spread the flow. In addition to modifications at the chute, other alternatives included filling in the plunge pool and the addition of a downstream rock and weir channel.

Initial studies in the physical model indicated that a relatively simple and economical flow deflector installed on the sloping face at the downstream end of the existing spillway chute had sufficient potential to provide a flow regime that would reduce TDG levels in the downstream channel with significantly less disruption of the existing structure than any of the other conceptual alternatives identified. Therefore, the physical modeling component of the study was revised to more fully develop the flow deflector design in lieu of more limited testing of three alternatives originally selected for testing.

Approximately twenty-four different geometric refinements were evaluated in the model to develop an economical deflector design that maximizes the potential of reducing TDG downstream of the spillway. The flow regimes used to evaluate the alternatives have been shown to reduce TDG levels at other project sites; however, it is not possible to accurately predict the magnitude of the TDG reduction that can be expected for the Oxbow project from the physical model results.

The proposed final hydraulic TRS design is a flow deflector located along the entire side and end sloping faces at the downstream end of the existing spillway chute as shown in Figures 6.3.1 through 6.3.3. The deflector along the east side of the spillway chute has a length of about 250 ft, a width (in the direction of flow) of 16 ft, and a top surface elevation at El. 1691.5 ft. The end deflector has a length in the direction of flow of 40 ft, a width of 49 ft and a top surface elevation at El. 1689.5 ft. The hydraulic regime resulting with this design provides a good “skimming surface jet” off the side deflector and a strong “undulating surface jet” off the end deflector. These types of flow regimes have previously been shown at projects on the Columbia and Snake Rivers to provide the hydraulic characteristics that minimize TDG levels downstream of spillway releases.

The proposed final design also incorporates a 50-ft long training wall on the west side and extending downstream from the end of the spillway chute, removal of an existing concrete fillet on the west side of the existing bench at the downstream end of the spillway chute, and placement of an approximately 10-ft blanket thickness by a 40 to 50 ft width of riprap along the upstream 250 ft length of the east side of the spillway chute.

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1 INTRODUCTION

northwest hydraulic consultants (**nhc**) was contracted by Idaho Power Corporation (IPC) in February 2007 to develop a total dissolved gas reduction structure (TRS) alternative for the Oxbow Dam spillway. A physical model was constructed and tested to assist with the evaluation and development of the TRS alternatives. This work was conducted under Master Service Agreement No. 2053 dated February 2, 2007.

1.1 SYSTEM DESCRIPTION

1.1.1 HELLS CANYON COMPLEX

Idaho Power's Hells Canyon Complex consists of the Brownlee, Oxbow, and Hells Canyon hydroelectric projects on the segment of the Snake River forming the border between Idaho and Oregon. The complex is located approximately 20 miles northwest of Cambridge, Idaho; 90 miles northwest of Boise, Idaho; and 45 miles east of Baker City, Oregon. Flow past Brownlee Dam discharges into Oxbow Reservoir, with the Oxbow Dam located about 12 miles downstream from Brownlee Dam, and flow past Oxbow Dam discharges into the Hells Canyon Reservoir, with the Hells Canyon Dam located about 25 miles downstream of Oxbow Dam. The river below Hells Canyon Dam is unobstructed by artificial structures until it reaches the headwaters of Lower Granite Reservoir approximately 100 miles downstream of Hells Canyon Dam.

1.1.2 OXBOW PROJECT

The Oxbow Project consists of an earth and rockfill dam located at river mile 272.5 on the Snake River. The dam and intake structures are separated from the powerhouse by a natural rock ridge in a bend of the Snake River, as shown in Photo 1.1. The powerhouse inflow from the Oxbow Reservoir is carried through the rock ridge to the powerhouse via two 36 ft diameter, concrete-lined power tunnels. The intake to these tunnels is located approximately 2,400 ft upstream of the Oxbow Dam, while the powerhouse itself is located approximately 2 miles downstream of the dam. The powerhouse contains four 47.5 MW units with a combined discharge capacity of approximately 28,000 cfs.

The long, narrow hairpin bend of the river channel downstream of the dam and around the rock ridge to the powerhouse location is referred to as the "Oxbow Bypass". The bypass reach is normally submerged by the Hells Canyon Reservoir except during low-flow periods when the Hells Canyon Reservoir is drafted. In accordance with the current license and as proposed by IPC for future operations, a minimum flow of 100 cfs is released past Oxbow Dam at all times to maintain flows through the bypass reach.

The Oxbow Dam is a clay-core, earth and rockfill structure measuring 960 feet long. The maximum reservoir depth, from the deepest point in the reservoir in front of the dam to the normal maximum reservoir elevation (El. 1805 ft), is approximately 130 feet. All elevations in this report are provided in NGVD29 unless noted otherwise. Some of the information obtained during the course of this project was provided in NAVD88. NAVD88 information was converted to NGVD29 by subtracting the datum difference of 3.45 ft. The crest of the dam is cambered from El. 1820 ft at the abutments to approximately El. 1,825 ft at the original center of the river channel.

There are two spillway structures at Oxbow Dam – the Oregon Spillway and the Idaho Spillway, having a combined capacity of 300,000 cfs when the reservoir is surcharged to El. 1810 ft. The Oregon Spillway is the principal spillway with a capacity of 150,000 cfs at a reservoir elevation of El. 1810 ft. This spillway is excavated into the left (west) rock abutment, along the Oregon side of the Snake River, and is a 3-bay ogee-shaped reinforced concrete structure surmounted by three side-by-side 32-foot wide by 50-foot high radial gates. The spillway bays are separated by 8-foot wide concrete piers leading to a 112-foot wide concrete-lined chute that carries spill to the river channel below the dam. The spillway crest is at El. 1755 ft and the top bridge deck is at El. 1820 ft.

Photo 1.2 illustrates the Oregon Spillway operating at its minimum discharge of approximately 100 cfs, and Figure 1.1 shows a plan and elevation of the spillway chute. The spillway chute is set at a slope of 0.010 ft/ft, from El. 1725.37 at its upstream end to El. 1719.58 at its downstream end over a distance of approximately 580 ft. Flow down the chute is contained by high training walls for a distance of about 374 ft downstream from the spillway ogee. At that location, the right side training wall terminates allowing water to spill off the right (east) side of the chute down a steeply sloping concrete face onto a concrete bench at an average elevation of about 1665 ft, about 25 ft below typical tailwater elevation. The downstream end of the chute is asymmetrical (about 40 ft in width) and terminates about 30 ft above an approximately 80-ft long horizontal apron set at El. 1687.5 ft that is typically submerged by 2-3 ft. Flow discharging from this apron continues down a steeply sloping face to a bench set at El. 1676 ft that is typically submerged by about 15 ft. At the downstream end of the chute, the chute lip and sloping face are perpendicular to the chute centerline and flow is generally directed in the downstream direction. However, along the right side of the chute, the lip and sloping face are aligned at an angle to the chute centerline, such that flow spilling down the right side of the chute lip and sloping face is directed across the river channel toward the opposite bank at an approximate angle of about 15-20 degrees from the main river channel.

The natural channel immediately downstream of the benches, along both the end and side of the spillway chute, has been scoured to approximately El. 1660 ft. The bathymetric survey information (combination of multi-beam and single-beam soundings, supplemented with shoreline surveys) used for this study was provided by IPC and was taken in 2004. The river channel in the Oxbow Bypass is comprised of native sands, gravels, and boulders with bedrock outcroppings along the shorelines; however, the depth of bedrock is unknown at this time. The plunge pool depth near the downstream end of the spillway chute is about 40 ft maximum with spillway discharge on the order of 20,000 cfs and covers approximately one acre. The narrow (10-20 ft wide) concrete benches located along the base of the spillway chute likely provide some protection against erosion along the toe of the sloping faces of the chute. Material scoured from the plunge pool has been deposited in two areas including directly downstream of the spillway chute and in a depositional bar near the right bank of the river (as shown in Photo 1.3).

The steep-faced slope at the downstream end of the spillway chute has been prone to erosive damage since its initial construction in 1962. In 1977, a large portion of the sloping face and apron at the downstream end of the spillway was rebuilt due to severe damage from erosive undermining. The reconstruction included re-filling and re-building a large portion of the sloping face, building the concrete apron and benches along the toe of the sloping faces, and extending the left wall of the chute. While the rehabilitated spillway has incurred less damage than the original, underwater diving surveys in 1997 found that some undermining has occurred downstream of the apron toe (IPC, November 2006).

The Idaho Spillway serves as a secondary (emergency) spillway at the Oxbow Project. This spillway is excavated into the right rock abutment, on the Idaho side of the Snake River, and was constructed to ensure that the probable maximum flood (PMF) of 300,000 cfs could pass the project. The emergency spillway consists of a 450 ft long erodible “fuse plug” embankment and a 75 ft wide concrete-lined chute that discharges to the Snake River downstream. The fuse plug was designed and constructed to wash out if inflows to Oxbow Reservoir exceed the capacity of the powerhouse and the principal spillway. The operation of the Idaho Spillway was not considered in the present study.

1.2 PROJECT BACKGROUND

Field monitoring within the Oxbow Bypass reach has shown that there is a potential for elevated total dissolved gas (TDG) concentrations downstream of the Oregon Spillway. TDG concentrations as high as 127 % have been recorded in this area (IPC, November 2006). State standards mandate that the TDG concentrations in releases from dam impoundments must not exceed 110% when the flow rate is less than the 7Q10 flow for the project (where "7Q10" is the highest average seven consecutive day flow with an average recurrence frequency of once in ten years determined hydrologically). For the Oxbow project, the 7Q10 flow is 41,060 cfs. This corresponds to a total river discharge of about 69,000 cfs with approximately 28,000 cfs diverted to the Oxbow powerhouse.

Based on this, IPC identified a need to develop conceptual design plans for a Total Dissolved Gas Reduction Structure (TRS) for the Oxbow Spillway to reduce the TDG concentrations downstream of the project for spillway flows up to 41,060 cfs. The following design objectives were identified:

- The preferred design should be effective at reducing the downstream TDG levels to below 110% for all spillway flows up to the 7Q10 discharge of 41,060 cfs.
- The preferred design should not result in increased erosion potential downstream of the spillway for all discharges up to the spillway design flow of 150,000 cfs.
- The preferred design should not impact the ability for the spillway to pass the design discharge of 150,000 cfs at a reservoir level of El. 1,810 ft.
- The preferred design should not adversely impact fish habitat in Oxbow Bypass Reach.

1.3 STUDY OBJECTIVES

This present investigation was conducted to develop a proposed design for a TRS for the Oxbow spillway. Specific design objectives included:

- Develop conceptual design alternatives of TRS alternatives.
- Develop an HEC-RAS model of the Oxbow reach to provide tailwater information at the spillway.
- Construct and test a physical model to evaluate up to three TRS alternatives.
- Select and test a preferred alternative.

In the course of the model testing, the objectives were changed to include more detailed testing and refinement of a single concept rather than limited testing of three alternatives. This change was based on the fact that the selected alternative was significantly more cost-effective than the remaining alternatives and initial testing indicated that it provided a high potential to reduce plunging flow off the spillway chute..

1.4 ACKNOWLEDGEMENTS

Several individuals worked with **nhc** on this project and contributed to the development of the study. Scott Zimmerman was the project manager from Idaho Power and was involved in all aspects of the project. Scott Larrondo, Ralph Meyers, and Brian Hoelscher, all from Idaho Power, were also involved in the project and witness tests. Duncan Hay, Oakwood Consulting, provided independent technical review. He played a key role in the development of the recommended TRS solution. Steve Wittmann-Todd, Jacobs Civil Inc., provided constructability input on the conceptual alternatives and the recommended TRS. Steve Wilhelms provided a significant amount of TDG background and research for use on this project as well as contributions to the development of TRS alternatives. **nhc** appreciates the contribution of these individuals.

2 DEVELOPMENT OF HEC-RAS MODEL

Water surface elevation versus discharge data between the Oxbow powerhouse and Oxbow Dam are not available; therefore, a HEC-RAS numerical model was developed to estimate water surface elevations through the Oxbow Bypass reach for use in determining the tailwater elevation curve near the downstream end of the spillway chute for various spillway discharges required for the conceptual design development of TRS alternatives and subsequently for use in the physical model study. A detailed discussion of the HEC-RAS numerical model evaluation is included in Appendix A. The following sections provide a brief summary of the numerical modeling work.

The HEC-RAS model geometry was based on channel transects and bathymetry data developed by IPC. IPC also furnished a total river discharge (Oxbow spillway release plus Oxbow powerhouse release) rating curve at a location just upstream of the Oxbow powerhouse as shown on Figure 2.1. This observed rating curve accounts for the variability in the Hells Canyon pool elevation and was used as a downstream boundary for the numerical model computations to compute water surface elevations at the dam for various spillway discharges. A unique relationship between a given spillway discharge and water surface elevation at the dam does not exist but rather varies with the Hells Canyon pool elevation and the portion of the total river discharge passing through the powerhouse.

As a result of the variability of the Hells Canyon pool elevation, the portion of the total river discharge passing through the Oxbow powerhouse and the uncertainty in the prototype hydraulic roughness coefficient in the river reach between the powerhouse and the dam, the discharge rating curve at Oxbow Dam for a given spillway discharge is defined by upper and lower limits as computed with the numerical model. This range of water elevations at the dam for a given spillway discharge is defined in this report as the operating range for the TRS design. Due to the lack of available spillway discharge versus water surface elevation data in the bypass reach upstream of the powerhouse, selection of the model roughness was based on professional experience and comparison of channel characteristics in the reach with photographic information presented in the U.S. Geological Survey publication "Roughness Characteristics of Natural Channels" (Barnes, 1987). In addition, a roughness value sensitivity evaluation was conducted by using Manning's n-values ranging from 0.025 to 0.035. This range of roughness values was considered adequate for use in estimating the potential upper and lower limits of the discharge tailwater rating curve at the dam.

The resulting discharge rating curves computed at locations upstream of the powerhouse (consistent with the downstream end of the physical model and just downstream of the Oxbow Dam spillway) are shown on Figures 2.2 and 2.3, respectively. In evaluating performance of the various TRS designs in the physical model, the model was run for any given spillway discharge with the downstream boundary condition set at both the lower and upper limit computed by the numerical model to ensure that the deflector design was robust enough to perform satisfactorily through the entire design operating range.

A natural hydraulic control exists in the channel downstream of the spillway that attenuates the operating range of the Hells Canyon forebay elevation. This hydraulic control is very apparent at the lower discharges where the control makes the spillway tailwater elevations nearly independent of the Hells Canyon forebay. For design flows of 20,000 cfs and 40,000 cfs, the physical model showed that for a 1 ft change in water level near the downstream end of the model, the water level just downstream of the spillway changes by about 0.2 ft.

3 DEVELOPMENT OF TRS ALTERNATIVES

At the beginning of the project, **nhc** conducted a brainstorming meeting with IPC to identify potential TRS alternatives suitable for the Oxbow project. Through this process a total of eight alternatives were identified and are described in detail in the Oxbow Spillway TRS Project – TRS Alternatives Summary memorandum in Appendix B. A short summary of the alternatives is provided herein.

For the existing configuration, flow exiting the spillway chute plunges to depths on the order of 30 to 50 ft and entrained air is forced into solution, thereby generating elevated TDG concentrations. The velocities and flow depth at the downstream end of the spillway chute at the 7Q10 discharge of 41,000 cfs are on the order of 50 fps and 7.5 ft, respectively. The unit discharge at the downstream end of the chute was originally estimated by dividing the estimated discharge exiting the end of the chute by the crest length along the end of the spillway chute. The resulting unit discharge was calculated in the order of 350 - 500 cfs/ft. Flow distribution subsequently estimated in the physical model, as discussed in Section 4, suggests that the unit discharge at the end of the chute was on the order of 450 cfs/ft. These unit discharge values are extremely high when considering typical designs that are used to reduce plunging flow and made the development of an effective TRS design particularly challenging.

Based on the collective TDG abatement experience of the project team, the following eight alternatives were developed into conceptual designs schematics.

- Alternative 1 - Standard Stilling Basin Downstream of Spillway Chute with Flow Deflector
- Alternative 2 - Standard Stilling Basin Downstream of Widened Spillway Chute with Flow Deflector
- Alternative 3 - Flip-bucket, Three-Bay Version
- Alternative 4 - Flip-bucket, One-Bay Version with Dividing Wall
- Alternative 5 - Two-stage Energy Dissipation Structure
- Alternative 6 - Stepped Spillway Downstream of Chute
- Alternative 7 - Downstream Rock Weir and Ramp
- Alternative 8 - Fill in Existing Plunge Pool.

Conceptual level drawings of all of these alternatives are included in Appendix B.

The alternatives that were considered to have the highest potential at this site included Alternatives 2, 3, and 7. These three alternatives were initially recommended for evaluation in the physical model. Subsequent to the conceptual development of the alternatives, additional considerations were discussed. Specifically, Alternative 8, which was a relatively simple concept to test in the model and was considered to be relatively economical to construct in the field, was also selected for model testing. This alternative appeared to have the potential to work in conjunction with any of the other alternatives to further reduce TDG. In addition, a traditional flow deflector installed on the steeply sloping faces along the right side and end of the spillway chute was also proposed for testing in the model. Although this concept had questionable performance issues at this site due to the high-unit discharge values and non-uniform approach flow conditions, the relative simplicity of the concept made it attractive as a starting point. The concept would not require significant modification to the existing chute structure compared to the other alternatives considered. Based on this, the two alternatives that were first tested in the model were filling in the plunge pool and adding a flow deflector along the steep faces at the downstream end of the spillway chute.

4 PHYSICAL MODEL DESCRIPTION

4.1 SIMILITUDE AND SCALE

Scale hydraulic modeling requires that the force relationships in the model and prototype are dynamically similar. To achieve this similarity, the ratios of the inertial, to the gravity, pressure, viscous, and surface tension forces must be the same between model and prototype. Only a 1:1 scale model can achieve these criteria. Modeling at reduced scale involves identifying the primary force relationship to accurately simulate prototype conditions, then selecting a model scale to minimize any scale effects. For free-surface flow conditions of the type being examined in the current study, the inertial and gravitational forces are the dominant forces that define the hydrodynamic flow conditions. As a result, the Froude number, as defined below, is the key force ratio that must be equal in the model and prototype. That is,

$$F_r = \frac{F_M}{F_P} = 1$$

where, $F_M = \textit{Froude number in the model} = \frac{U_M}{\sqrt{g\,L_M}} = \frac{\textit{Inertial Force}}{\textit{Gravitational Force}}$

$$F_P = \textit{Froude number in the prototype} = \frac{U_P}{\sqrt{g\,L_P}}$$

and,

U = characteristic flow velocity

g = gravitational acceleration

L = characteristic length

M = model values

P = prototype values

Given the model study objectives, the spillway discharges and the size of the various system components, **nhc** adopted a geometric scale of 1:48 for the Oxbow TRS model study. At this scale, adherence to Froude criterion for similitude resulted in the following scale relationships.

Model Scale Relationships

Parameter	Relation	Ratio
Length	L_r	1 : 48
Velocity	$L_r^{1/2}$	1 : 6.93
Discharge	$L_r^{5/2}$	1 : 15,962

4.2 MODEL DESCRIPTION

Figures 4.1 through 4.13 illustrate the layout of the physical model and model structures. The physical hydraulic model reproduced an area extending approximately 450 ft upstream of the dam and 3,300 ft downstream of the dam. Photo 4.1 shows the physical model with a dry bed, and Photo 4.2 shows a photo of the model operating. The bathymetry reproduced in the model was provided by IPC and included transect survey data as well as a contour map that was developed from the transect data. The Oregon spillway was replicated in the model from as-built drawings, renderings and photographs provided by IPC. Due to the limited detail provided at certain locations on these drawings and some contradictory information discovered over the course of the study, there may be some deviations between field and model geometries of certain structures. In particular, it was necessary to rely on sketches and photographs in reproducing the area at the downstream end of the chute and along the left (west) bank downstream of the chute. The elevations and general configuration are not in question; however, a detailed survey of the immediate area associated with construction of the proposed TRS alternative is highly recommended prior to proceeding into preparation of final structural design and contract documents.

Mobile Bed – A portion of the model bed downstream of the spillway chute was installed using mobile bed material, as shown in Photo 4.3. IPC staff provided visual observations that suggest the existing surface gradation is on the order of 5 to 45 inches. The mobile bed mix selected for the model was a gap gradation with 80% washed sand, 10% pea gravel, and 7/8 inch washed gravel. This gradation roughly simulates a prototype gradation of 80% at 2-inch, 10% at 10 to 12-inch, and 10% at 36 to 38-inch. Existing sub-strata information is not available; therefore, the model results relative to scour depth can not be considered to be absolutely accurate but are acceptable for use in relative comparisons.

4.3 MODEL MEASUREMENTS AND INSTRUMENTATION

The following controls and instrumentation were provided for the study:

> ***Flow Rates*** **-** The model flow was circulated using two centrifugal laboratory pumps supplying flow to manifold pipes in the headbox. The flow to the headbox was regulated with a valve in each pipe (supply pipes were 8 inches and 10 inches) and the model discharge was measured using orifice plate flow meters installed in the model supply lines. The orifice plate sizes in the 8 inch and 10 inch pipes were 6.30 inches and 8.11 inches, respectively. The precision of flow measurement is approximately +/- 2%. Air-water manometers used to measure the pressure

differential across the orifice plates. The orifice plate and pressure taps were installed in accordance with American Society of Mechanical Engineers (ASME) Standards (2004).

***Water Levels* -** Measurement of the water levels within the forebay, spillway chute, and tailrace was achieved by using flush-mounted piezometric pressure taps. The location of the pressure taps are indicated in Figure 4.1. The precision of the water level measurements is approximately +/- 0.1 ft. The downstream tailrace elevation in the model was controlled by an adjustable overflow weir that discharged into the model sump.

***Velocities* -** Velocity measurements were recorded using a miniature propeller meter (Novar Streamflo Probe). At the proposed scale of 1:48, the propeller meter had a threshold velocity of approximately 2 ft/s (prototype) and an accuracy of ±0.2 ft/s (prototype). All velocity probes utilized in the study were calibrated at the onset of the study.

***TDG Flow Classification* –** In this study, the performance of the TRS alternatives in the physical model was evaluated by qualitative analyses. The measurement of TDG in physical models is not practical due to the reduced magnitude of flow depths and scale effects[1] of air bubbles. However, a significant amount of research has been conducted by the U.S. Army Corps of Engineers Research and Development Center (ERDC) on the production of TDG levels in spillway/stilling basin flows (USACE, 2002). This work has shown that plunging aerated flow can cause significant TDG absorption in the immediate stilling basin. Since it is virtually impossible to prevent air entrainment, alternatives have been adopted to minimize the depth to which entrained air bubbles are transported. In general, for spillways, the most apropos retrofit structure has been a spillway deflector.

Additional research conducted by ERDC showed that hydraulic performance of a deflector was dictated by unit discharge and tailwater submergence. Flow performance classifications, developed by ERDC for spillways, are shown in Figure 4.14 and were used to estimate the effectiveness of Oxbow deflector alternatives. The skimming flow regime shown on the figure is the optimum flow regime for TDG reduction purposes. The plunging flow regime is considered to contribute to high TDG elevations. Achieving skimming flow for all water surface elevation

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[1] Air bubbles in this scale model are significantly oversized. Thus, in the model, the surface area for gas transfer is undersized and bubble contact time is greatly reduced because of the higher buoyancy of the oversized bubbles.

and discharges that are of interest may not be achievable; therefore, the undulating flow surface jet classification is also considered acceptable. In addition, consideration to the total discharge is also taken into account when classifying flows as acceptable or unacceptable. A very low discharge will have less impact on TDG levels than a higher discharge; therefore, flow classifications that are not as ideal are considered more acceptable at lower flows. For the Oxbow project, the final TRS deflector alternative was designed to be optimum at the 40,000 cfs design, which was the maximum design flow for TDG reduction purposes.

5 TEST PROGRAM

The test program included baseline tests to calibrate the model and developmental tests to optimize a TRS alternative.

5.1 BASELINE TEST PROGRAM

The baseline test program included testing the existing condition at spillway discharges of 20,000 cfs, 40,000 cfs, 60,000 cfs, and 100,000 cfs. For all of these tests, water surface elevations were taken at the pressure tap locations shown on Figure 4.1, and near-shore velocities were taken at 11 transect locations downstream of spillway. In addition, an erosion test was conducted for a spillway discharge of 70,000 cfs, which is an estimate of the maximum peak spill that has occurred at the project. Although an entire history of the maximum prototype spill hydrograph is not available, for this test the model was run for 1 hour (approximately 7 hours prototype) at 70,000 cfs and then velocities were taken. The model was then run for a 2-hour (approximately 14 hours prototype) and a 4-hour (approximately 28 hours prototype) interval at 70,000 cfs. After the 4-hour interval, the contours were mapped on the mobile bed at 10 ft intervals. Limited testing was also conducted for a 150,000 cfs test of the existing condition for potential erosion as a subsequent comparison to the selected TRS alternative potential erosion.

For all of the baseline tests, the downstream water surface in the model was set at pressure tap 16 (located approximately 60 ft model scale, 2, 800 ft prototype, downstream of the spillway crest) to simulate the water surface elevation associated with a minimum operating Hells Canyon pool elevation and a minimum Oxbow powerhouse flow of 5,000 cfs. This condition was considered to represent the lower project operating boundary tailwater condition for design of Oxbow TRS alternatives. The lower tailwater condition was used as it was considered to be more conservative as plunging flow is more likely to occur with a lower tailwater elevation. During the performance curve testing discussed in detail in Section 6 for the final alternative, both high and low tailwater elevations were used. The downstream tailwater elevation used for the baseline tests was developed using the HEC-RAS numerical model discussed in Section 2 and Appendix A. This appendix also provides details regarding the roughness ‘n’ values that were evaluated during the sensitivity analyses.

5.2 DEVELOPMENTAL TEST PROGRAM

After the baseline tests were conducted, TRS modifications were constructed, installed in the model and tested. Developmental testing was accomplished for: (1) the plunge pool fill-in alternative; and, (2) a deflector concept added to the steep faced slope at the downstream end of the chute. As noted previously, although the original test plan included preliminary evaluation of up to three TRS alternatives, initial testing of the deflector alternative suggested that it provided high potential to address the TDG objectives with fewer construction issues and less disruption to the existing facility; therefore, subsequent testing was limited to refinement of the deflector design. A total of 24 deflector configurations were tested and documented in the model. Due to the large number of deflector configurations tested, the data collection and documentation for each configuration varied depending upon how promising the deflector performed during preliminary tests. In addition, some of the deflector configurations were evaluated qualitatively during witness tests, which also limited the documentation time available for the alternative.

The deflector design development program typically included testing at spillway discharges of 20,000 and 40,000 cfs to classify the flow performance with respect to TDG potential. The most promising designs were also tested at discharges of 10,000 and 30,000 cfs. A lower than normal tailwater condition, simulating a channel controlled tailwater condition, was also used for the limited testing. This tailwater condition was evaluated to ensure that a plunging flow regime, which exists if the submergence depth on the deflector is too low, would not occur. For the more detailed testing, including developing the flow classification performance curves, four tailwater conditions, covering the entire range of possible Hells Canyon pool, Oxbow powerhouse flow, and channel roughness value conditions, were tested. The objective during this testing process was to develop a deflector design that would result in flow off the deflector being in either the “skimming regime” (preferred) or, in the “undulating surface jet regime” (as a minimum). Figure 4.14 shows the flow performance classifications that were used for this project.

For the final deflector configuration, performance curves were developed to demonstrate the flow classifications for a range of operating conditions.

6 TEST RESULTS

Summaries of the test results are provided in this section and the tables, figures, and photos. The DVDs included with the report provide comprehensive video collected during this study.

6.1 BASELINE CONDITIONS

The baseline tests included documentation of flow conditions for the existing spillway configuration; collection of water surface elevations and velocities in the downstream channel for spillway discharges of 20,000 cfs, 40,000 cfs, 60,000 cfs, 100,000 cfs, and 150,000 cfs; and conducting an erosion test at a discharge of 70,000 cfs. At the beginning of each test, the mobile bed was raked and leveled to survey pins that coincide with the top of the existing bed from the bathymetry data provided by IPC.

Flow Patterns

For the existing spillway configuration, the majority of the spillway flow is directed in a downstream direction with a smaller portion off the right side of the chute directed across the river channel.
Photos 6.1.1 thru 6.1.10 show flow patterns observed for the baseline tests conducted at flows ranging from 20,000 cfs to 150,000 cfs. In addition, the enclosed DVDs provide video footage of all of the baseline tests. The flow in the chute exhibited numerous standing waves emanating from the spillway piers and the chute sidewall transitions at the toe of the ogee crest. These standing waves were further enhanced by the converging left wall of the chute near the downstream end. With three-bay operation, these conditions created a highly non-uniform flow distribution at the end of the chute with a significantly larger unit discharge along the left side of the chute. Preliminary testing conducted with one spillway gate closed (right spill gate) demonstrated that the flow distribution at the end of the chute was significantly more uniform with two-bay operation. Subsequent measurements in the model indicated that approximately 45 percent of the total spillway discharge occurs off the downstream lip of the chute. With three bay operation, approximately 60 percent of the discharge off the downstream lip exists on the left side of the chute while with two bay operation the discharge is nearly equally distributed across the chute.

As shown in Photos 6.1.1 through 6.1.6, “plunging flow” off the right side (Photo 6.1.3 identifies plunging location), angled portion of the spillway chute occurred for 20,000 cfs, 40,000 cfs, and 60,000 cfs conditions. This flow generated a strong vertical circulation cell that spiraled parallel to the spillway toe and entrained flow from the larger horizontal circulation cell which formed in the channel to the east of the spillway chute downstream of the dam as identified in Photo 6.1.9. This type of flow is typically associated with high levels of TDG as the air entrained in the flow is driven to depth. By comparison, the flow off the downstream end of the spillway impacted on the bench at El. 1687 ft, which deflected flow across the surface in what could be classified as a “ramped jet” (refer to Figure 4.14). Due to the combination of the flow concentration along the left side of the spillway and the spiraling circulation cell along the right side of the spillway, velocities along the left bank were relatively high. In addition, water impacting the small wedge-shaped fillet constructed along the left wall at the downstream end of the chute “bench” created a jet directed into the plunge area and appeared to contribute to the hydraulic flow conditions downstream of the chute.

Water Surface Elevations and Velocities

Figures 6.1.1 through 6.1.7 and Tables 6.1.2 and 6.1.3 present the downstream water surface profiles collected in the model for the baseline tests.

Table 6.1.1 provides the limited field data which has been used for comparison with data from the physical model. The powerhouse operating conditions associated with these values are unknown; however, the values still provide a means for a rough comparison with the model data. Since water surface elevations at the Oxbow powerhouse were unknown for these values, the low tailwater downstream control was used for this comparison purpose. In this table, the location for the spillway tailwater elevation measurement roughly coincides with the Pressure Tap 8 in the physical model. Field data coinciding to 21,500 cfs and 39,000 cfs are plotted on Figures 6.1.1 and 6.1.2 to show the correlation between the field data and the physical model. For 21,500 cfs the field observed water surface elevation is El. 1697.6 and for 20,000 cfs in the model, the water surface elevation was measured at El. 1697.4 ft. Similarly, for 39,000 cfs the field observed water surface elevation is El. 1699.3 ft and for 40,000 cfs in the model, the water surface elevation was measured at El. 1698.9 ft. These comparisons show very good agreement between the field measurements and model data, indicating that the channel bathymetry as constructed in the model provides a good representation of the conditions in the field.

Figures 6.1.8 and 6.1.9 and Tables 6.1.4 through 6.1.9 provide the nearshore velocities measured in the channel downstream from the spillway chute for spillway discharges ranging from 20,000 cfs to 150,000 cfs. As expected, immediately downstream of the chute the velocities are highest along the left bank of the channel and approach 20 fps at a discharge of 40,000 cfs. However, approximately 1,700 ft downstream of the spillway chute, the right bank velocities become higher downstream (around 17 fps) due to natural bathymetry and the more downstream directed flow off the side of the spillway chute, both conditions that direct flow towards the right bank of the channel. The large clock-wise re-circulation zone that exists also results in fairly high velocities of around 12 fps with a discharge of 40,000 cfs upstream along the right bank of the channel and laterally across the downstream face of the dam. The 150,000 cfs velocity tests resulted in erosion of the mobile bed to the model deck elevation of 1640.0 ft.

Downstream Erosion

The 70,000 cfs erosion test was conducted to determine whether the model could adequately reproduce the prototype bed levels that currently exist downstream of the spillway and to provide a basis of comparison for subsequent TRS alternatives. The existing bed topography, as furnished by IPC, is believed to have developed as a result of a maximum spillway discharge in the order of 70,000 cfs.

As described in Section 5.1, the erosion test included running the model for 1 hour and then collecting velocities. The model was then run for 2 hour and 4 hour intervals. The model bed following the 70,000 cfs test was then mapped and marked with yarn for visual purposes. Comparison of the model scour with the existing baseline topography is presented in Figure 6.1.10 and shows that the model reasonably simulates the overall scour and depositional patterns observed in the prototype. As shown on the contour maps, maximum scour depths predicted by the model are generally greater than those existing in the prototype.

6.2 TRS ALTERNATIVES

TRS development testing included evaluating a number of alternatives in the model. The initial alternative tested consisted of filling in the existing scour hole downstream of the spillway chute with large rock to limit the depth of plunging. The results of this test were not promising; therefore, subsequent alternatives tested consisted of adding deflectors on the sloping faces at the downstream end of the chute.

6.2.1 PLUNGE POOL FILLING ALTERNATIVE

As shown in Photo 6.2.1, the plunge pool was filled in to approximately El. 1685 ft with 8 to 16 ft (prototype) diameter rock to provide a tailwater depth downstream of the spillway between 10 and 15 ft. Testing was conducted at flows of 10,000 cfs, 20,000 cfs, 40,000 cfs and 100,000 cfs. A significant increase in velocities was recorded along the left bank downstream of the chute with this bed configuration. This was likely due to the shallower depth and decreased energy dissipation created by raising the bed in the plunge area. The flow regime exiting from the chute was similar to that observed for the baseline tests. As a result of the raised bed levels, the flow did not appear to plunge as deep compared to the existing condition, which is considered beneficial for reducing TDG; however, the flow classification entering the tailwater was still considered to be in the “plunging” category. For flows up to 40,000 cfs, there was minimal movement in the rip rap material. More substantial movement was observed at 60,000 cfs and significant movement was noted at 100,000 cfs.

Based on the results of these tests, combined with the fact that 8 to 16 ft size rock would be extremely difficult to obtain in large quantities, this alternative was considered impractical and was eliminated from further consideration. This test was conducted at the June 7th witness test (see Appendix C).

6.2.2 DEFLECTOR ALTERNATIVES

Initial Design

A preliminary test of a “generic” flow deflector concept installed along the sloping face at the downstream end of the spillway chute was conducted to determine whether this option improved performance. Testing of this concept was conducted during the June 8th, 2007 witness test. The configuration tested was a deflector installed at El. 1690 ft along the entire perimeter of the chute discharge slope. The width of the deflector along the right side of the chute was 20 ft and the “width” at the downstream end of the chute was 40 ft. This deflector configuration was shown previously in Photo 6.2.1.

With the deflector installed, the flow off the side of the chute was generally classified within the skimming surface jet or undulating surface jet regimes, while the flow off the end of the chute was fairly rough and classified within the undulating surface jet or ramped surface jet regimes. In any event there was no tendency to form a plunging flow condition off either the side or end deflectors. From the initial observations, it was concluded that the deflector concept had significant potential to provide the favorable flow regimes associated with minimizing TDG at a reasonable cost and that further testing should be made to refine the design to optimize its hydraulic performance. Specifically, the hydraulic conditions observed in the model suggested that the side deflector elevation could be raised somewhat and still provide the desired flow regime, while the end deflector would need to be lowered to achieve a skimming surface jet regime. This conclusion appeared reasonable as the higher unit discharge that exists at the end of the chute generally require a deeper submergence on the deflector to create skimming flow than does the lower unit discharge along the side of the chute. A more detailed description of the conditions and the observations associated with this deflector design are included in the meeting minutes from the June 7 & 8 witness test included in Appendix C.

“Generic” Concepts 2 & 3

Following the initial “generic” concept testing, two additional deflector designs were tested (refer to Table 6.2.1). First, the deflector along the side of the chute was raised by 2 ft to elevation 1692 ft and the end deflector was lowered by 1 ft to elevation 1689 ft. In addition, the width of the end deflector was increased to 80 ft and it was extended around the corner of the chute for a distance of approximately 50 ft. The transition between the side deflector and end deflector elevations was accomplished via a 1V:3H slope.

Generic Concept 2 is shown operating in Photo 6.2.2. Testing of this deflector indicated that the lowered end deflector should be confined to the end of the chute, in lieu of extending it 50 ft upstream along the side of the chute. Based on this, the side deflector (at El. 1692 ft) was extended 50 ft downstream to the end of the chute and the 1V:3H transition to the end deflector (at El. 1689) was relocated and aligned at about 20 degrees (clockwise)from the chute centerline (Photo 6.2.3). This modification appeared to provide a more reasonable location for the transition between the two deflectors but did not develop a very uniform distribution of flow across the channel downstream of the spillway chute. Plunging flow was not observed with the raised side deflector or the lowered end deflector; however, the lowered end deflector still did not result in a skimming flow regime. More detailed observations from these tests are provided in Appendix D - Oakwood Consulting Memorandum, July 19, 2007. The conclusion of this test series was that further testing should be conducted to better optimize hydraulic performance of the design concept by varying the elevation, width, and step transition location.

Deflector Configurations 1 through 6

For deflector configurations 1 through 6, the 20 ft side deflector width and 80 ft end deflector width were retained, while the elevations of the deflectors were varied. The elevation of the end deflector was varied from El. 1689 to 1691 ft, and the elevation of the side deflector was varied from El. 1689 to 1694 ft. The location of the elevation transition was varied slightly to obtain a location that would result in the most uniform spreading of the jet downstream from the deflector. Photos 6.2.4 through 6.2.9 and Table 6.2.2 provide the documentation of Deflector 1 through 6 geometry and flow performance characteristics.

Plunging flow was observed downstream of the side deflector when it was installed at elevation 1694 ft and downstream of the end deflector when installed at elevation 1691 ft.

Deflector 6, which had the side deflector at El. 1692.5 ft and the end deflector at El. 1689.5 ft, appeared to optimize hydraulic performance for discharges ranging up to 40,000 cfs. For discharges from 10 kcfs to 40 kcfs, flow off the end deflector was generally within the undulating surface jet and ramped surface jet regimes while flow off the side deflector was within the skimming surface jet to undulating surface jet regimes for all discharges tested. While the flow conditions off the downstream corner of the deflector, where the two deflectors met, were typically quite rough and exhibited a relatively steep face, the flow was still considered to be within the undular surface jet regime. In addition, a relatively strong reverse flow was observed along the left side of the channel downstream from the end deflector. This reverse flow was entrained into the higher velocity flow exiting from the end deflector and significantly altered the flow characteristics in this area. Preliminary testing showed that installing a wall along the left side of the deflector and underlying apron reduced the adverse effects of this recirculation.

Deflector 6 was tested with various combinations: 1-bay, 2-bay, and 3-bay spillway operation at a discharge of 40,000 cfs, and it was shown that the performance characteristics were not significantly affected by gate operation. Although the flow off the downstream corner of Deflector 6 design was not considered ideal, as assessed by the design team, the overall performance of the design was shown to be relatively robust with respect to spillway gate operation and was considered to be acceptable by the design team.

Deflector Configurations 7 & 8

Testing of the Deflector 6 configuration indicated that the steepness of the undular surface jet that formed off the corner of the deflector was reduced when the deflector submergence was minimized (i.e., at lower tailwater conditions, or with a higher deflector elevation). On the basis of this, two additional deflector configurations were tested: Deflector 7 raised the corner portion of the deflector to El. 1695.5 ft; and Deflector 8 raised the corner section to elevation El. 1694.5 ft. Photo 6.2.10 shows Deflector 8 installed in the model (Deflector 7 was very similar), and Table 6.2.2 provides a summary of the geometry associated with Deflectors 7 and 8.

Deflector configuration 8 appeared to reduce the steepness of the undular surface jet off the corner of the deflector without compromising the performance of the side and end deflectors; however, the overall flow regime off the corner of the deflector was not considered to be improved sufficiently to warrant further consideration of this modification.

Deflector Configurations 9 through 12

Although performance of Deflector 6 was considered to be generally acceptable by the design team, a subsequent series of tests was conducted to optimize the width of the deflector and improve the overall hydraulic conditions exiting the downstream end and corner portions of the deflector. The side deflector width was reduced to 10 ft and the end deflector width was shortened to 40 ft. In addition, the elevation transition between the side and end deflectors was relocated a short distance downstream towards the end deflector and the sloping transition was replaced by a vertically-faced transition. A short training wall extending downstream along the left side of the end deflector to eliminate the reverse flow from being entrained into the exit flow was also during these tests.

While reducing the width of the deflectors did not have an adverse impact on the overall flow regime downstream of the deflector, a noticeable depression in the local water elevation formed off the downstream corner of the deflector at a spillway discharge of 40,000 cfs with three bays operating (refer to Photo 6.2.11). This condition resulted in an unacceptable plunging flow regime off the corner. Potential modifications to eliminate this plunging condition included lowering the deflector in the corner and/or increasing the width of the deflector at the corner. Specific details of these modifications are listed in Table 6.2.3.

Other modifications tested to improve the flow conditions off the corner and end of the deflector included adding a parabolic shaped drop between the end of the chute and the end deflector to support the jet and minimize the direct impact on the end deflector, and a large shaped slope transition extending upstream along the side slope of the chute to better direct flow into the corner. Neither of these modifications illustrated sufficient improvement to warrant further consideration.

Table 6.2.3, and a more detailed description of testing results with these design configurations are presented in the August 16th and 17th Witness Test minutes in Appendix C.

Deflector Configurations 13 through 18

Various modifications to the narrowed deflectors were made in an attempt to eliminate the plunging flow condition that had formed off the corner with these deflectors. Table 6.2.4 provides a summary of the geometries for Deflectors 13 through 18. Deflector 13 replaced the vertical elevation transition with the sloping transition, as tested previously, but was not effective in eliminating the plunging condition off the corner. Deflector 14, shown operating in Photo 6.2.12 reverted back to the vertical face elevation transition between the side and end deflectors and increased the width of the end deflector in the corner by approximately 6 ft. This configuration was also shown to be ineffective at eliminating the plunging flow. Deflectors 15 and 16 (see Photos 6.2.13 and 6.2.14) increased the width of the end deflector at the corner by an additional 6 ft and 12 ft, respectively. With either of these modifications, the depressed water levels and associated plunging flow regime was eliminated. Deflector 17 (Photo 6.2.15) streamlined the geometry at the transition between the end and side deflectors and increased the width of the side deflector to range from 14 to 16 ft. Deflector 18 included additional refinement to the Deflector 17 design by reducing the width of the corner deflector. Acceptable performance existed with this design and the depressed water levels and plunging flow regime off the corner were eliminated.

Deflector Configuration 19

Deflector 19 (Photo 6.2.16) consisted of reverting back to the plan geometry of Deflector 12 but lowering the side deflector to El. 1689.5 ft (to coincide with the elevation of the end deflector) beginning about 50 ft upstream of the corner (see Table 6.2.4). A 1V:1H sloping faced transition was made between the side and end deflector elevations. This design configuration also performed acceptably although the flow off the corner was slightly more within the ramped surface jet regime than that existing with Deflector 18.

Deflector Configuration 20

Deflector 18 was further refined to produce Deflector configuration 20 by making the side deflector width a constant 16 ft and by lowering the side deflector to El. 1691.5 ft (see Table 6.2.4). The end deflector elevation was retained at 1689.5 ft. Photo 6.2.17 shows a dry photo of the Deflector 20 configuration. In addition, the downstream face of the side deflector was extended vertically downward to meet the surface of the existing discharge slope, thereby preventing flow recirculation beneath the deflector.

At a spillway discharge of 20,000 cfs, skimming flow occurred off the side deflector for both 2-bay and 3-bay spillway operating conditions. The flow off of the end deflector was within the undulating surface jet regimes. Shock waves through the spillway chute and into the end deflector were significantly less severe with 2-bay vs. 3-bay operation. At a discharge of 40,000 cfs, with either 2-bay or 3-bay operation, the flow regime off the side deflector was within the skimming surface jet regime while flow off the end deflector was within the undulating surface jet regime. The flow off the corner of the deflector still exhibited significant undulating flow characteristics, but Deflector 20 was considered to optimize formation of acceptable flow classifications that produce skimming and undulating flow regimes up to the design discharge condition. In addition, this deflector design was considered to be a feasible structural modification having minimal impact on the existing facility.

Deflector Configuration 21

Following development of the preferred deflector configuration (Deflector 20), additional modifications were made to the model to determine if a more well-defined skimming flow regime could be produced off the end deflector by lowering the elevation of the end deflector to better replicate deflector submergence that has resulted in skimming flow at more traditional spillway configurations. A review of available deflector performance data suggests that for the unit discharges that exist along the left side of the spillway chute a submergence of approximately 25 ft should produce skimming flow. Based on an average tailwater level at El. 1700 for a river discharge of 40,000 cfs, Deflector 21 (Photo 6.2.18) included lowering the end deflector to El. 1676 ft (a submergence of about 24 ft).

With this design installed in the model, preliminary testing was conducted at discharges of ranging from 10,000 to 40,000 cfs. Photo 6.2.19 shows flow conditions associated with Deflector 21 operating at 40,000 cfs with a low tailwater. For all discharges, a strong hydraulic jump formed on the end deflector for both 2-bay and 3-bay spillway operation. The hydraulic jump dissipated sufficient energy downstream of the chute such that relatively tranquil flow conditions existed farther downstream. However, the flow contained high quantities of entrained air which could be drawn to depth and result in increasing TDG concentrations in the downstream channel. Based on these results, this design configuration was considered to be unacceptable with respect to TDG reduction.

6.2.3 TRAINING WALL DOWNSTREAM OF SPILLWAY CHUTE

Deflector configuration 20, which is the final recommended design, includes a training wall extending downstream from the end of the spillway chute on the west side. The training wall (Figure 6.3.3) with a top elevation of 1707 ft and extending approximately 50 ft downstream along the left side of the end deflector is recommended to eliminate the high velocity return flow along the left bank from affecting the hydraulic performance of the end deflector.

6.2.4 EXISTING FILLET ON BENCH AT DOWNSTREAM END OF SPILLWAY CHUTE

As discussed in Section 6.1, water impacting the existing small wedge-shaped fillet located along the left wall of the bench at the downstream end of the chute created a jet directed into the plunge area and appeared to contribute to the inefficient hydraulic flow conditions downstream of the chute. Removal of this wedge in the model significantly improved the overall hydraulic conditions existing along the bench approaching the end deflector and is recommended for incorporation into the proposed final design.

6.2.5 RIPRAP ALONG TOE OF DEFLECTOR

Although the riprap test results described in Section 6.2.1 showed that filling in the downstream plunge pool was not practical due to the size of riprap required, those tests were conducted prior to the installation of the flow deflectors. Since the installation of the deflector changes the flow conditions along the side slope and reduces the jet impact, any riprap placed along the toe of the deflector would not be subject to the extremely high velocities that exist without the deflector and would provide added bed protection along the toe discharge slope. In addition, filling in of the scour area adjacent to the deflector would provide an additional TDG benefit by decreasing the tailwater plunge depth available.

While Deflector 21 was in place, some initial riprap tests were conducted to gain a better understanding of the appropriate size of riprap to be located along the apron along the right side of the spillway discharge slope. As shown in Photo 6.2.20, the first test included placing a 20 ft wide strip of individual 6 to 10 ft diameter riprap pieces placed in two layers along the side deflector on the existing bed which effectively raised the bed elevation to about the elevation of the apron (around 1670 ft, apron varies slightly along the length). Addition of this riprap protection decreased the depth of the scour hole along the side of the spillway chute by about 15-20 ft. There was no observed movement in the riprap when subjected to spillway flows up to 70, 000 cfs for a prototype duration of approximately 7 hours. Smaller sized riprap (4 to 6 ft stone size) along the side deflector was then tested. After running a spillway discharge of 70,000 cfs for a prototype duration of approximately 7 hours, there was a small amount of movement at the downstream end of the protected area as shown on Photo 6.2.21. The test was run for an additional 14 hours (prototype) with no additional displacement of the rip rap observed.

A riprap test was completed to confirm the riprap size for the final design deflector configuration 20. The 4 to 6 ft individual sized riprap pieces were placed in two layers on the existing bed along the deflector in a manner similar to that previously tested with the Deflector 21 riprap test; however, the riprap was extended approximately 100 ft further downstream. Addition of this riprap protection decreased the depth of the scour hole along the side of the spillway chute by about 8-12 ft. Photos 6.2.22 and 6.2.23 show the results of 40,000 cfs and 60,000 cfs tests that were each run for 7 hours. There was minimal movement in the riprap during these tests.

Final design of the riprap protection blanket will need to incorporate appropriate sized/graded stone filter blankets (underlayers) to provide an acceptable transition between the existing bed material and the large sized stone in the riprap blanket. Additionally, the downstream end of the ripap will need to be designed so that it is keyed into the existing bed to minimize displacement of the riprap in this area.

6.3 PROPOSED FINAL DESIGN DOCUMENTATION TESTING

The proposed final design for the TRS (Figures 6.3.1 through 6.3.3)includes installation of the Deflector 20, installation of the training wall downstream from the end of the spillway chute, installation of the riprap blanket along the upstream portion of the side deflector, and removal of the existing fillet located on the bench at the downstream end of the spillway chute. Final documentation testing of the proposed final design included duplication of the test program conducted for the baseline tests. Water elevations on the exterior and interior faces of the training wall were measured. A maximum differential head of 20 ft acting from the exterior face to the interior face is recommended for design purposes.

Flow classifications were documented, and a deflector performance curve was developed from this information. Water surface elevations and near shore velocities in the downstream channel were recorded for spillway discharges of 20,000 cfs, 40,000 cfs, 60,000 cfs, 100,000 cfs, and 150,000 cfs. In addition, an erosion test was conducted for a discharge of 70,000 cfs.

Flow Patterns

Photos 6.3.1 through 6.3.5 provide photos of the final documentation testing for flows ranging from 20,000 cfs to 150,000 cfs, and Photo 6.3.6 shows the model and mobile bed following the 70,000 cfs final documentation erosion test. Deflector performance was evaluated for two conditions: 1) for a mobile bed condition where the bed was raked to the existing condition and 2) following the 70,000 cfs erosion test with the bed fixed to that resulting from the 70,000 cfs erosion test during the final documentation testing process.

Deflector performance was evaluated both with 2- and 3-bay spillway operation. The 2-bay operation significantly reduced the shock waves through the spillway chute and into the end deflector and subsequently provided a much more uniform flow distribution across the end deflector than that existing with 3-bay operation. With 3-bay operation and tailwater elevations near the lower limit of the normal operating range, a very small unstable depression in the local water elevation off the corner piece of the end deflector would periodically appear. This condition was not considered to be detrimental to satisfactory performance of the deflector and did not occur with 2-bay operation. Because the deflector performance with 3-bay operation was slightly less hydraulically effective than with 2-bay operation, performance curves for Deflector 20 were developed with the 3-bay operation.

Flow Performance – Mobile Bed:

For the performance curves developed for the mobile bed condition (Figures 6.3.4 and 6.3.5), the bed was raked to the existing condition. The tailwater elevation shown on the performance curves corresponds to the tailwater elevation at the downstream end of the model. Table 6.3.1 provides the tailwater elevation located near the upstream end of the deflector at Pressure Tap 8 (see Figure 4.1 for the P8 location) as well as other information collected during the performance curve tests. The flow regime along the side deflector with spillway discharges ranging from 10,000 through 40,000 cfs with tailwater elevations in the normal project operating range exhibited very good skimming / undular surface jet characteristics. In general, the flow regime along the upstream 50-75 percent length of deflector was more of the skimming nature while the downstream reach was more of an undular nature. Additionally, the skimming regime improves as the discharge increases above 20,000 cfs. With a spillway discharge of 5,000 cfs the flow regime along the upstream 60-70 percent length of the side deflector was of an undular surface jet nature. The flow regime along the remaining downstream length was a surface hydraulic jump. The deflector submergence depth is less than 5 ft at this discharge, a strong surface oriented jet exists downstream of the jump and a relatively small percentage of the overall spillway discharge exists in this reach. Therefore, the existence of a hydraulic jump is not considered detrimental to acceptable performance of the deflector at these low discharges.

The end deflector exhibited very strong undular surface flow characteristics throughout the operating range with some conditions very close to the skimming regime. The only exception occurred at spillway discharges less than 10,000 cfs where a hydraulic jump formed on the corner piece of the end deflector. With the 10,000 cfs condition, a surface jump occurred while at 5,000 cfs a submerged jump occurred on the corner piece and a surface jump occurred on the end deflector. As stated for the side deflector, these low spillway discharge conditions are not considered detrimental to satisfactory deflector performance.

Flow Performance – 70 kcfs Fixed Bed:

The performance curves developed for the 70 kcfs fixed bed condition are shown in Figures 6.3.6 through 6.3.8. The tailwater elevation shown on the performance curves corresponds to the tailwater elevation at the downstream end of the model. Table 6.3.2 provides the tailwater elevation located near the upstream end of the deflector at Pressure Tap 8 (see Figure 4.1 for the P8 location) as well as other information collected during the performance curve tests. This fixed bed test was conducted to ensure that satisfactory performance of the deflector was not overly sensitive to changes in the downstream river channel bathymetry that could occur after a large flood event. For these tests, the bed formed by the 70,000 cfs erosion test was fixed by coating the bed with a cement-slurry mix.

Deflector 20 performance was evaluated with discharges of 10,000 cfs; 20,000 cfs; 30,000 cfs; and 40,000 cfs with the bed topography that existed following the 70 kcfs erosion test. Tailwater elevations existing at the deflector with spillway discharges of 10 to 40 kcfs and the fixed post-70 kcfs bed geometry were generally on the order of 4 to 6.5 ft higher than existed with the mobile bed that had formed with discharges up to 40 kcfs due to the hydraulic control produced by the deposition near the mobile-fixed bed transition in the model. The higher tailwater elevations with the fixed post-70,000 cfs bed significantly increased submergence on the deflector and therefore resulted in significantly greater submergence on the deflector with the post-70 kcfs bed geometry than with the 40,000 cfs mobile bed geometry. More pronounced skimming flow existed along the side of the chute for all discharges tested and generally a less severe undulating surface jet downstream from the end of the chute with spillway discharges greater than about 30 kcfs. At the 30 kcfs discharge, a surface jump occurred along the left half of the corner piece deflector immediately downstream of the deflector while an undular surface jet existed off the remaining portion of the corner piece. This condition did not occur with the higher and lower discharges tested. With a discharge of 10,000 cfs a surface jump occurred along the entire width of the end deflector and with 20,000 a surface jump occurred immediately downstream of the end deflector with a high tailwater condition and a surface jump occurred on the right hand corner of the end deflector with a low tailwater condition.

With the model bed fixed to the post-70,000 cfs geometry, the model does not simulate the dynamic bed movement that would occur in the prototype. Additionally, the considerable amount of material scoured from the channel downstream of the spillway chute during the 70,000 cfs erosion test and deposited in the model bed near the location where the model changed from mobile bed to fixed bed may be a model related condition and not a condition that would exist in the prototype with extremely large spillway discharges. The bed deposition that occurred near the transition between the fixed and mobile bed with the 70,000 cfs erosion test, and then fixed in place to prevent movement during the subsequent deflector performance evaluation, created localized tailwater elevations at the deflector significantly (up to 6.5 ft) higher than occurred in the mobile bed condition at comparable discharges and resulted in the surface jump characteristics exhibited on the end deflector on some discharge conditions. These conditions cast some suspicion with regard to the validity of the tailwater elevations produced in the model with the fixed post-70,000 cfs bed geometry. Even if the model produced tailwater elevations reasonably reflect the prototype tailwater elevations under such conditions, the submergence on the end deflector when the surface jumps occurred were less than about 12 ft and the discharge associated with the end/corner deflector is a relatively small percentage of the overall spillway discharge. Therefore, the surface jump conditions that occurred near the end deflector in the model with the fixed post-70,000 cfs bed geometry are not considered to reflect unsatisfactory deflector performance with the Deflector 20 design configuration.

The overall flow downstream from the spillway chute with the post-70,000 cfs fixed bed geometry was directed more in a downstream direction than occurred with the 40,000 cfs mobile bed geometry because the higher tailwater with the 70 kcfs bed tended to suppress the more eastward directed flow off the side of the chute that exists with lower tailwater elevations associated with the 40,000 cfs mobile bed geometry. .

Water Surface Elevations and Velocities

Figures 6.3.9 through 6.3.15 and Tables 6.3.3 and 6.3.4 summarize the water surface elevation data and Figure 6.3.16 and 6.3.17 and Tables 6.3.5 though 6.3.10 present the near shore velocities collected during the final documentation tests.

The addition of the deflector re-directs the flow coming off the side slope of the chute more laterally across the channel. This re-direction of the flow changes the local velocity regime and subsequently the bed movement from that occurring with the existing condition. In addition the large clock-wise circulation that exists under existing conditions is significantly reduced. These changes in hydraulic conditions and bathymetry have some beneficial impact on local water surface elevations near the corner of the spillway chute. Under existing conditions, a large and significant depression in the water surface elevation exists immediately downstream from the corner of the spillway chute. This large depression results in high velocities and deep scour occurs along the side of the chute. Subsequently, the entrained air in the large clock-wise circulation cell may be taken to depth which then reinforces high TDG concentrations downstream from the spillway chute. With the deflector installed, the localized water levels in this area are higher than those that occur with the existing condition. Therefore, the submergence on the deflector is increased which subsequently reduces the velocities and scour depth along the side of the chute as well as providing the submergence necessary to form the desired skimming-type flow regime beneficial to minimize TDG concentration. Since the deflector is located downstream of the high velocity chute, the addition of the deflector has no affect on spillway capacity as it causes no back-water effects on the spillway.

The velocity regime in the channel downstream from the spillway chute is impacted by the addition of the deflector. The addition of the deflector changes the angle of the flow leaving the side slope of the chute and significantly reduces the re-circulation flow pattern downstream of the dam. The velocities along the left bank of the channel immediately downstream of the spillway chute are less than 20 fps for 40,000 cfs. The velocities farther downstream are still higher along the right bank of the channel and are about the same magnitude as those that occur with the existing condition. In the re-circulation zone, the velocities associated with the deflector condition with a discharge of 40,000 cfs are on the order of 4 fps, a significant reduction from the 12 fps velocities that exist with the existing spillway chute configuration.

Spillway Discharge of 150,000 cfs

A 150,000 cfs test was conducted to observe the overall erosion patterns associated with this type of large event. The bed eroded to the basin deck, elevation 1640.0 ft, as it did with the baseline 150,000 cfs test. Due to the uncertainties associated with the bed substrate, conclusions associated with the erosion potential at a high discharge of 150,000 cfs are difficult to make; however, the velocities can be compared to the model tests conducted for the baseline condition. In general, the velocities associated with the deflector condition were lower than the baseline test.

Downstream Erosion

The bed topography following the 70,000 cfs erosion test was mapped with yarn for visual purposes. Comparison of the bed topography resulting with the deflector installed and the topography that currently exists in the field is shown in Figure 6.3.18. Comparison to the bed levels that developed during the baseline erosion tests is shown in Figure 6.3.19. With the deflector installed, the bed levels that developed in the model were generally 5 to 10 ft higher immediately downstream of the spillway chute along both the side and end of the chute. The large depositional bar located across the channel to the east of the spillway was found to be about 5 ft higher than what developed during the baseline tests. The bed, beginning about 100 ft downstream from the end of the chute and extending downstream for a distance of about 250 ft over a width of about 100 ft, is up to 20 ft lower than occurs with the existing field condition. Although these values should be considered approximate due to the uncertainty that exists in model simulation of prototype bed materials, this comparison does suggest that installation of the deflector should not be expected to produce a significant change to erosion along the toe of the spillway chute and may in fact reduce the scour depths in this area. However, more erosion could be expected in the area farther downstream and additional deposition on the mid-river bar may be generated.

7 SUMMARY

The purpose of the study was to develop a TRS that would reduce high TDG levels currently experienced downstream of the Oxbow dam spillway. The Oxbow TRS study included a numerical backwater analysis to determine spillway discharge versus water surface elevation relationships at the dam, development of conceptual hydraulic designs of TRS alternatives, and physical model testing to test and refine selected alternatives. Due to the unique configuration of the project and complex hydraulics, a physical model was required to design and refine TRS solutions.

The first task required the development of a HEC-RAS steady-state numerical model to compute hydraulic characteristics for the river reach between the Oxbow powerhouse and Oxbow Dam. The results of the model were used to provide tailwater elevation versus spillway discharge predictions at the spillway for use in developing the conceptual designs of TRS alternatives and to provide a rating curve for the downstream boundary condition in the physical model.

Conceptual designs were developed for eight TRS alternatives that were considered to have the potential to reduce TDG concentrations resulting from spillway operation. Four of the alternatives identified in the conceptual design study were proposed for construction and testing in a physical model. One of those alternatives, filling in of the existing deep plunge pool, was tested in the physical model. After the completion of the conceptual design report, one additional alternative was considered to have merit as it had the potential to reduce TDG while also minimizing construction complexities. This alternative was comprised of a deflector along the side and end faces of the steeply sloping discharge slope at the downstream end of the spillway chute. Based on preliminary testing of this alternative, the deflector performance appeared promising; therefore, all subsequent testing in the model focused on refining this deflector concept.

During the first witness test, the filling in the plunge pool option and the original deflector concept were both tested. Filling in the existing plunge pool with 8 to16 ft size rock was only marginally effective in limiting TDG production downstream of the spillway and showed some instability when subjected to high spillway flows. Based on these results, filling in the plunge pool as a stand alone alternative was eliminated from further consideration.

Initial testing of the deflector concept installed along the side and end discharge slopes of the spillway chute indicated that this alternative had a high potential to achieve the design objectives to reduce TDG concentrations associated with spillway releases up to the 7Q10 design discharge of 41,060 cfs. Numerous alternative configurations of side and end deflectors were tested in developing a final hydraulic design for the deflector.

Deflector configuration 20, a 16-ft wide (in direction of flow) deflector installed along the side of the spillway discharge slope at El. 1691.5 ft in conjunction with a 40 ft wide deflector installed along the discharge slope at the downstream end of the chute at El. 1689.5 ft (Figures 6.3.1 through 6.3.3), was selected as the proposed final design. This deflector provided flow conditions similar to those shown to be effective at other projects in minimizing TDG concentrations downstream from highly aerated spillway releases. The flow off the side deflector produced a well-defined skimming surface jet regime for the design discharge conditions while the flow off the end deflector, although not being the preferred skimming flow regime, produced an acceptable undulating surface jet regime. In addition to the deflector, the proposed final recommended design includes:

- A 50-ft long training wall extending downstream along the west side of the bench at the end of the spillway chute,
- Removal of the existing wedge-shaped fillet on the west side of the bench at the downstream end of the spillway chute and
- Addition of a 10- thick blanket of riprap along the most upstream 250 ft length of the spillway chute along the east side of the chute

Testing of the proposed final design indicated that installation of the deflector would be expected to reduce scour potential that could occur immediately downstream from the spillway chute discharge slope and increase deposition on the mid-channel bar for discharges up to 70,000 cfs. Operation of the spillway with the PMF discharge of 150,000 cfs with the deflector installed, showed no increase in erosion compared to the baseline condition based on the mobile bed results.

While these flow regimes have been shown to reduce TDG levels at other project sites, it is not possible to accurately predict the magnitude of the TDG reduction that can be expected for the Oxbow project. However, the final recommended alternative deflector prevents the plunging flow that occurs with the existing design. Based on past experimental and field experience with flow deflectors installed at more traditional spillway facilities, preventing plunging flow also leads to reduced TDG levels.

8 REFERENCES

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TABLES

OXBOW DAM SPILLWAY
TRS ALTERNATIVES STUDY
HYDRAULIC MODEL STUDY

TABLE 6.1.1

IPC Observed Data

1999 and 2006 data for the powerhouse, and manual measurements for the tailrace elevations at Oxbow.

Date and Time	Spill flow (cfs)	Spill Tailwater Elev (ft)	Powerhouse Elev (ft)	TW-PH Difference (ft)
5/23/06 8:23 AM	8527	1694.3	1692.8	1.5
5/24/06 9:00 AM	8527	1694.3	1692.7	1.6
5/25/06 11:45 AM	7890	1694.2	1692.4	1.8
5/26/06 10:21 AM	12752	1696.3	1693.3	3.0
5/27/06 11:30 AM	5613	1694.0	1692.4	1.6
5/28/06 11:30 AM	5613	1694.0	1692.4	1.6
5/29/06 1:00 PM	5746	1694.1	1691.5	2.6
7/7/99 12:00 AM	200	1688.5	1688.1	0.4
6/23/99 12:00 AM	3340	1692.8	1692.0	0.8
4/19/99 12:00 AM	21500	1697.6	1692.7	4.9
4/5/99 12:00 AM	23400	1697.3	1691.0	6.3
4/14/99 12:00 AM	25050	1697.5	1692.0	5.5
4/19/99 12:00 AM	26000	1698.0	1692.7	5.3
4/19/99 12:00 AM	30500	1698.7	1692.7	6.0
4/19/99 12:00 AM	35000	1699.0	1692.7	6.3
4/19/99 12:00 AM	39000	1699.3	1692.7	6.6

OXBOW DAM SPILLWAY
TRS ALTERNATIVES STUDY
HYDRAULIC MODEL STUDY

TABLE 6.1.2

Water Surface Elevation Data Summary
Baseline Spillway Configuration

Gage	Location	Water Surface Elevation (ft)				
		20,000 cfs	40,000 cfs	60,000 cfs	100,000 cfs	150,000 cfs
	Model Spillway Gate Opening (ft)	*5.0*	*11.0*	*17.5*	*34.0*	*Wide Open*
Reservoir						
P1	408 ft upstream of spillway crest	1804.0	1804.8	1805.0	1805.8	1810.9
P2	404 ft upstream of spillway crest	1803.8	1804.8	1804.8	1804.9	1810.2
P3	202 ft upstream of spillway crest	1803.6	1804.5	1804.3	1803.4	1807.7
P4	110 ft upstream of spillway crest	1803.4	1804.3	1804.0	1802.3	1805.4
Spillway Chute						
P5	92 ft downstream of spillway crest	1730.6	1734.5	1740.1	1753.8	1768.6
P6	284 ft downstream of spillway crest	1723.8	1727.4	1730.1	1734.8	1741.9
P7	476 ft downstream of spillway crest	1723.3	1723.8	1726.2	1732.8	1740.6
Downstream River Channel						
P8	478 ft downstream of spillway crest	1697.4	1698.9	1698.4	1703.2	1710.0
P9	660 ft downstream of spillway crest	1694.0	1693.6	1691.3	1696.5	1698.0
P10	669 ft downstream of spillway crest	1697.3	1698.8	1697.6	1702.5	--
P11	914 ft downstream of spillway crest	1698.7	1700.7	1701.1	1706.5	--
P12	1,299 ft downstream of spillway crest	1698.2	1701.5	1704.9	1712.2	1718.1
P13	1,691 ft downstream of spillway crest	1694.2	1699.5	1702.9	1707.1	1715.2
P14	2,081 ft downstream of spillway crest	1693.8	1697.7	1701.0	1706.9	1714.5
P15	2,475 ft downstream of spillway crest	1694.1	1698.3	1701.3	1707.0	1715.8
P16	2,867 ft downstream of spillway crest	1694.4	1699.2	1702.2	1708.2	1716.2
P17	3,300 ft downstream of spillway crest	1694.2	1699.1	1702.4	1708.9	1717.1

NOTES:

1) Elevations are in the NGVD29 Datum
2) Refer to Figure 4.1 for Pressure Tap Locations.
3) Gate openings are equal in all three spillway bays.

OXBOW DAM SPILLWAY
TRS ALTERNATIVES STUDY
HYDRAULIC MODEL STUDY

TABLE 6.1.3

Water Surface Elevation Data Summary
Erosion Test - Baseline Spillway Configuration

Gage	Location	WSEL (ft)
		70,000 cfs
	Model Spillway Gate Opening (ft)	*21.5*
Reservoir		
P1	408 ft upstream of spillway crest	1806.1
P2	404 ft upstream of spillway crest	1805.8
P3	202 ft upstream of spillway crest	1805.2
P4	110 ft upstream of spillway crest	1804.6
Spillway Chute		
P5	92 ft downstream of spillway crest	1743.6
P6	284 ft downstream of spillway crest	1732.0
P7	476 ft downstream of spillway crest	1727.9
Downstream River Channel		
P8	478 ft downstream of spillway crest	1700.5
P9	660 ft downstream of spillway crest	1691.8
P10	669 ft downstream of spillway crest	1699.6
P11	914 ft downstream of spillway crest	--
P12	1,299 ft downstream of spillway crest	1707.5
P13	1,691 ft downstream of spillway crest	1705.7
P14	2,081 ft downstream of spillway crest	1702.8
P15	2,475 ft downstream of spillway crest	1703.9
P16	2,867 ft downstream of spillway crest	1704.1
P17	3,300 ft downstream of spillway crest	1703.9

NOTES:

1) Elevations are in the NGVD29 Datum
2) Refer to Figure 4.1 for Pressure Tap Locations.
3) Gate openings are equal in all three spillway bays.

OXBOW DAM SPILLWAY
TRS ALTERNATIVES STUDY
HYDRAULIC MODEL STUDY

TABLE 6.1.4

Downstream Velocity Data Summary
Baseline Spillway Configuration
20,000 cfs Spillway Discharge

Measurement Location		**Left Bank Velocities (ft/s)**			**Right Bank Velocities (ft/s)**		
	Distance from bank (ft)	*10*	*25*	*50*	*50*	*25*	*10*
Template 14	*629ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	-	-	-	3	4	4
Template 15	*735 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	-	-	-	4	5	4
Template 16	*867ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	-	-	-	5	7	7
Template 17	*1,010ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	5	9	16	-	-	-
Template 18	*1,177 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	17	16	15	5	5	5
Template 19	*1,328 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	10	11	13	10	11	13
Template 20	*1,569ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	14	15	16	11	9	5
Template 21	*1,718ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	3	7	5	15	14	12
Template 22	*1,887 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	5	5	7	12	3	7
Template 23	*2,054 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	7	8	10	16	15	12
Template 24	*2,215 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	3	11	11	5	8	9

NOTES:

1) Refer to Figure 6.1.8 for velocity measurement locations.
2) Velocity values shown are the average values recorded. Fluctuations of approximately 10% (or greater) were noted at most locations.

OXBOW DAM SPILLWAY
TRS ALTERNATIVES STUDY
HYDRAULIC MODEL STUDY

TABLE 6.1.5

Downstream Velocity Data Summary
Baseline Spillway Configuration
40,000 cfs Spillway Discharge

Measurement Location	**Left Bank Velocities (ft/s)**			**Right Bank Velocities (ft/s)**		
Distance from bank (ft)	*10*	*25*	*50*	*50*	*25*	*10*
Template 14 *629ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	10	11	12
Mid-depth velocity (ft/s)	-	-	-	8	9	10
Template 15 *735 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	11	10	10
Mid-depth velocity (ft/s)	-	-	-	10	9	7
Template 16 *867ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	9	10	8
Mid-depth velocity (ft/s)	-	-	-	9	10	9
Template 17 *1,010ft d/s of spillway crest*						
Near-surface velocity (ft/s)	5	11	20	6	6	7
Mid-depth velocity (ft/s)	8	5	5	7	8	9
Template 18 *1,177 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	17	17	19	5	4	3
Mid-depth velocity (ft/s)	18	16	15	4	3	3
Template 19 *1,328 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	16	18	18	5	4	5
Mid-depth velocity (ft/s)	15	17	16	4	3	4
Template 20 *1,569ft d/s of spillway crest*						
Near-surface velocity (ft/s)	5	10	16	11	11	10
Mid-depth velocity (ft/s)	--	8	15	11	11	9
Template 21 *1,718ft d/s of spillway crest*						
Near-surface velocity (ft/s)	7	7	5	15	13	12
Mid-depth velocity (ft/s)	--	7	6	14	--	--
Template 22 *1,887 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	5	7	9	15	14	7
Mid-depth velocity (ft/s)	--	6	8	15	12	--
Template 23 *2,054 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	8	11	14	18	12	--
Mid-depth velocity (ft/s)	--	--	13	17	--	--
Template 24 *2,215 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	5	15	17	7	7	--
Mid-depth velocity (ft/s)	6	12	16	7	--	--

NOTES:

1) Refer to Figure 6.1.8 for velocity measurement locations.
2) Velocity values shown are the average values recorded. Fluctuations of approximately 10% (or greater) were noted at most locations.

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TABLE 6.1.6

Downstream Velocity Data Summary
Baseline Spillway Configuration
60,000 cfs Spillway Discharge

Measurement Location	**Left Bank Velocities (ft/s)**			**Right Bank Velocities (ft/s)**		
Distance from bank (ft)	*10*	*25*	*50*	*50*	*25*	*10*
Template 14 *629ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	18	15	9
Mid-depth velocity (ft/s)	-	-	-	16	15	--
Template 15 *735 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	14	15	12
Mid-depth velocity (ft/s)	-	-	-	13	12	10
Template 16 *867ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	12	14	11
Mid-depth velocity (ft/s)	-	-	-	13	14	9
Template 17 *1,010ft d/s of spillway crest*						
Near-surface velocity (ft/s)	10	9	9	10	11	11
Mid-depth velocity (ft/s)	6	8	15	12	12	13
Template 18 *1,177 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	16	24	23	7	9	8
Mid-depth velocity (ft/s)	20	20	16	6	8	8
Template 19 *1,328 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	18	22	22	6	4	5
Mid-depth velocity (ft/s)	21	21	22	3	3	3
Template 20 *1,569ft d/s of spillway crest*						
Near-surface velocity (ft/s)	8	18	22	13	13	7
Mid-depth velocity (ft/s)	--	--	20	13	13	7
Template 21 *1,718ft d/s of spillway crest*						
Near-surface velocity (ft/s)	7	7	4	19	15	12
Mid-depth velocity (ft/s)	--	--	--	17	15	--
Template 22 *1,887 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	3	6	8	17	7	3
Mid-depth velocity (ft/s)	--	5	6	17	8	--
Template 23 *2,054 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	7	11	14	19	14	11
Mid-depth velocity (ft/s)	--	--	12	19	--	--
Template 24 *2,215 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	8	18	17	5	4	5
Mid-depth velocity (ft/s)	7	15	17	5	--	--

NOTES:

1) Refer to Figure 6.1.8 for velocity measurement locations.
2) Velocity values shown are the average values recorded. Fluctuations of approximately 10% (or greater) were noted at most locations.

OXBOW DAM SPILLWAY
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TABLE 6.1.7

Downstream Velocity Data Summary
Baseline Spillway Configuration
100,000 cfs Spillway Discharge

Measurement Location	**Left Bank Velocities (ft/s)**			**Right Bank Velocities (ft/s)**		
Distance from bank (ft)	*10*	*25*	*50*	*50*	*25*	*10*
Template 14 *629ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	17	12	4
Mid-depth velocity (ft/s)	-	-	-	17	13	5
Template 15 *735 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	19	19	14
Mid-depth velocity (ft/s)	-	-	-	18	19	17
Template 16 *867ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	17	17	15
Mid-depth velocity (ft/s)	-	-	-	17	18	18
Template 17 *1,010ft d/s of spillway crest*						
Near-surface velocity (ft/s)	26	11	7	7	12	11
Mid-depth velocity (ft/s)	12	7	8	15	15	12
Template 18 *1,177 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	16	19	25	11	5	5
Mid-depth velocity (ft/s)	20	20	13	5	4	6
Template 19 *1,328 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	22	25	23	11	8	7
Mid-depth velocity (ft/s)	22	23	23	7	5	5
Template 20 *1,569ft d/s of spillway crest*						
Near-surface velocity (ft/s)	22	24	24	16	16	5
Mid-depth velocity (ft/s)	23	23	24	17	18	7
Template 21 *1,718ft d/s of spillway crest*						
Near-surface velocity (ft/s)	5	9	5	20	17	13
Mid-depth velocity (ft/s)	--	7	6	18	19	15
Template 22 *1,887 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	3	3	6	20	16	9
Mid-depth velocity (ft/s)	--	--	4	6	15	11
Template 23 *2,054 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	11	13	14	21	20	15
Mid-depth velocity (ft/s)	--	13	14	7	19	
Template 24 *2,215 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	3	3	4	4	5	5
Mid-depth velocity (ft/s)	--	--	--	6	7	--

NOTES:

1) Refer to Figure 6.1.9 for velocity measurement locations.
2) Velocity values shown are the average values recorded. Fluctuations of approximately 10% (or greater) were noted at most locations.

OXBOW DAM SPILLWAY
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TABLE 6.1.8

Downstream Velocity Data Summary
Baseline Spillway Configuration
150,000 cfs Spillway Discharge

Measurement Location		**Left Bank Velocities (ft/s)**			**Right Bank Velocities (ft/s)**		
	Distance from bank (ft)	*10*	*25*	*50*	*50*	*25*	*10*
Template 14	*629ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	-	-	-	-	150	-
Template 15	*735 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	-	-	-	-	-	-
Template 16	*867ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	-	50	-	-	134	-
Template 17	*1,010ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	-	-	-	-	-	-
Template 18	*1,177 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	-	40	-	-	90	-
Template 19	*1,328 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	-	-	-	-	-	-
Template 20	*1,569ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	-	140	-	-	188	-
Template 21	*1,718ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	-	-	-	-	-	-
Template 22	*1,887 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	-	140	-	-	175	-
Template 23	*2,054 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	-	-	-	-	-	-
Template 24	*2,215 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	-	-	-
	Mid-depth velocity (ft/s)	-	-	-	-	-	-

NOTES:

1) Refer to Figure 6.1.9 for velocity measurement locations.
2) Velocity values shown are the average values recorded. Fluctuations of approximately 10% (or greater) were noted at most locations.

TABLE 6.1.9

Downstream Velocity Data Summary
Erosion Test - Baseline Spillway Configuration
70,000 cfs Spillway Discharge

Measurement Location		**Left Bank Velocities (ft/s)**			**Right Bank Velocities (ft/s)**		
	Distance from bank (ft)	*10*	*25*	*50*	*50*	*25*	*10*
Template 14	*629ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	16	11	4
	Mid-depth velocity (ft/s)	-	-	-	15	12	4
Template 15	*735 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	16	14	11
	Mid-depth velocity (ft/s)	-	-	-	13	14	11
Template 16	*867ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	16	14	15
	Mid-depth velocity (ft/s)	-	-	-	17	17	17
Template 17	*1,010ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	17	9	10	10	12	13
	Mid-depth velocity (ft/s)	11	9	9	12	13	15
Template 18	*1,177 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	16	22	24	5	5	6
	Mid-depth velocity (ft/s)	22	21	13	4	6	5
Template 19	*1,328 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	21	22	20	7	5	4
	Mid-depth velocity (ft/s)	22	23	19	4	3	3
Template 20	*1,569ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	19	22	25	15	12	7
	Mid-depth velocity (ft/s)	--	24	24	13	15	13
Template 21	*1,718ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	5	5	7	17	15	11
	Mid-depth velocity (ft/s)	--	4	7	17	17	13
Template 22	*1,887 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	9	12	15	19	13	4
	Mid-depth velocity (ft/s)	10	11	10	20	11	5
Template 23	*2,054 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	9	13	15	19	15	11
	Mid-depth velocity (ft/s)	--	14	13	19	16	--
Template 24	*2,215 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	11	17	17	7	8	4
	Mid-depth velocity (ft/s)	7	15	17	7	9	--

NOTES:

1) Refer to Figure 6.1.9 for velocity measurement locations.
2) Velocity values shown are the average values recorded. Fluctuations of approximately 10% (or greater) were noted at most locations.

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TABLE 6.2.1

Initial Deflector Design Geometries

Name	Testing Date	Deflector Type	D/S Edge Length	D/S Edge Elevation	Step Transition	Side Edge Width	Side Edge Elevation
Witness Test 6/8/2007 (Day 2, Friday)	6/8/2007	Constant Elevation	~40'	1690'	N/A	~20'	1690'
Concept 1 (7/13/2007 Duncan Visit)	7/13/2007	Two Step	~80'	1689'	1v:3h 50' U/S of NE Corner	~20'	1692'
Concept 2 (7/13/2007 Duncan Visit)	7/13/2007	Two Step	~80'	1689'	1v:3h ~20° NE from NE corner	~20'	1692'

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TABLE 6.2.2

Deflectors 1 through 8 Design Geometries

Name	Testing Date	Deflector Type	D/S Edge Length	D/S Edge Elevation	Step Transition	Side Edge Width	Side Edge Elevation
Deflector Configuration 1	7/16/2007	Two Step	~80'	1689'	1v:3h Parallel to Spillway CL	~20'	1692'
Deflector Configuration 2	7/17/2007	Constant Elevation	~80'	1689'	N/A	~20'	1689'
Deflector Configuration 3	7/18/2007	Two Step	~80'	1689'	1v:3h Curve Expansion from	~20'	1692'
Deflector Configuration 4	7/22-23/2007	Two Step	~80'	1691'	1v:3h Curve Expansion from	~20'	1694'
Deflector Configuration 5	7/25/2007	Two Step	~80'	1690'	1v:3h Curve Expansion from	~20'	1693'
Deflector Configuration 6	8/1-2/2007	Two Step	~80'	1689.5'	1v:3h Curve Expansion from	~20'	1692.5'

Name	Testing Date	Deflector Type	D/S Edge Length	D/S Edge Elevation	Step Transition	D/S Side Edge Width	D/S Side Edge Elevation	Step Transition	U/S Side Edge Width	U/S Side Edge Elevation
Deflector Configuration 7	8/2/2007	Three Step	~80'	1689.5'	~1v:3h Curve Expansion from	~20'	1695.5'	~1v:2h slope, 45° off	~20'	1692.5'
Deflector Configuration 8	8/2/2007	Three Step	~80'	1689.5'	~1v:3h Curve Expansion from	~20'	1694.5'	~1v:2h slope, 45° off	~20'	1692.5'

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TABLE 6.2.3

Deflectors 9 through 12 Design Geometries

Deflector Configurations - August 16th and 17th Witness Test

Name	Testing Date	Deflector Type	D/S Edge Length	D/S Edge Elevation	Step Transition	Side Edge Width	Side Edge Elevation	Notes
Deflector Configuration 9	8/16/2007	Two Step	~40'	1689.5'	1v:3h Curve Expansion from NE corner	~10'	1692.5'	Deflector 6 modified by reducing width by roughly half.
Deflector Configuration 10	8/17/2007	Two Step	~40'	1689.5'	Parallel to Spillway CL at NE corner, no slope	~10'	1692.5'	Deflector 9 modified by replacing sloped transition with a step. Deflector width along NE corner is reduced to ~10', continuation of side.
Deflector Configuration 11	8/17/2007	Two Step	32' LS 44' RS	1690'	Parallel to Spillway CL at NE corner, no slope	~10'	1692.5'	Deflector 10 modified by: 1) 12' removed from D/S end length 2) 4' added to RS of D/S end def 3) 0.5' added to D/S end elev (1690')
Deflector Configuration 12	8/17/2007	Two Step	32' LS 44' RS	1689.5'	Parallel to Spillway CL at NE corner, no slope	~10'	1692.5'	Deflector 11 modified by: 1) D/S end elev lowered 0.5' (1689.5') 2) 4' removed from RS of D/S end def

Deflector Addition Options - August 16th and 17th Witness Test

Name	Description
Parabolic Drop	The Parabolic drop addition fits on the to the downstream end of the spillway chute. The parabolic curve was designed per Corps specifications. The performance of this addition was evaluated after it was fitted to the Deflector Configuration 6.
Fillet	This Fillet forms a smoothed transition from the right side of the Parabolic drop to slope of the right side of the spillway chute. The performance of the fillet was evaluated after it was fitted to the Deflector Configuration 6 with the Parabolic Drop.
Brow	The brow addition fits to the downstream end of the spillway chute. The brow has a more aggressive downward curve than the Parabolic drop and is shorter. It does not support the flow all the way to the D/S end deflector. The brow was evaluated in conjunction with Deflector Configuration 10

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TABLE 6.2.4

Deflectors 13 through 21 Design Geometries

Name	Testing Date	Deflector Type	D/S Edge Length	D/S Edge Elevation	Step Transition	Side Edge Width	Side Edge Elevation	Notes
Deflector Configuration 13	8/21/2007	Two Step	32' LS 44' RS	1689.5'	Parallel to Spillway CL at NE corner, 1v:3h slope	~10'	1692.5'	Deflector 12 modified by: Replaced stepped transition with sloped transition. SW suggestion
Deflector Configuration 14	8/21/2007	Two Step	32' LS 44' RS	1689.5'	Parallel to Spillway CL at NE corner, no slope	~10'	1692.5'	Deflector 13 modified by: Reverted back to stepped (from sloped) transition at NE corner. Adding 6' to width of the NE corner. (20')
Deflector Configuration 15	8/21/2007	Two Step	32' LS 44' RS	1689.5'	Parallel to Spillway CL at NE corner, no slope	~10'	1692.5'	Deflector 14 modified by: Adding an additional 6' to width of the NE corner. (26', 2nd addition)
Deflector Configuration 16	8/21/2007	Two Step	32' LS 44' RS	1689.5'	Parallel to Spillway CL at NE corner, no slope	~10'	1692.5'	Deflector 15 modified by: Adding an additional 6' to width of the NE corner. (32', 3rd addition)
Deflector Configuration 17	8/21/2007	Two Step	32' LS 44' RS	1689.5'	Parallel to Spillway CL at NE corner, no slope	16'/14'/26'	1692.5'	Entirely new addition built for corner and side. Increased width of side deflector at very U/S end. NE corner extended out
Deflector Configuration 18	8/21/2007	Two Step	32' LS 44' RS	1689.5'	Parallel to Spillway CL at NE corner, no slope	16'/14'/26'	1692.5'	Economized 17 by trimming back corner some, final nhc at this point
Deflector Configuration 19	8/21/2007	Two Step	32' LS 44' RS	1689.5'	1v:3h slope, moved U/S to middle of side deflector	10'	1689.5' / 1692.5	Duncan's proposed modification to Deflector 12, lower elevation of the corner to 1689.5. Transition is midway up the side deflector
Deflector Configuration 20	9/4/2007	Two Step	32' LS 44' RS	1689.5'	Parallel to Spillway CL at NE corner, no slope	16'	1691.5'	Final Proposed Design
Deflector Configuration 21	8/21/2007	Two Step	~60'	1676'	Parallel to Spillway CL at NE corner, no slope	16'	1691.5'	Academic Experiment 1: Tested lowering end deflector drastically so that there was ~25' of submergence

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TABLE 6.3.1

Deflector 20 Flow Performance Curve Data
Mobile Bed

Spillway Discharge (cfs)	P16 Tailwater Elevation (ft)	P8 Tailwater Elevation (ft)	End Deflector Performance	Side Deflector Performance
10,000	1,700.0	1,699.8	Surface Jump/Sub. Jump	Surface Jump/Sub. Jump
10,000	1,695.0	1,697.3	SkSJ/USJ	SkSJ/USJ
10,000	1,691.5	1,697.3	SkSJ/Surface Jump	SkSJ/USJ
20,000	1,702.0	1,699.2	USJ/Surface Jump	SkSJ/USJ
20,000	1,698.0	1,696.6	SkSJ/USJ	SkSJ/USJ
20,000	1,697.3	1,696.9	USJ	SkSJ/USJ
20,000	1,694.5	1,696.3	USJ	SkSJ/USJ
20,000	1,693.5	1,696.3	USJ	SkSJ/USJ
30,000	1,700.0	1,696.9	USJ	SkSJ
30,000	1,699.0	1,696.6	USJ	SkSJ
30,000	1,697.0	1,696.3	USJ	SkSJ
30,000	1,696.0	1,696.1	USJ	SkSJ
40,000	1,704.0	1,698.0	SkSJ/USJ	SkSJ
40,000	1,702.1	1,697.1	SkSJ/USJ	SkSJ/USJ
40,000	1,699.1	1,696.2	SkSJ/USJ	SkSJ
40,000	1,698.0	1,696.0	SkSJ/USJ	SkSJ

Abbreviation Key
RSJ: Ramped Surface Jet
USJ: Undular Surface Jet
SkSJ: Skimming Surface Jet

OXBOW DAM SPILLWAY
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TABLE 6.3.2

Deflector 20 Flow Performance Curve Data
70,000 cfs Fixed Bed

Spillway Discharge (cfs)	P16 Tailwater Elevation (ft)	P8 Tailwater Elevation (ft)	End Deflector Performance	Corner of Deflector Performance	Side Deflector Performance
10,000	1,692.5	1,701.0	Surface Jump	SkSJ	SkSJ
20,000	1,694.5	1,702.1	Surface Jump/USJ	SkSJ	SkSJ
20,000	1,697.5	1,702.2	Surface Jump	SkSJ	SkSJ
30,000	1,699.3	1,703.0	USJ	USJ/Surface Jump	SkSJ
30,000	1,696.5	1,702.5	SkSJ/USJ	USJ/Surface Jump	SkSJ
40,000	1,699.1	1,702.9	USJ	USJ	SkSJ
40,000	1,702.1	1,702.9	Mild USJ	Steep USJ	SkSJ

Abbreviation Key
RSJ: Ramped Surface Jet
USJ: Undular Surface Jet
SkSJ: Skimming Surface Jet

OXBOW DAM SPILLWAY
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TABLE 6.3.3

Water Surface Elevation Data Summary
Final Documentation

Gage	**Location**	**Water Surface Elevation (ft)**				
		20,000 cfs	**40,000 cfs**	**60,000 cfs**	**100,000 cfs**	**150,000 cfs**
	Model Spillway Gate Opening (ft)	*5.0*	*11.0*	*17.5*	*34.0*	*Wide Open*
Reservoir						
P1	408 ft upstream of spillway crest	1805.7	1805.7	1805.6	1806.6	1811.1
P2	404 ft upstream of spillway crest	1805.7	1805.6	1805.5	1806.1	1810.4
P3	202 ft upstream of spillway crest	1805.6	1805.4	1805.0	1804.7	1807.8
P4	110 ft upstream of spillway crest	1805.6	1805.3	1804.6	1803.7	1805.6
Spillway Chute						
P5	92 ft downstream of spillway crest	1730.5	1735.7	1741.2	1754.5	1768.9
P6	284 ft downstream of spillway crest	1727.4	1730.1	1733.2	1738.3	1742.6
P7	476 ft downstream of spillway crest	1724.7	1726.7	1729.0	1735.1	1740.5
Downstream River Channel						
P8	478 ft downstream of spillway crest	1702.1	1702.9	1702.4	1707.7	1717.0
P9	660 ft downstream of spillway crest	1702.0	1701.9	1700.5	1700.8	1713.2
P10	669 ft downstream of spillway crest	1702.2	1702.9	1702.1	1707.0	1713.5
P11	914 ft downstream of spillway crest	1702.3	1703.6	1705.9	1708.8	1711.3
P12	1,299 ft downstream of spillway crest	1702.3	1705.1	1707.0	1711.1	1720.8
P13	1,691 ft downstream of spillway crest	1693.9	1698.2	1703.1	1710.1	plugged
P14	2,081 ft downstream of spillway crest	1694.1	1698.1	1700.9	1707.9	1719.5
P15	2,475 ft downstream of spillway crest	1694.3	1698.4	1703.8	1709.1	1719.0
P16	2,867 ft downstream of spillway crest	1694.5	1699.1	1704.2	1708.0	1718.5
P17	3,300 ft downstream of spillway crest	1694.6	1699.0	1702.4	1708.0	1719.0

NOTES:

1) Elevations are in the NGVD29 Datum
2) Refer to Figure 4.1 for Pressure Tap Locations.
3) Gate openings are equal in all three spillway bays.

OXBOW DAM SPILLWAY
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TABLE 6.3.4

Water Surface Elevation Data Summary
Erosion Test - Final Documentation

Gage	Location	WSEL (ft)
		70,000 cfs
	Model Spillway Gate Opening (ft)	*21.5*
Reservoir		
P1	408 ft upstream of spillway crest	1806.6
P2	404 ft upstream of spillway crest	1806.3
P3	202 ft upstream of spillway crest	1805.6
P4	110 ft upstream of spillway crest	1805.2
Spillway Chute		
P5	92 ft downstream of spillway crest	--
P6	284 ft downstream of spillway crest	--
P7	476 ft downstream of spillway crest	--
Downstream River Channel		
P8	478 ft downstream of spillway crest	1700.9
P9	660 ft downstream of spillway crest	1696.8
P10	669 ft downstream of spillway crest	1700.2
P11	914 ft downstream of spillway crest	1702.3
P12	1,299 ft downstream of spillway crest	1707.7
P13	1,691 ft downstream of spillway crest	1706.0
P14	2,081 ft downstream of spillway crest	1702.9
P15	2,475 ft downstream of spillway crest	1703.0
P16	2,867 ft downstream of spillway crest	1704.0
P17	3,300 ft downstream of spillway crest	--

NOTES:

1) Elevations are in the NGVD29 Datum
2) Refer to Figure 4.1 for Pressure Tap Locations.
3) Gate openings are equal in all three spillway bays.

OXBOW DAM SPILLWAY
TRS ALTERNATIVES STUDY
HYDRAULIC MODEL STUDY

TABLE 6.3.5

Downstream Velocity Data Summary
Final Documentation
20,000 cfs Spillway Discharge

Measurement Location		**Left Bank Velocities (ft/s)**			**Right Bank Velocities (ft/s)**		
	Distance from bank (ft)	*10*	*25*	*50*	*50*	*25*	*10*
Template 14	*629ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	4	4	3
	Mid-depth velocity (ft/s)	-	-	-	4	5	-
Template 15	*735 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	3	3	3
	Mid-depth velocity (ft/s)	-	-	-	3	3	3
Template 16	*867ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	4	4	4
	Mid-depth velocity (ft/s)	-	-	-	4	4	4
Template 17	*1,010ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	7	5	13	5	7	8
	Mid-depth velocity (ft/s)	4	12	17	5	7	7
Template 18	*1,177 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	16	16	12	-	11	11
	Mid-depth velocity (ft/s)	15	11	6	-	10	12
Template 19	*1,328 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	13	12	15	3	15	17
	Mid-depth velocity (ft/s)	13	15	14	-	15	14
Template 20	*1,569ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	20	19	23	11	11	4
	Mid-depth velocity (ft/s)	-	-	-	12	11	-
Template 21	*1,718ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	4	5	4	16	9	8
	Mid-depth velocity (ft/s)	-	7	4	15	13	-
Template 22	*1,887 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	3	6	10	15	5	5
	Mid-depth velocity (ft/s)	-	-	10	12	4	5
Template 23	*2,054 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	7	11	12	17	13	7
	Mid-depth velocity (ft/s)	-	13	13	16	15	-
Template 24	*2,215 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	6	11	13	4	9	7
	Mid-depth velocity (ft/s)	-	11	13	5	9	5

NOTES:

1) Refer to Figure 6.3.16 for velocity measurement locations.
2) Velocity values shown are the average values recorded. Fluctuations of approximately 10% (or greater) were noted at most locations.

OXBOW DAM SPILLWAY
TRS ALTERNATIVES STUDY
HYDRAULIC MODEL STUDY

TABLE 6.3.6

Downstream Velocity Data Summary
Final Documentation
40,000 cfs Spillway Discharge

Measurement Location	**Left Bank Velocities (ft/s)**			**Right Bank Velocities (ft/s)**		
Distance from bank (ft)	*10*	*25*	*50*	*50*	*25*	*10*
Template 14 *629ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	3	3	3
Mid-depth velocity (ft/s)	-	-	-	3	-	-
Template 15 *735 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	4	3	4
Mid-depth velocity (ft/s)	-	-	-	3	4	4
Template 16 *867ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	4	3	3
Mid-depth velocity (ft/s)	-	-	-	4	3	3
Template 17 *1,010ft d/s of spillway crest*						
Near-surface velocity (ft/s)	6	9	13	4	3	3
Mid-depth velocity (ft/s)	5	7	14	3	3	3
Template 18 *1,177 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	11	16	12	5	8	10
Mid-depth velocity (ft/s)	15	13	9	7	8	9
Template 19 *1,328 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	15	15	17	4	10	12
Mid-depth velocity (ft/s)	17	14	17	3	10	11
Template 20 *1,569ft d/s of spillway crest*						
Near-surface velocity (ft/s)	20	22	22	8	10	3
Mid-depth velocity (ft/s)	-	21	21	9	9	-
Template 21 *1,718ft d/s of spillway crest*						
Near-surface velocity (ft/s)	5	7	4	12	11	6
Mid-depth velocity (ft/s)	-	7	6	14	12	-
Template 22 *1,887 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	3	4	7	16	13	4
Mid-depth velocity (ft/s)	-	4	6	15	11	5
Template 23 *2,054 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	8	9	12	17	12	8
Mid-depth velocity (ft/s)	-	10	13	16	15	-
Template 24 *2,215 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	4	11	17	6	9	5
Mid-depth velocity (ft/s)	-	12	17	4	10	6

NOTES:

1) Refer to Figure 6.3.16 for velocity measurement locations.
2) Velocity values shown are the average values recorded. Fluctuations of approximately 10% (or greater) were noted at most locations.

OXBOW DAM SPILLWAY
TRS ALTERNATIVES STUDY
HYDRAULIC MODEL STUDY

TABLE 6.3.7

Downstream Velocity Data Summary
Final Documentation
60,000 cfs Spillway Discharge

Measurement Location	**Left Bank Velocities (ft/s)**			**Right Bank Velocities (ft/s)**		
Distance from bank (ft)	*10*	*25*	*50*	*50*	*25*	*10*
Template 14 *629ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	9	5	3
Mid-depth velocity (ft/s)	-	-	-	9	5	-
Template 15 *735 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	9	10	8
Mid-depth velocity (ft/s)	-	-	-	9	9	9
Template 16 *867ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	9	10	10
Mid-depth velocity (ft/s)	-	-	-	9	10	10
Template 17 *1,010ft d/s of spillway crest*						
Near-surface velocity (ft/s)	11	8	7	4	7	8
Mid-depth velocity (ft/s)	8	9	8	4	8	8
Template 18 *1,177 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	5	9	21	7	6	4
Mid-depth velocity (ft/s)	11	16	9	3	3	4
Template 19 *1,328 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	20	18	20	7	7	6
Mid-depth velocity (ft/s)	19	23	137	4	8	4
Template 20 *1,569ft d/s of spillway crest*						
Near-surface velocity (ft/s)	19	24	26	9	10	6
Mid-depth velocity (ft/s)	-	25	25	10	9	5
Template 21 *1,718ft d/s of spillway crest*						
Near-surface velocity (ft/s)	4	5	7	13	12	9
Mid-depth velocity (ft/s)	-	5	9	14	12	-
Template 22 *1,887 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	3	3	5	13	6	3
Mid-depth velocity (ft/s)	-	3	5	15	6	-
Template 23 *2,054 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	7	11	15	13	11	6
Mid-depth velocity (ft/s)	-	11	14	14	-	-
Template 24 *2,215 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	7	17	20	6	4	5
Mid-depth velocity (ft/s)	7	17	18	7	-	-

NOTES:

1) Refer to Figure 6.3.16 for velocity measurement locations.
2) Velocity values shown are the average values recorded. Fluctuations of approximately 10% (or greater) were noted at most locations.

OXBOW DAM SPILLWAY
TRS ALTERNATIVES STUDY
HYDRAULIC MODEL STUDY

TABLE 6.3.8

Downstream Velocity Data Summary
Final Documentation
100,000 cfs Spillway Discharge

Measurement Location		**Left Bank Velocities (ft/s)**			**Right Bank Velocities (ft/s)**		
	Distance from bank (ft)	*10*	*25*	*50*	*50*	*25*	*10*
Template 14	*629ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	10	10	4
	Mid-depth velocity (ft/s)	-	-	-	12	11	5
Template 15	*735 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	11	11	12
	Mid-depth velocity (ft/s)	-	-	-	10	14	13
Template 16	*867ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	-	-	-	13	11	12
	Mid-depth velocity (ft/s)	-	-	-	13	11	11
Template 17	*1,010ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	19	13	8	8	13	15
	Mid-depth velocity (ft/s)	16	15	11	5	5	13
Template 18	*1,177 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	19	13	8	8	13	15
	Mid-depth velocity (ft/s)	16	15	11	5	5	13
Template 19	*1,328 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	22	25	26	9	10	6
	Mid-depth velocity (ft/s)	25	21	22	11	8	9
Template 20	*1,569ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	23	8	5	16	15	10
	Mid-depth velocity (ft/s)	-	10	6	17	15	11
Template 21	*1,718ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	7	8	5	16	15	10
	Mid-depth velocity (ft/s)	-	10	6	17	15	11
Template 22	*1,887 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	4	7	9	17	14	11
	Mid-depth velocity (ft/s)	-	-	6	18	12	12
Template 23	*2,054 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	11	13	15	20	16	13
	Mid-depth velocity (ft/s)	-	10	13	21	18	-
Template 24	*2,215 ft d/s of spillway crest*						
	Near-surface velocity (ft/s)	4	4	4	6	8	4
	Mid-depth velocity (ft/s)	-	-	-	6	9	-

NOTES:

1) Refer to Figure 6.3.17 for velocity measurement locations.
2) Velocity values shown are the average values recorded. Fluctuations of approximately 10% (or greater) were noted at most locations.

OXBOW DAM SPILLWAY
TRS ALTERNATIVES STUDY
HYDRAULIC MODEL STUDY

TABLE 6.3.9

Downstream Velocity Data Summary
Final Documentation
150,000 cfs Spillway Discharge

Measurement Location	**Left Bank Velocities (ft/s)**			**Right Bank Velocities (ft/s)**		
Distance from bank (ft)	*10*	*25*	*50*	*50*	*25*	*10*
Template 14 *629ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	-	-	-
Mid-depth velocity (ft/s)	-	-	-	-	100	-
Template 15 *735 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	-	-	-
Mid-depth velocity (ft/s)	-	-	-	-	-	-
Template 16 *867ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	-	-	-
Mid-depth velocity (ft/s)	-	-	-	-	130	-
Template 17 *1,010ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	-	-	-
Mid-depth velocity (ft/s)	-	-	-	-	-	-
Template 18 *1,177 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	-	-	-
Mid-depth velocity (ft/s)	-	130	-	-	60	-
Template 19 *1,328 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	-	-	-
Mid-depth velocity (ft/s)	-	-	-	-	-	-
Template 20 *1,569ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	-	-	-
Mid-depth velocity (ft/s)	-	150	-	-	120	-
Template 21 *1,718ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	-	-	-
Mid-depth velocity (ft/s)	-	-	-	-	-	-
Template 22 *1,887 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	-	-	-
Mid-depth velocity (ft/s)	-	140	20	-	150	-
Template 23 *2,054 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	-	-	-
Mid-depth velocity (ft/s)	-	-	-	-	-	-
Template 24 *2,215 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	-	-	-
Mid-depth velocity (ft/s)	-	-	-	-	-	-

NOTES:

1) Refer to Figure 6.3.17 for velocity measurement locations.
2) Velocity values shown are the average values recorded. Fluctuations of approximately 10% (or greater) were noted at most locations.

OXBOW DAM SPILLWAY
TRS ALTERNATIVES STUDY
HYDRAULIC MODEL STUDY

TABLE 6.3.10

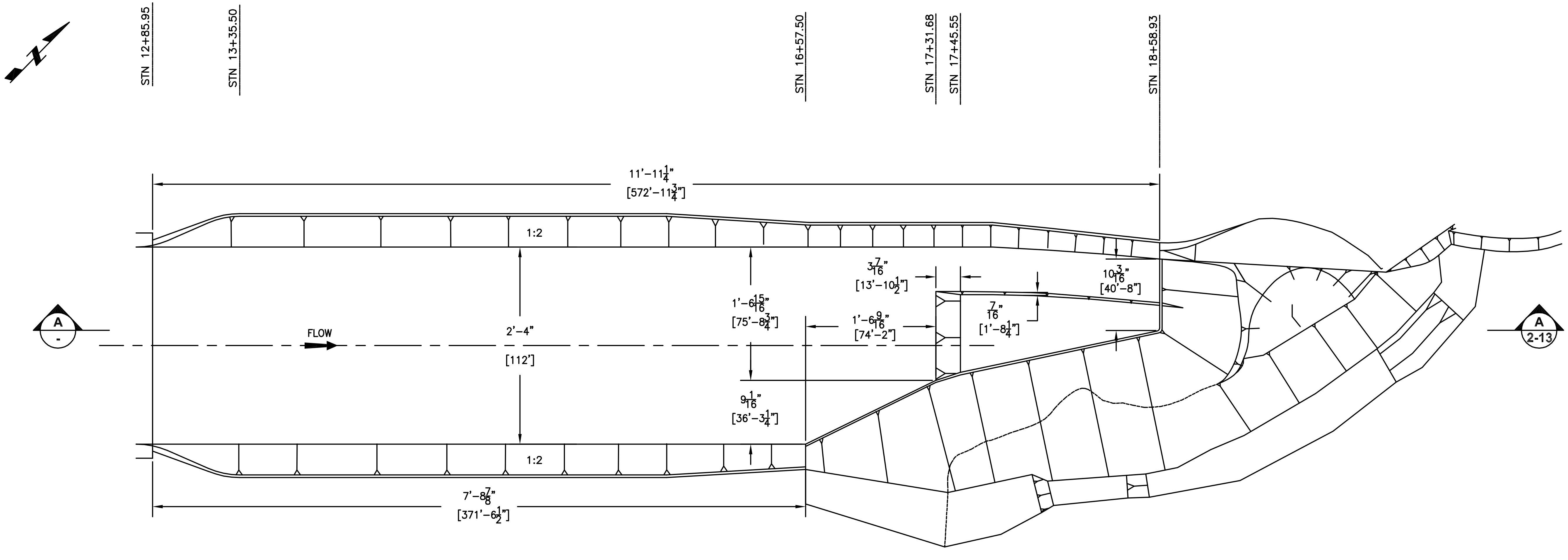
Downstream Velocity Data Summary
Erosion Test - Final Documentation
70,000 cfs Spillway Discharge

Measurement Location	**Left Bank Velocities (ft/s)**			**Right Bank Velocities (ft/s)**		
Distance from bank (ft)	*10*	*25*	*50*	*50*	*25*	*10*
Template 14 *629ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	14.0	8.1	4.3
Mid-depth velocity (ft/s)	-	-	-	14.7	8.7	4.3
Template 15 *735 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	14.3	14.7	14.0
Mid-depth velocity (ft/s)	-	-	-	14.0	15.2	16.0
Template 16 *867ft d/s of spillway crest*						
Near-surface velocity (ft/s)	-	-	-	13.4	12.7	12.0
Mid-depth velocity (ft/s)	-	-	-	14.7	14.7	14.7
Template 17 *1,010ft d/s of spillway crest*						
Near-surface velocity (ft/s)	13.4	9.4	13.4	10.7	13.4	11.4
Mid-depth velocity (ft/s)	8.1	12.0	14.7	6.8	9.4	12.7
Template 18 *1,177 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	13.4	18.6	11.4	8.7	6.8	6.1
Mid-depth velocity (ft/s)	13.4	13.4	12.7	6.4	6.1	4.1
Template 19 *1,328 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	21.3	22.6	20.0	7.4	7.2	8.1
Mid-depth velocity (ft/s)	21.3	18.0	18.0	6.2	7.7	8.7
Template 20 *1,569ft d/s of spillway crest*						
Near-surface velocity (ft/s)	17.3	14.0	22.6	14.2	12.7	6.1
Mid-depth velocity (ft/s)	-	14.0	22.6	15.5	16.0	6.8
Template 21 *1,718ft d/s of spillway crest*						
Near-surface velocity (ft/s)	5.5	5.5	8.1	16.7	14.7	11.4
Mid-depth velocity (ft/s)	-	4.1	9.4	18.0	15.3	10.7
Template 22 *1,887 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	8.1	14.0	17.3	15.2	10.1	3.7
Mid-depth velocity (ft/s)	-	14.0	13.4	15.5	8.1	3.5
Template 23 *2,054 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	8.7	15.3	17.3	18.0	15.2	7.4
Mid-depth velocity (ft/s)	-	14.7	16.7	18.6	15.5	-
Template 24 *2,215 ft d/s of spillway crest*						
Near-surface velocity (ft/s)	4.1	19.2	20.0	6.1	7.0	-
Mid-depth velocity (ft/s)	-	20.0	19.0	5.7	-	-

NOTES:

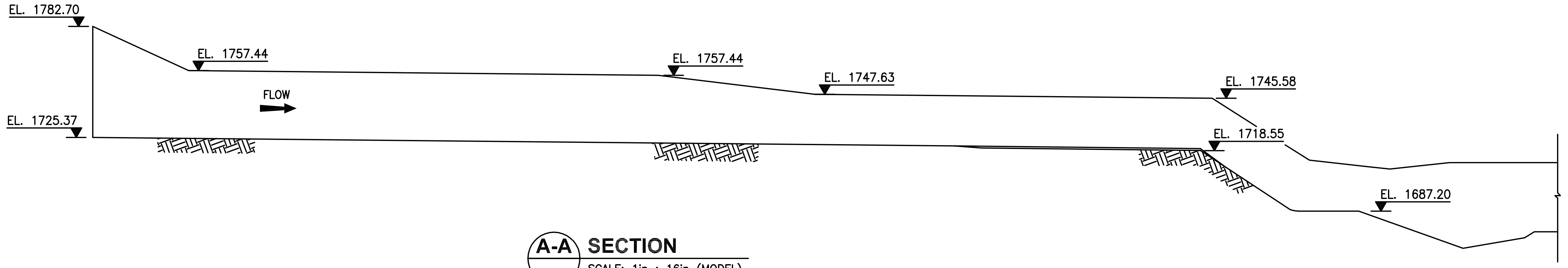
1) Refer to Figure 6.3.17 for velocity measurement locations.
2) Velocity values shown are the average values recorded. Fluctuations of approximately 10% (or greater) were noted at most locations.

FIGURES



- PLAN VIEW - SPILLWAY CHUTE

\- SCALE: 1in : 16in (MODEL)



A-A SECTION

\- SCALE: 1in : 16in (MODEL)

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Plan View and Elevation
of Spillway and Chute

21513–015	REV. NO.: 0	DRN. BY: RKJ	MAR–15–07

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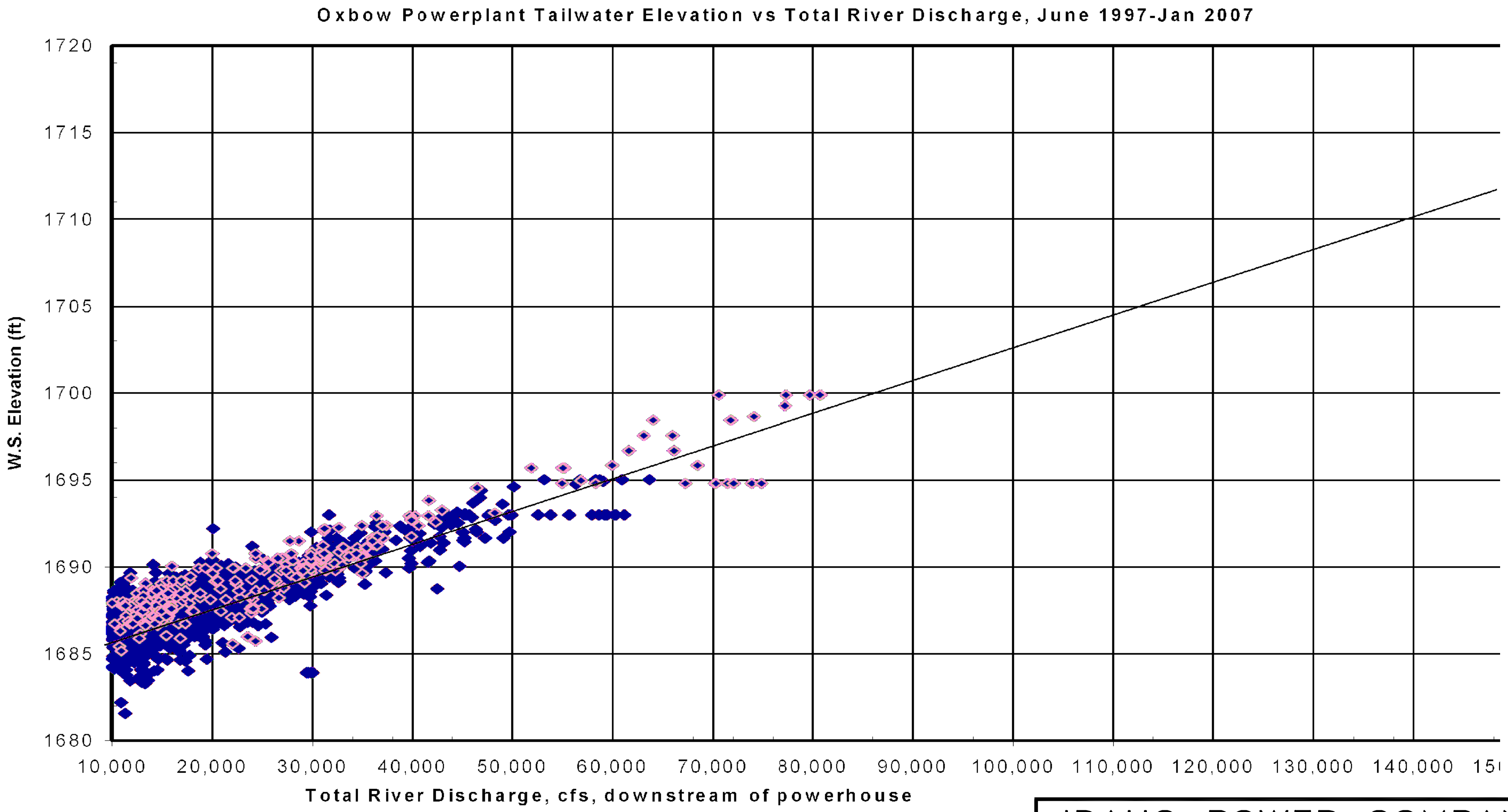
0 8" 16" 24" 32"

DISTANCE IN FEET AND INCHES
SCALE 1 in : 16in

NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
2. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET AND INCHES.
3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
4. MODEL SCALE 1:48
5. FABRICATION TOLERANCE = 1/16"

FIGURE 1.1



IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Rating Curve Upstream of
Oxbow Powerhouse

21513–8.5x11	REV. NO.: 0	DRN. BY: JAB	OCT–12–07

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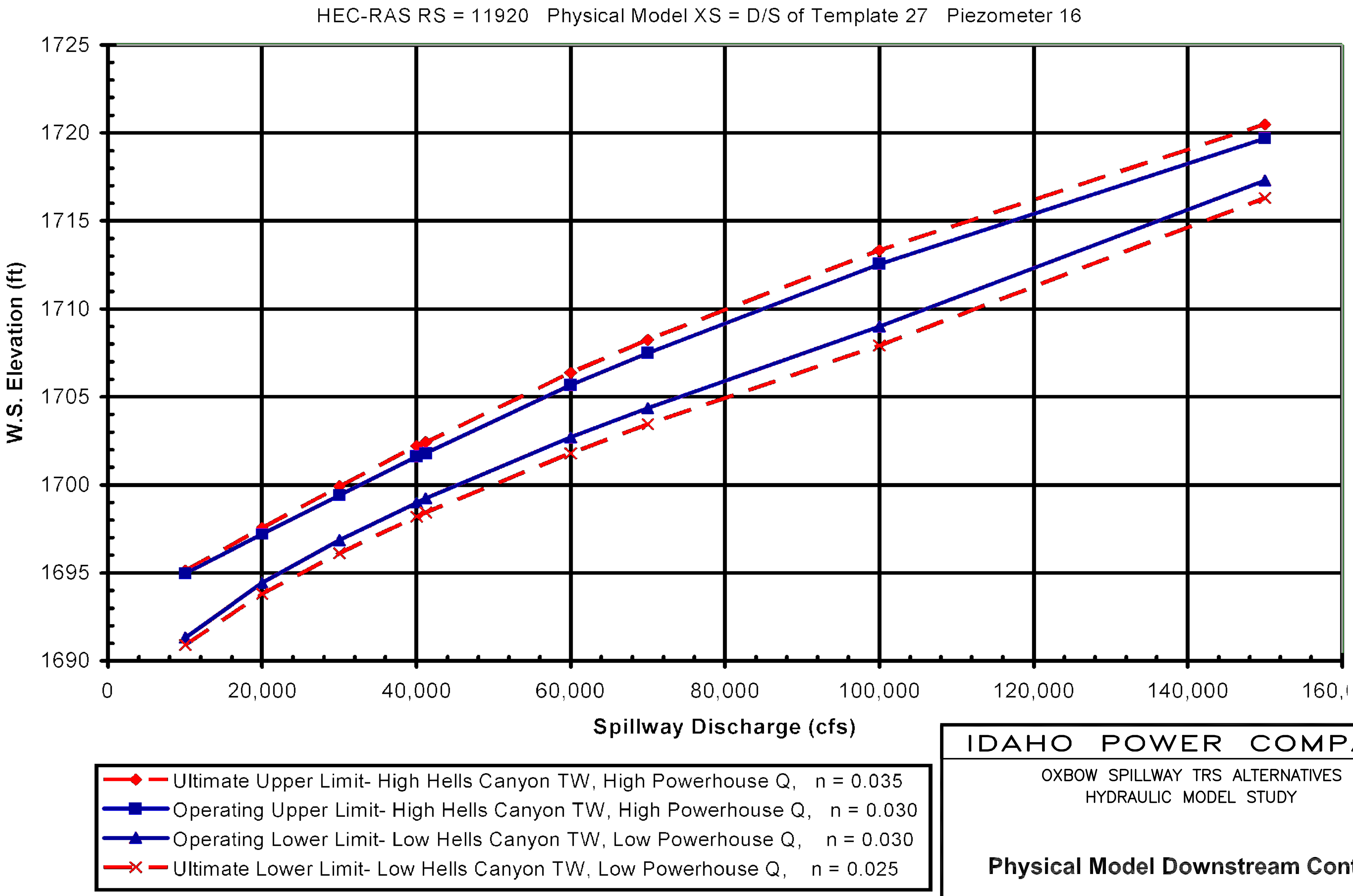
FIGURE 2.1



IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Physical Model Downstream Control
Rating Curve

21513-8.5x11	REV. NO.: 0	DRN. BY: JAB	OCT-12-07

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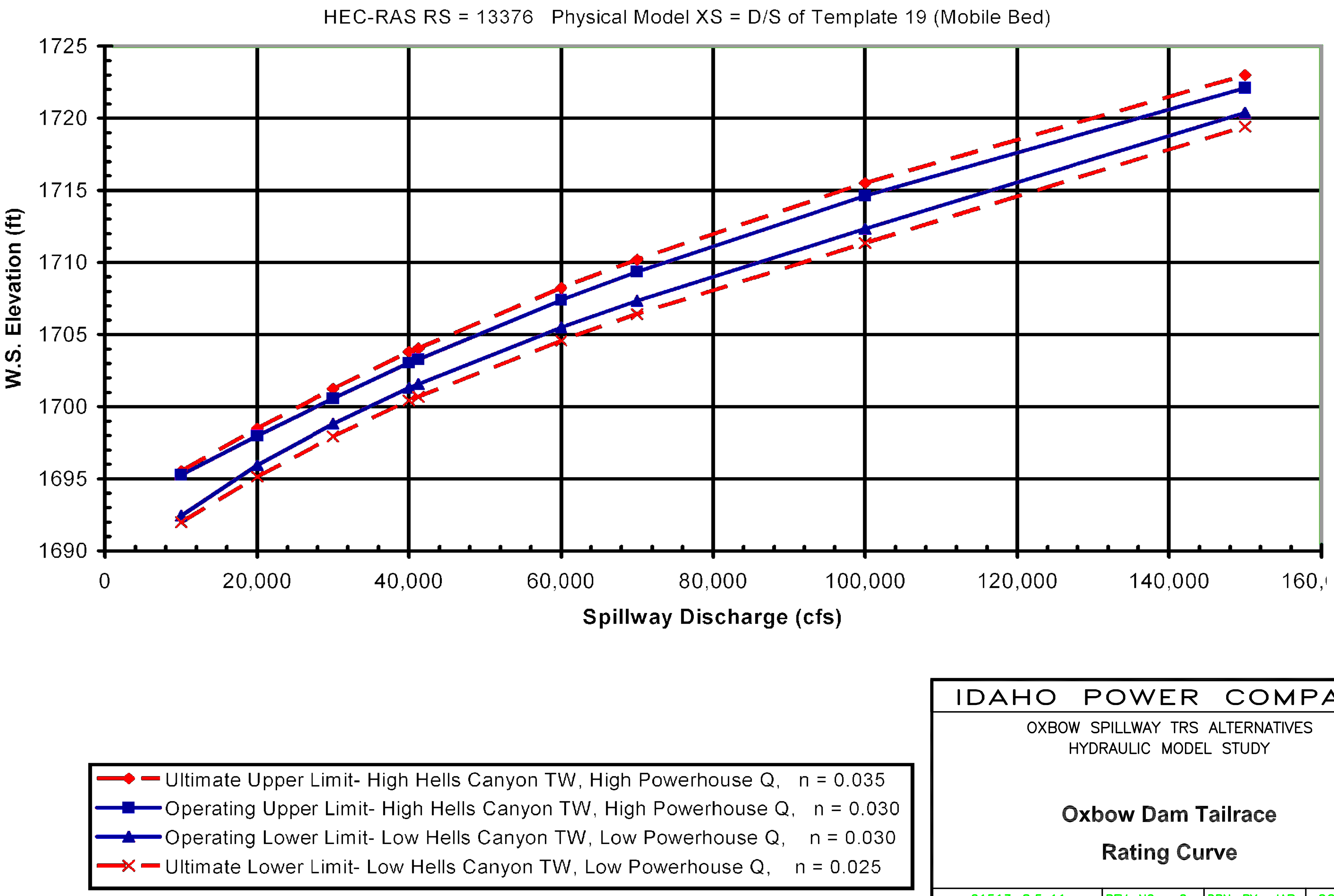
FIGURE 2.2



IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Oxbow Dam Tailrace

Rating Curve

21513–8.5x11	REV. NO.: 0	DRN. BY: JAB	OCT–12–07

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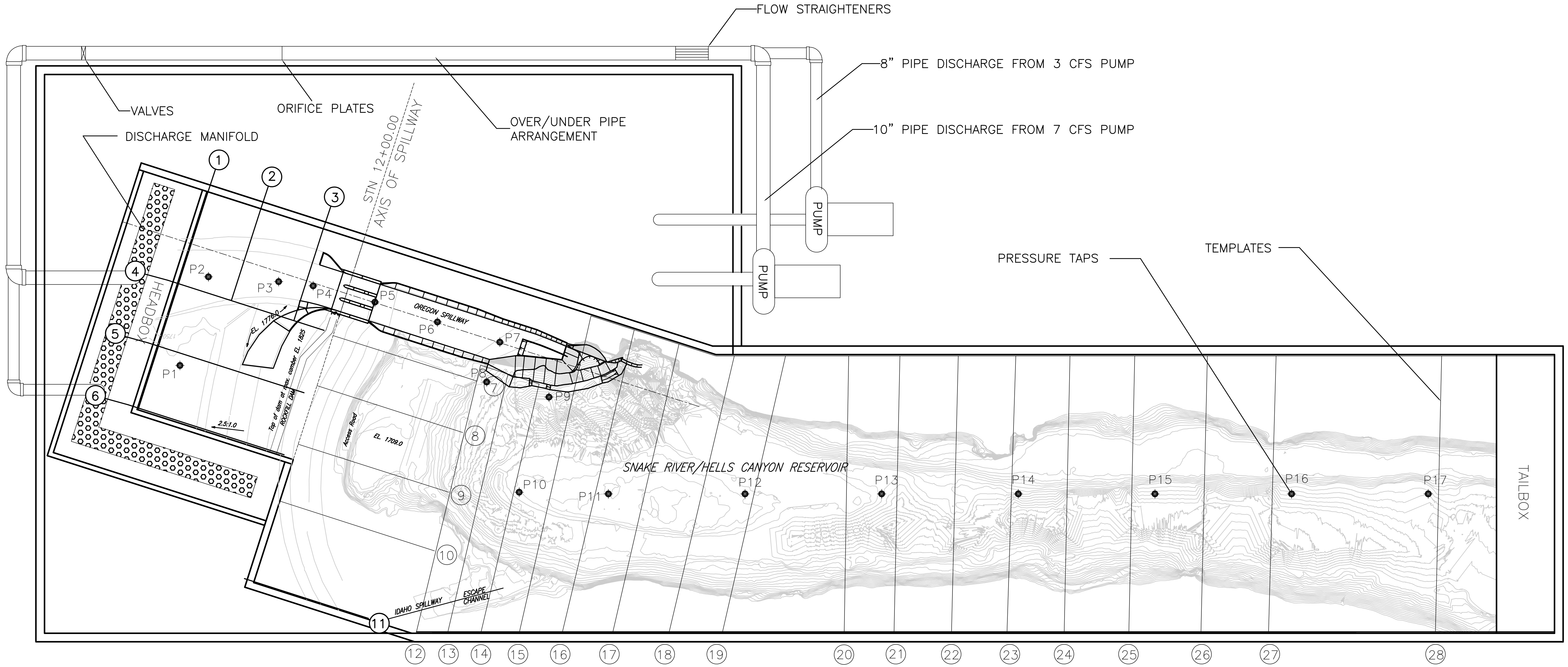
FIGURE 2.3



DISTANCE IN MODEL FEET
(1" = 6'-6")
0 3'-3" 6'-6" 9'-9" 13'
0 156' 312' 468' 624'
DISTANCE IN PROTOTYPE FEET
(1" = 312')

NOTES:
1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
2. ALL STATIONS AND ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
3. MODEL SCALE 1:48
4. FABRICATION TOLERANCE = 1/16"

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Model Layout
General Arrangement

21513-016	REV. NO.: 0	DRN. BY: JYJ	Nov-06-07

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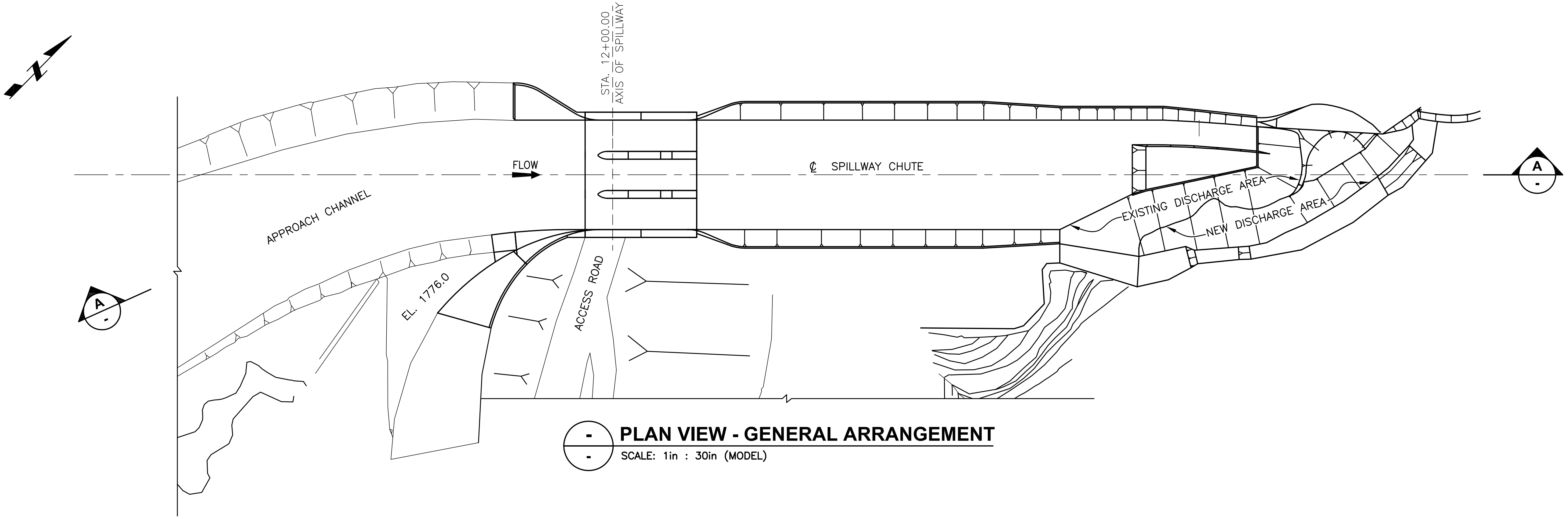
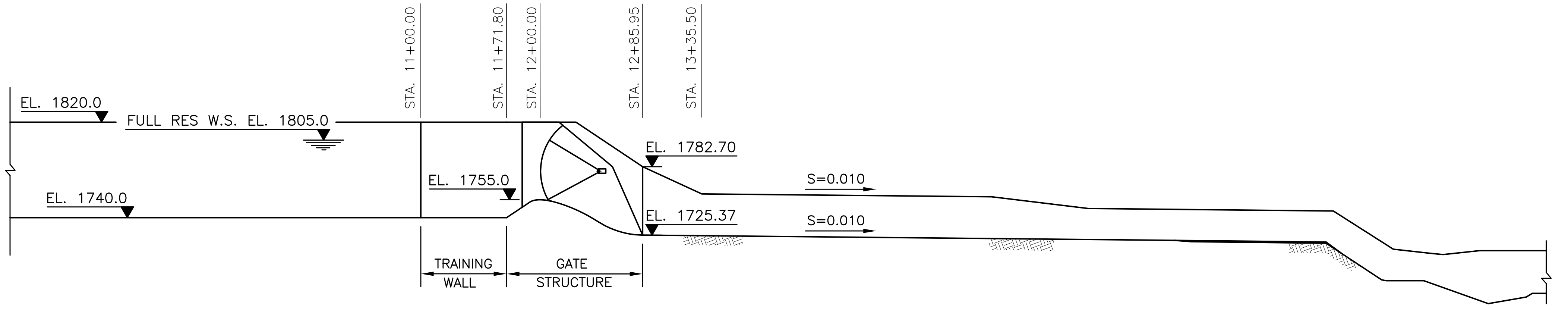
FIGURE 4.1



- **-** **PLAN VIEW - GENERAL ARRANGEMENT**

SCALE: 1in : 30in (MODEL)



A-A **-** **SECTION**

SCALE: 1in : 30in (MODEL)

NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET AND INCHES.
2. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.

0 15" 30" 45" 60"

DISTANCE IN FEET AND INCHES
SCALE 1in : 30in

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Model Layout
Spillway
General Arrangement and Section

21513-011	REV. NO.: 0	DRN. BY: RKJ	Nov-06-2007

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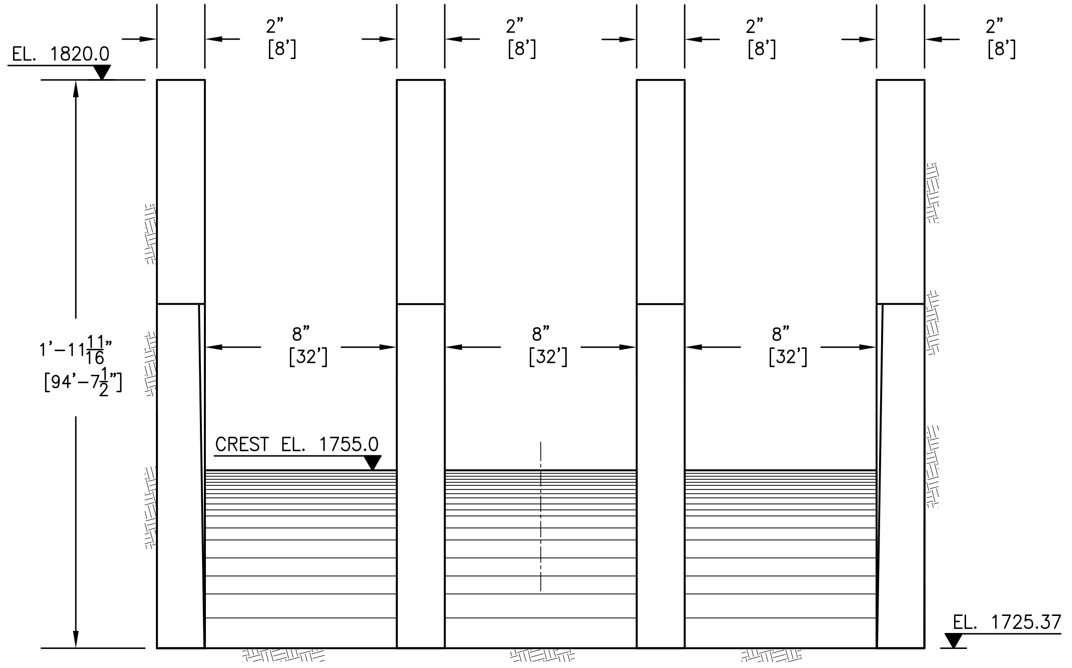
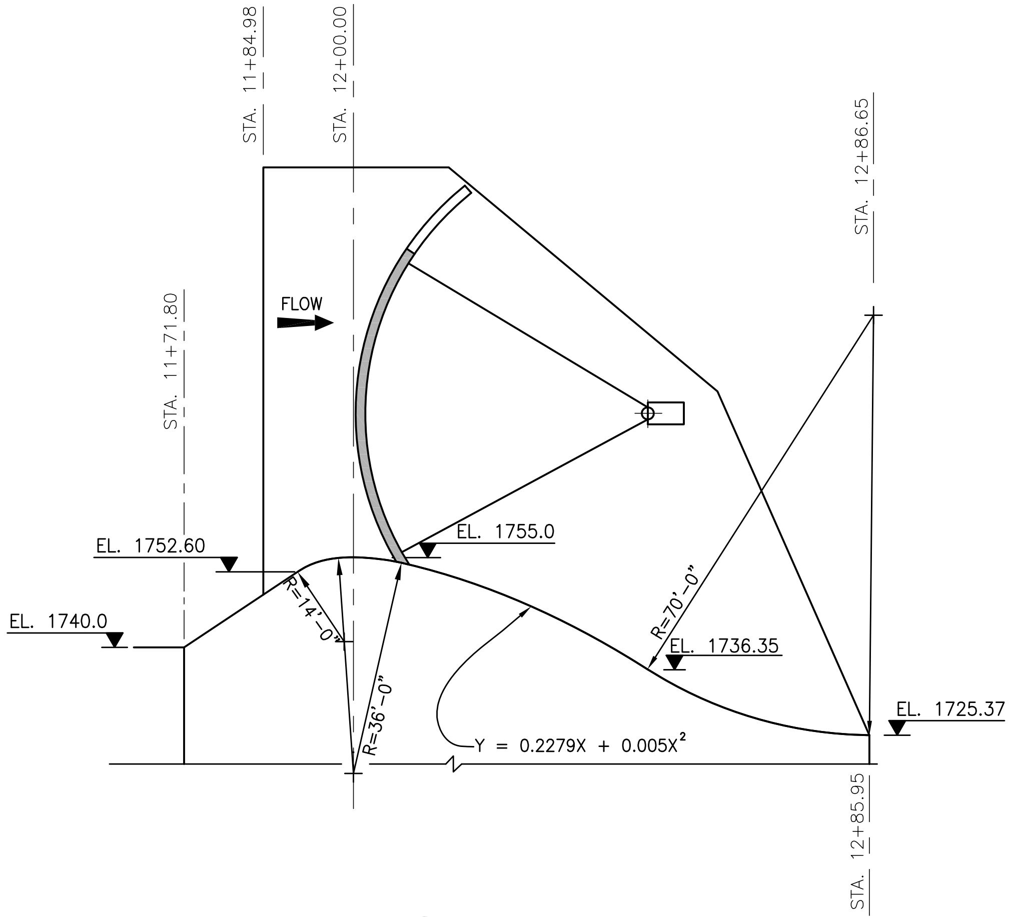
FIGURE 4.2



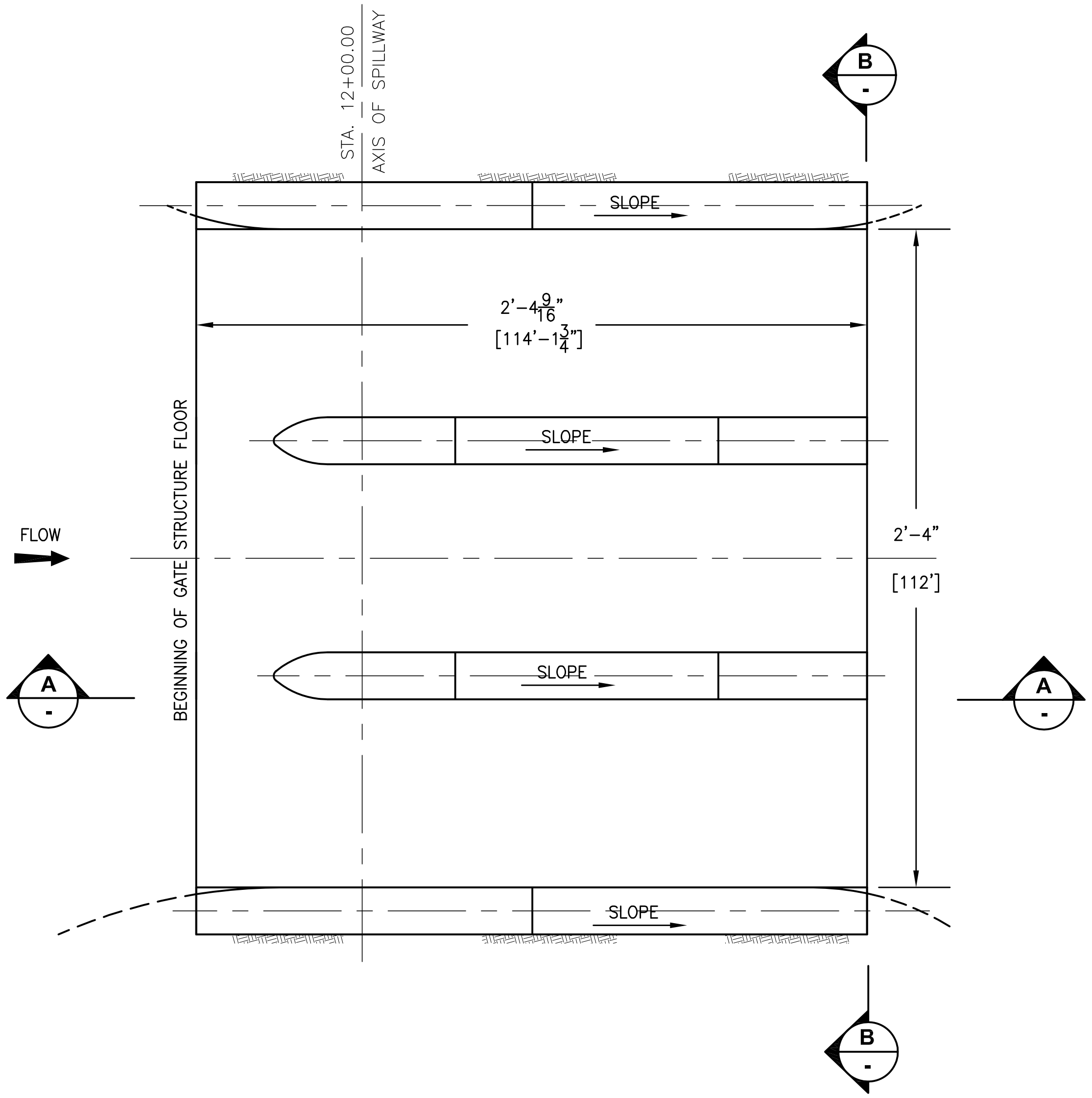
B-B SECTION
-
SCALE: 1in : 8in (MODEL)



A-A SECTION
-
SCALE: 1in : 8in (MODEL)

NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
2. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET AND INCHES.
3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
4. MODEL SCALE 1:48
5. FABRICATION TOLERANCE = 1/16"



- PLAN - SPILLWAY CREST
-
SCALE: 1in : 8in (MODEL)

0 4" 8" 12" 16"
DISTANCE IN FEET AND INCHES
SCALE 1in : 8in

IDAHO POWER COMPANY
OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Model Layout
Spillway Crest
Plan and Sections

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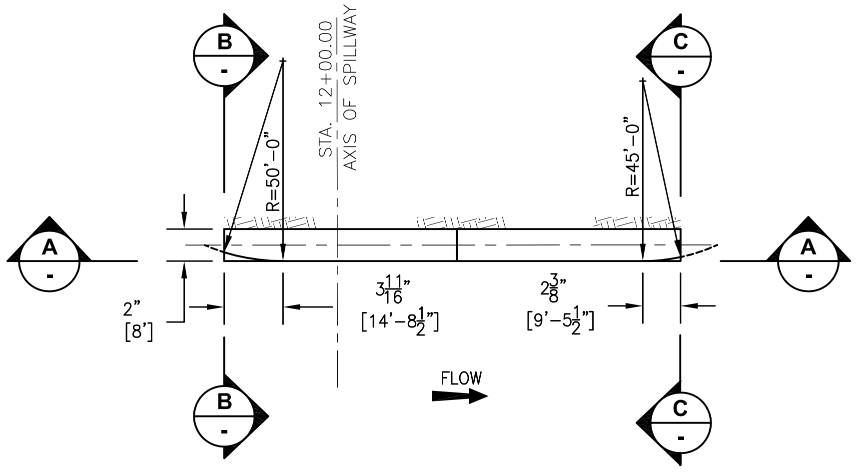
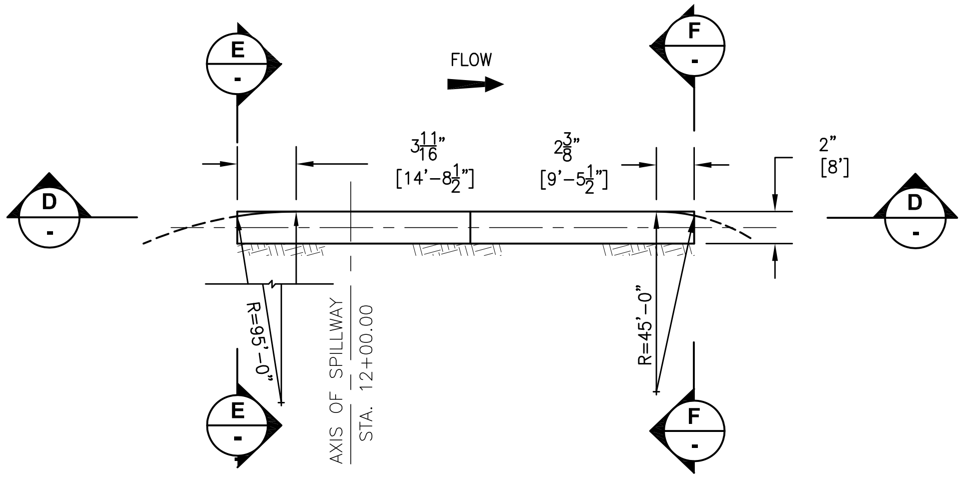
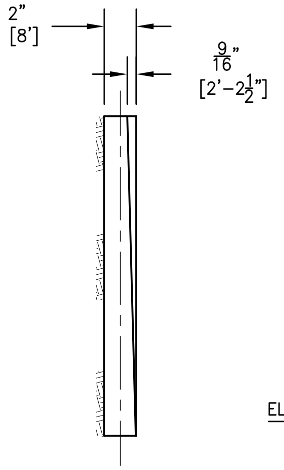
FIGURE 4.3



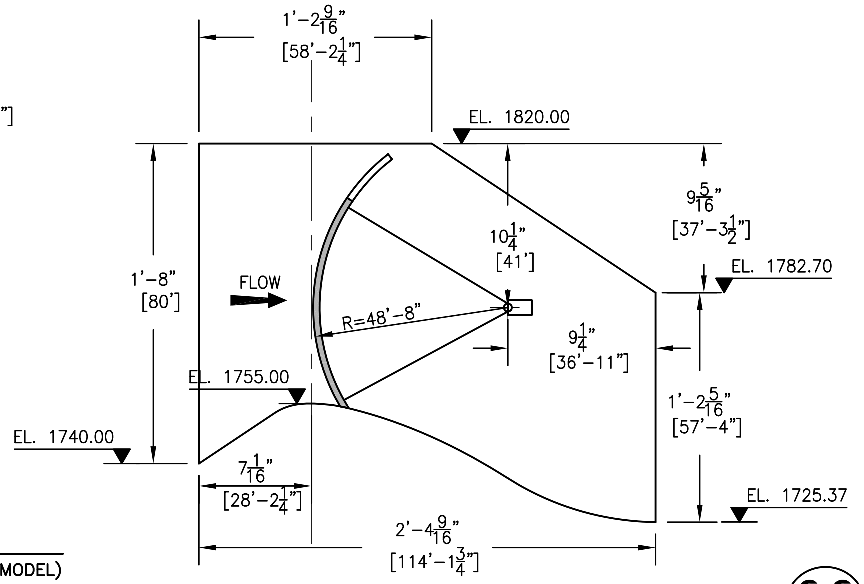
- PLAN - ABUTMENT PIER - NORTH SIDE
SCALE: 1in : 12in (MODEL)



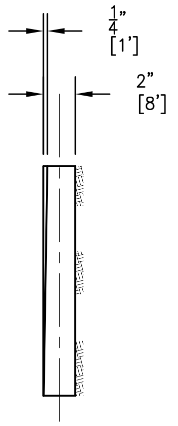
- PLAN - ABUTMENT PIER - SOUTH SIDE
SCALE: 1in : 12in (MODEL)



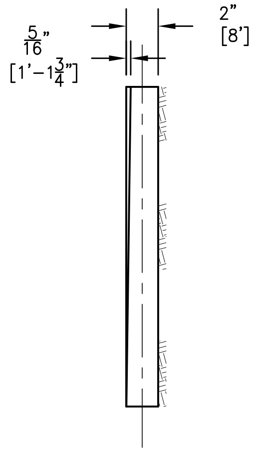
B-B SECTION
SCALE: 1in : 12in (MODEL)



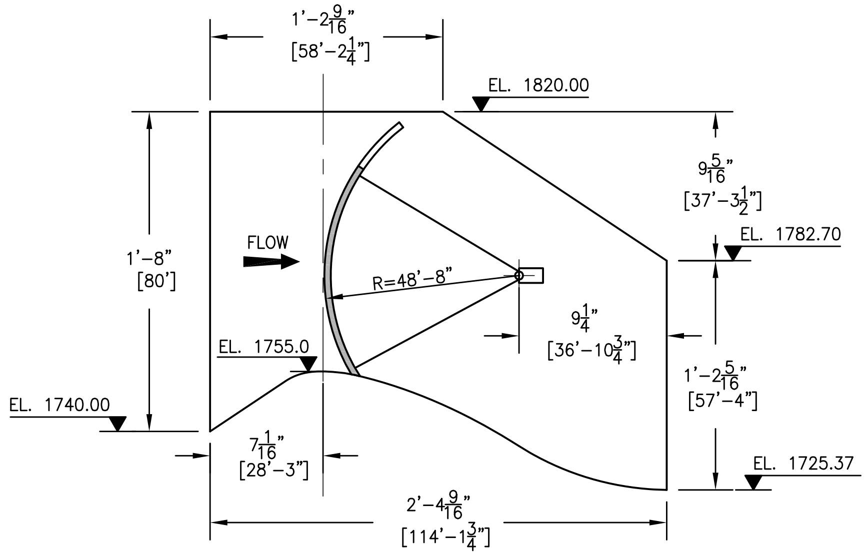
A-A SECTION
SCALE: 1in : 12in (MODEL)



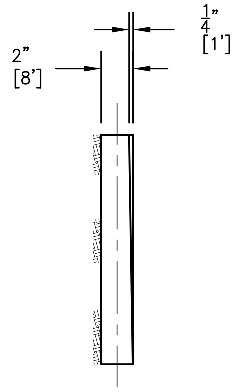
C-C SECTION
SCALE: 1in : 12in (MODEL)



E-E SECTION
SCALE: 1in : 12in (MODEL)



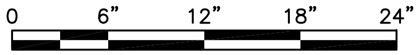
D-D SECTION
SCALE: 1in : 12in (MODEL)



F-F SECTION
SCALE: 1in : 12in (MODEL)

NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
2. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET AND INCHES.
3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
4. MODEL SCALE 1:48
5. FABRICATION TOLERANCE = 1/16"



DISTANCE IN FEET AND INCHES
SCALE 1in : 12in

IDAHO POWER COMPANY
OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Model Layout
Piers - North and South Side
Plan and Sections

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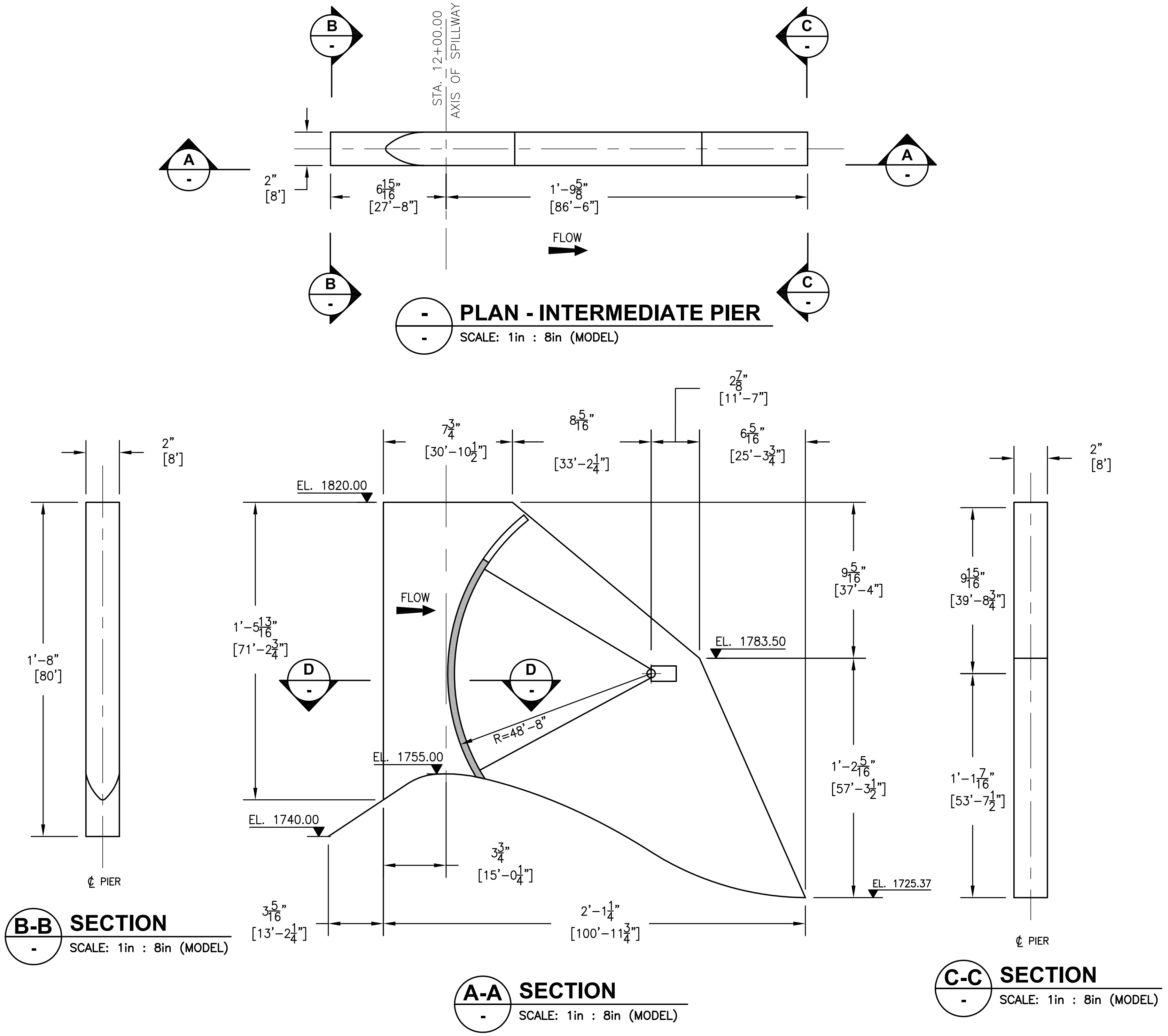
FIGURE 4.4

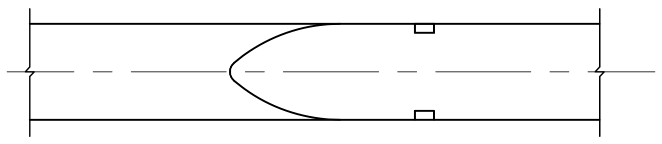


PLAN - INTERMEDIATE PIER
SCALE: 1in : 8in (MODEL)

B-B SECTION
SCALE: 1in : 8in (MODEL)

A-A SECTION
SCALE: 1in : 8in (MODEL)

C-C SECTION
SCALE: 1in : 8in (MODEL)



D-D SECTION
SCALE: 1in : 4in (MODEL)

0 2" 4" 6" 8"
DISTANCE IN FEET AND INCHES
SCALE 1in : 4in

NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
2. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET AND INCHES.
3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
4. MODEL SCALE 1:48
5. FABRICATION TOLERANCE = 1/16"

0 4" 8" 12" 16"
DISTANCE IN FEET AND INCHES
SCALE 1in : 8in

IDAHO POWER COMPANY
OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Model Layout
Intermediate Piers
Plan and Sections

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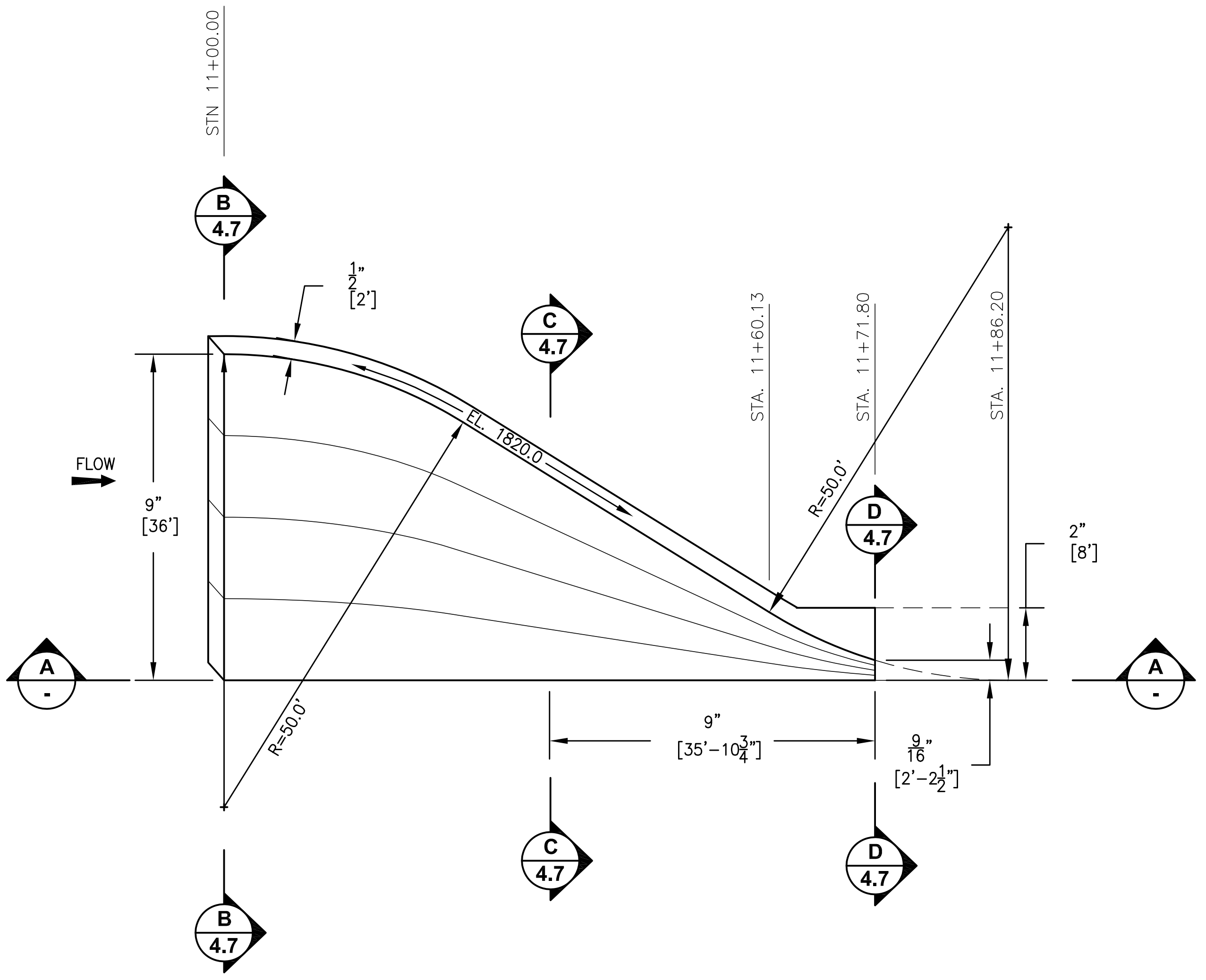
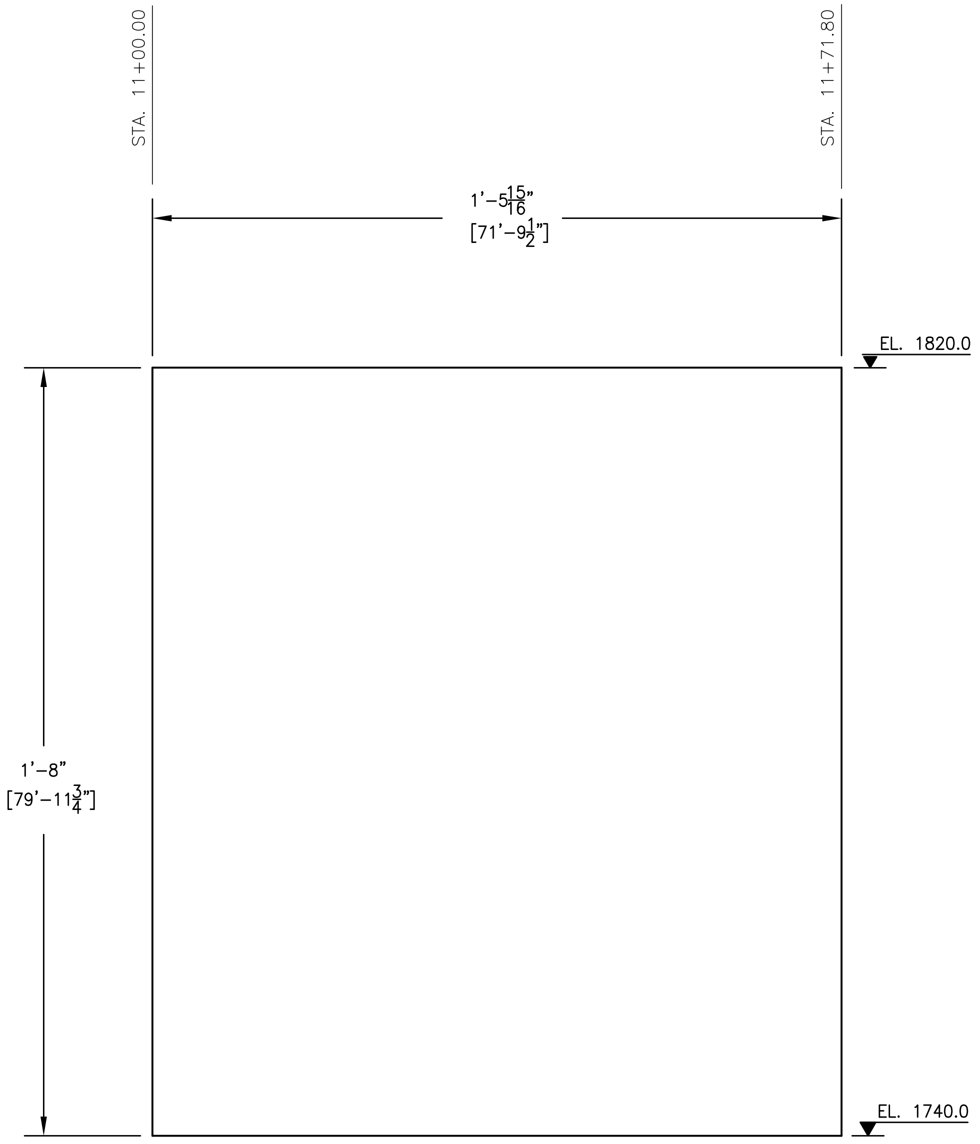
FIGURE 4.5



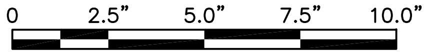
- | **PLAN VIEW - LEFT TRAINING WALL**
- | SCALE: 1in : 5in (MODEL)



A-A | **SECTION**
- | SCALE: 1in : 5in (MODEL)

NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
2. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET AND INCHES.
3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
4. MODEL SCALE 1:48
5. FABRICATION TOLERANCE = 1/16"



DISTANCE IN FEET AND INCHES
SCALE 1in : 5in

IDAHO POWER COMPANY
OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Model Layout
Spillway Training Wall - North Side
Plan and Section

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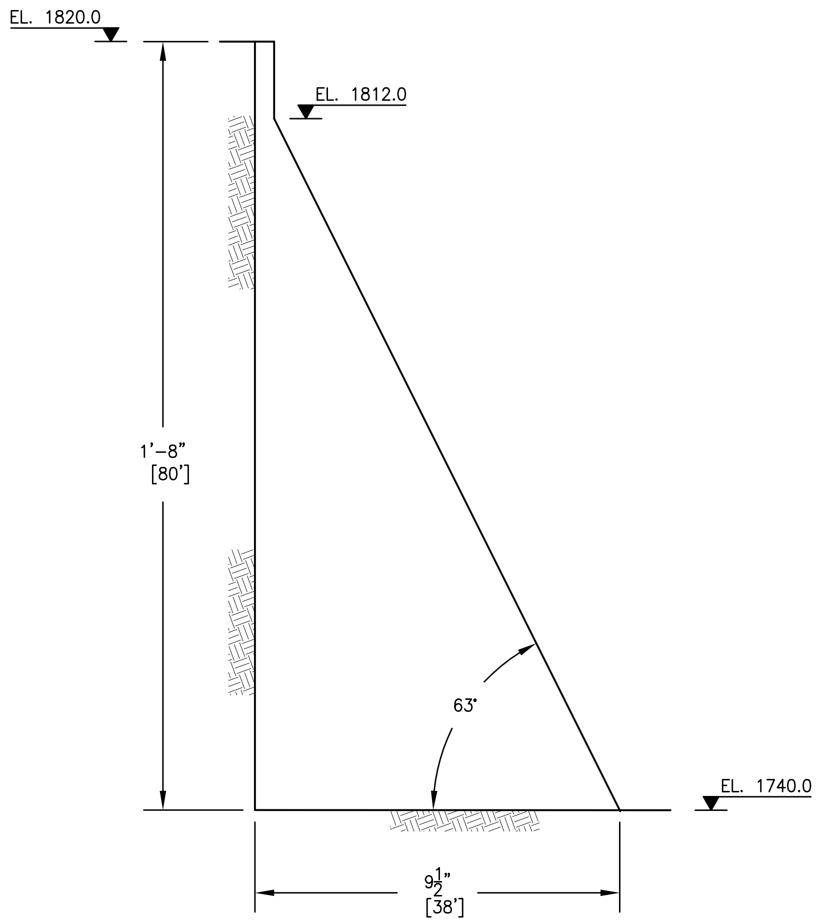
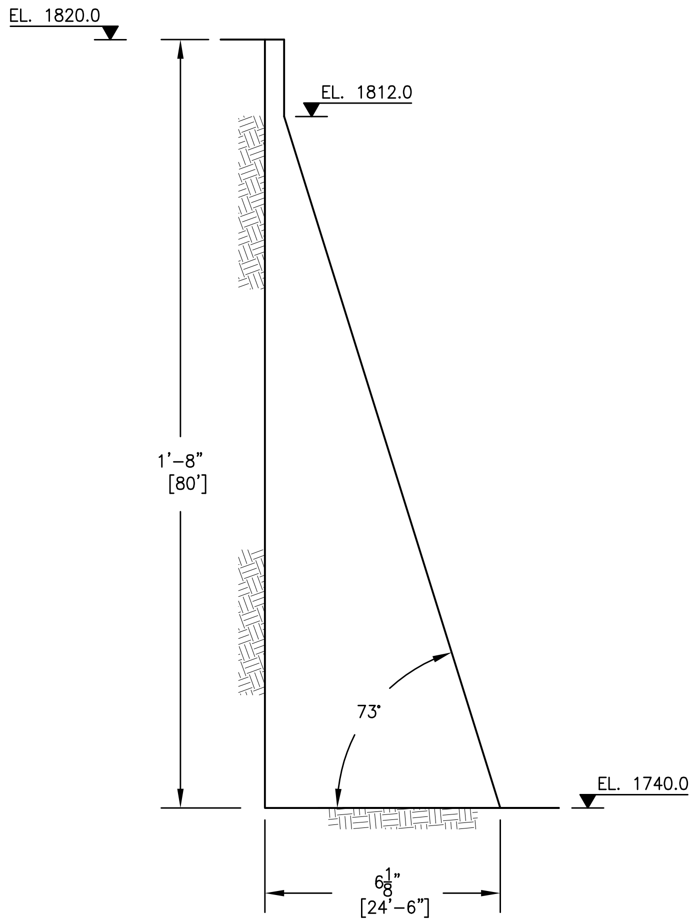
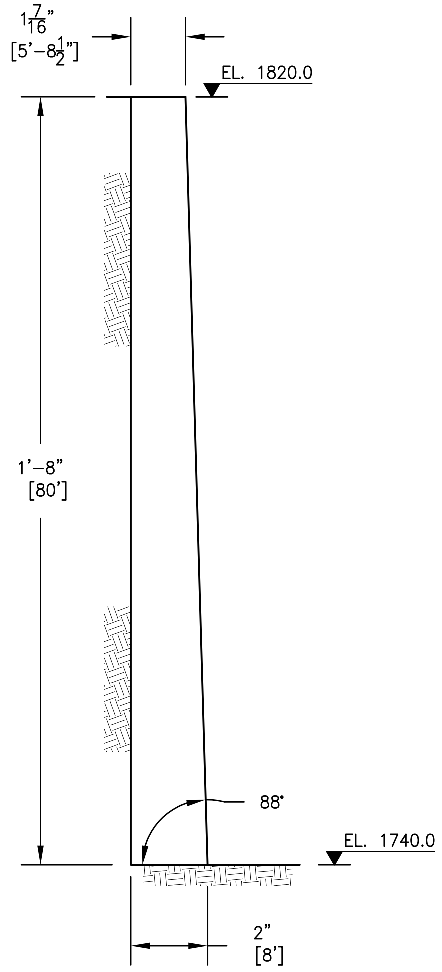
FIGURE 4.6



B-B **SECTION**
4.6
SCALE: 1in : 5in (MODEL)



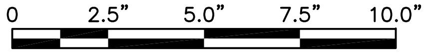
C-C **SECTION**
4.6
SCALE: 1in : 5in (MODEL)



D-D **SECTION**
4.6
SCALE: 1in : 5in (MODEL)

NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
2. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET AND INCHES.
3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
4. MODEL SCALE 1:48
5. FABRICATION TOLERANCE = 1/16"



DISTANCE IN FEET AND INCHES
SCALE 1in : 5in

IDAHO POWER COMPANY
OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Model Layout
Spillway Training Wall - North Side
Sections

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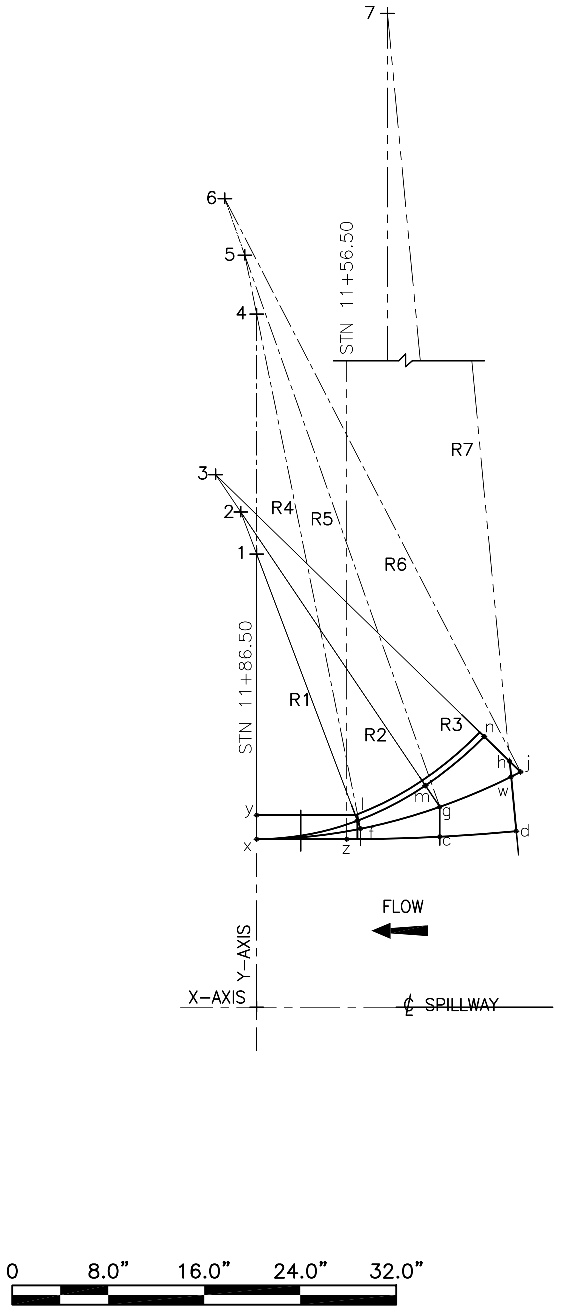
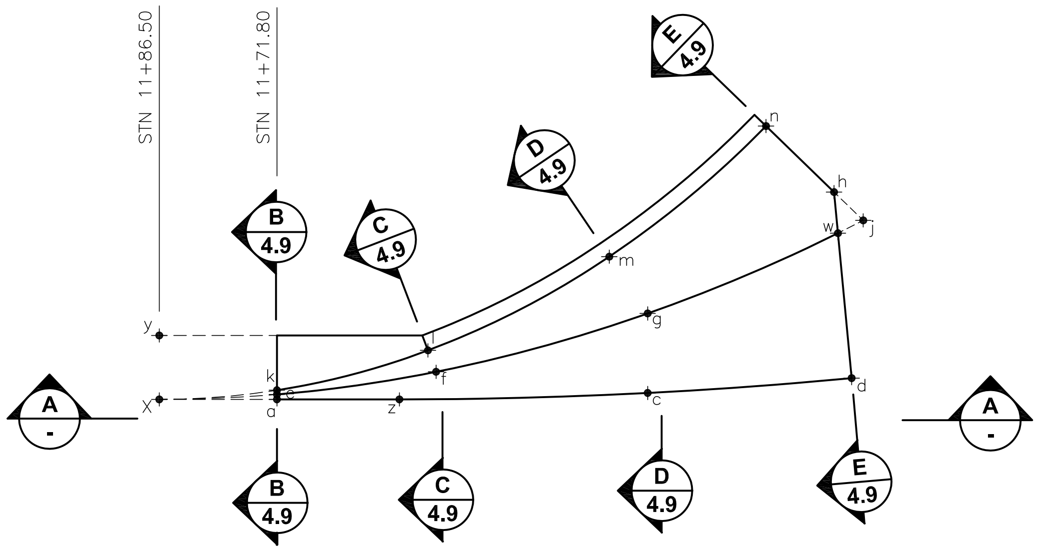
FIGURE 4.7

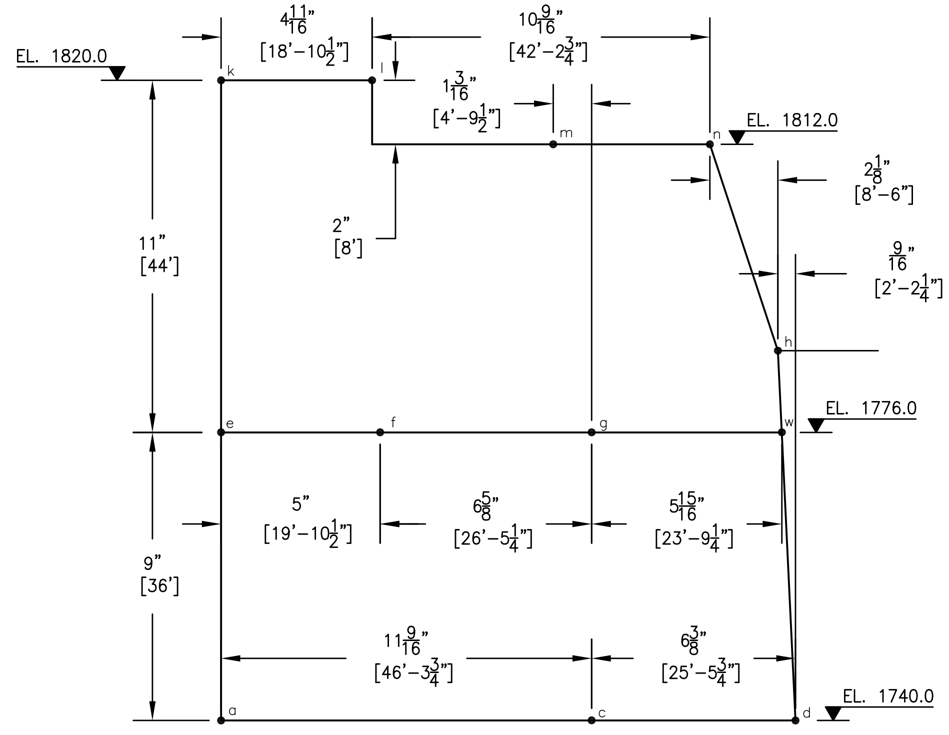


DISTANCE IN FEET AND INCHES
SCALE 1in : 16in

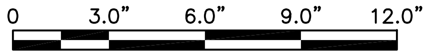


PLAN - SPILLWAY TRAINING WALL- SOUTH SIDE
SCALE: 1in : 6in (MODEL)

LAYOUT DATA			
POINT	ELEV.	COORDINATES	
		X	Y
x	1820.0	0	56.00
y	1820.0	0	64.00
a	1740.0	14.70	56.00
e	1776.0	14.70	56.62
k	1817.5	14.70	57.14
p	1817.5	14.70	64.00
f	1776.0	34.58	59.45
l	1812.0	33.57	62.13
c	1740.0	61.01	56.80
g	1776.0	61.01	66.75
m	1812.0	56.22	73.85
h	1786.2	84.31	81.93
w	1776.0	84.79	76.79
d	1740.0	86.50	58.66
j	1776.0	87.95	78.39
n	1812.0	75.80	90.19
z	1740.0	30.00	56.00
	RAD LENGTH	X	Y
1	95.00'	0.00	151.00
2	110.00'	-5.30	165.03
3	125.00'	-13.69	177.47
4	175.00'	0.00	231.00
5	195.00'	-3.95	250.61
6	215.00'	-10.62	269.46
7	600.00'	30.00	656.00



A-A SECTION
SCALE: 1in : 6in (MODEL)



DISTANCE IN FEET AND INCHES
SCALE 1in : 6in

NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
2. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET AND INCHES.
3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
4. MODEL SCALE 1:48
5. FABRICATION TOLERANCE = 1/16"

IDAHO POWER COMPANY
OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Model Layout
Spillway Training Wall - South Side Sheet 1
Plan and Section

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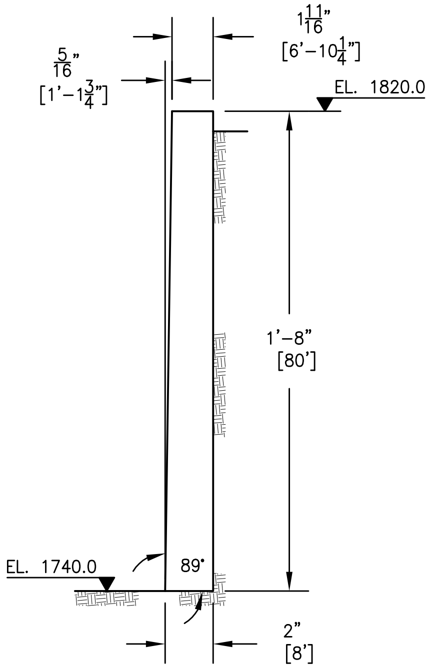
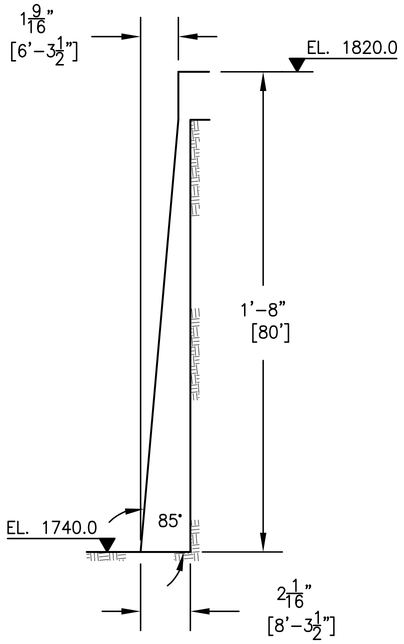
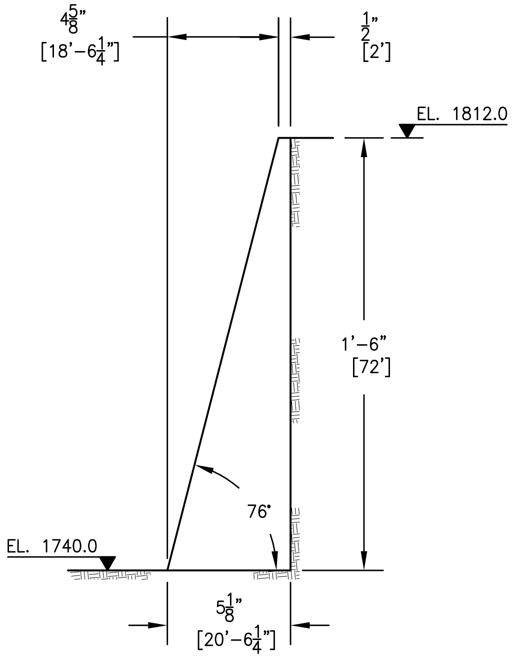
FIGURE 4.8



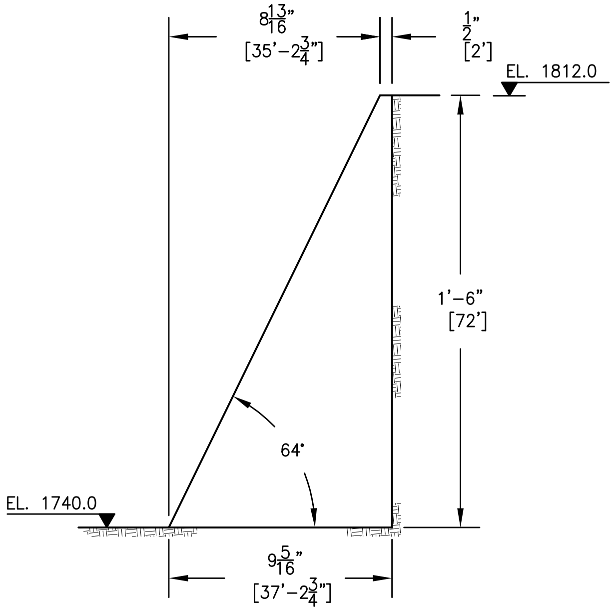
B-B SECTION
4.8 SCALE: 1in : 8in (MODEL)



C-C SECTION
4.8 SCALE: 1in : 8in (MODEL)



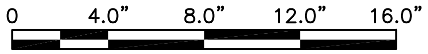
D-D SECTION
4.8 SCALE: 1in : 8in (MODEL)



E-E SECTION
4.8 SCALE: 1in : 8in (MODEL)

NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
2. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET AND INCHES.
3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
4. MODEL SCALE 1:48
5. FABRICATION TOLERANCE = 1/16"



DISTANCE IN FEET AND INCHES
SCALE 1in : 8in

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OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Model Layout
Spillway Training Wall - Right Side Sheet 1
Sections

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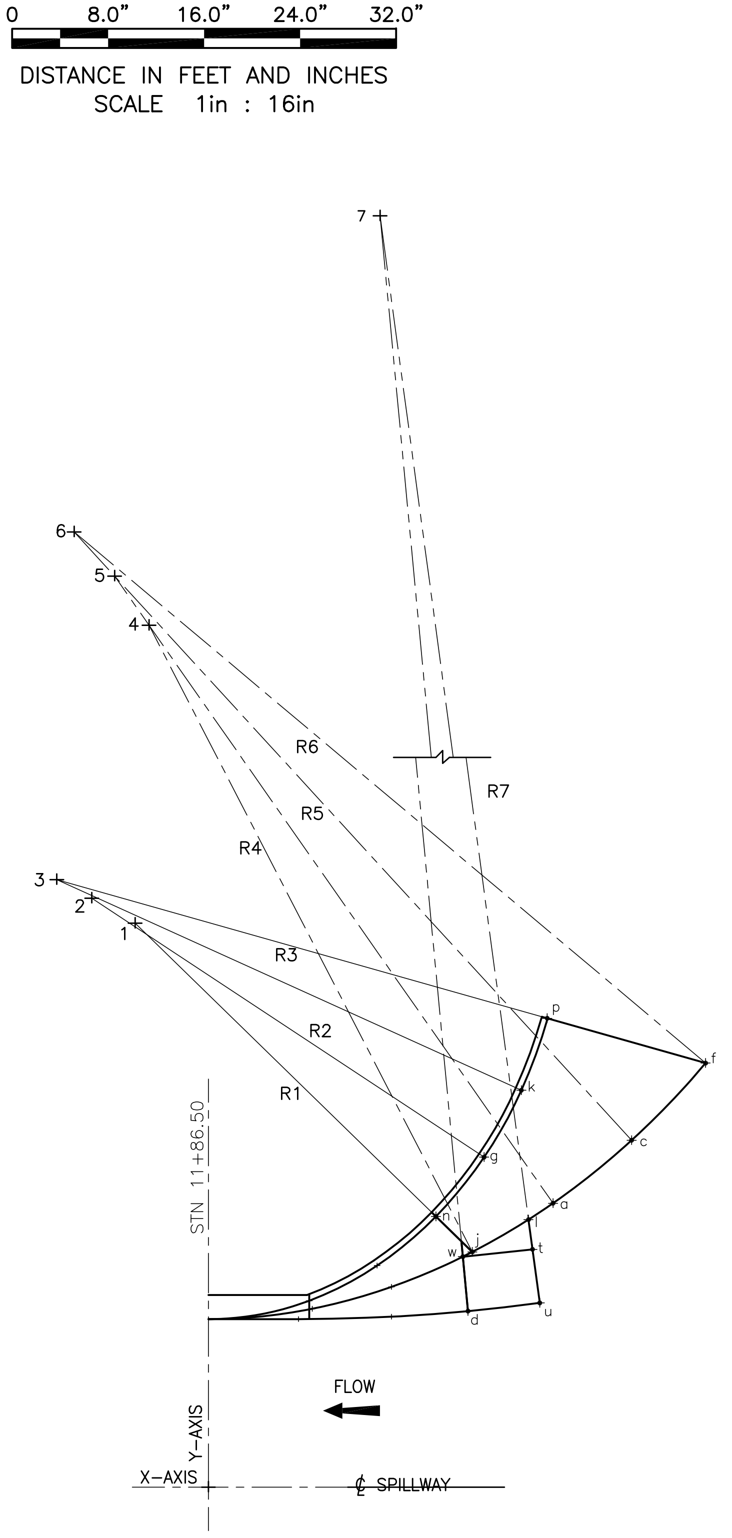
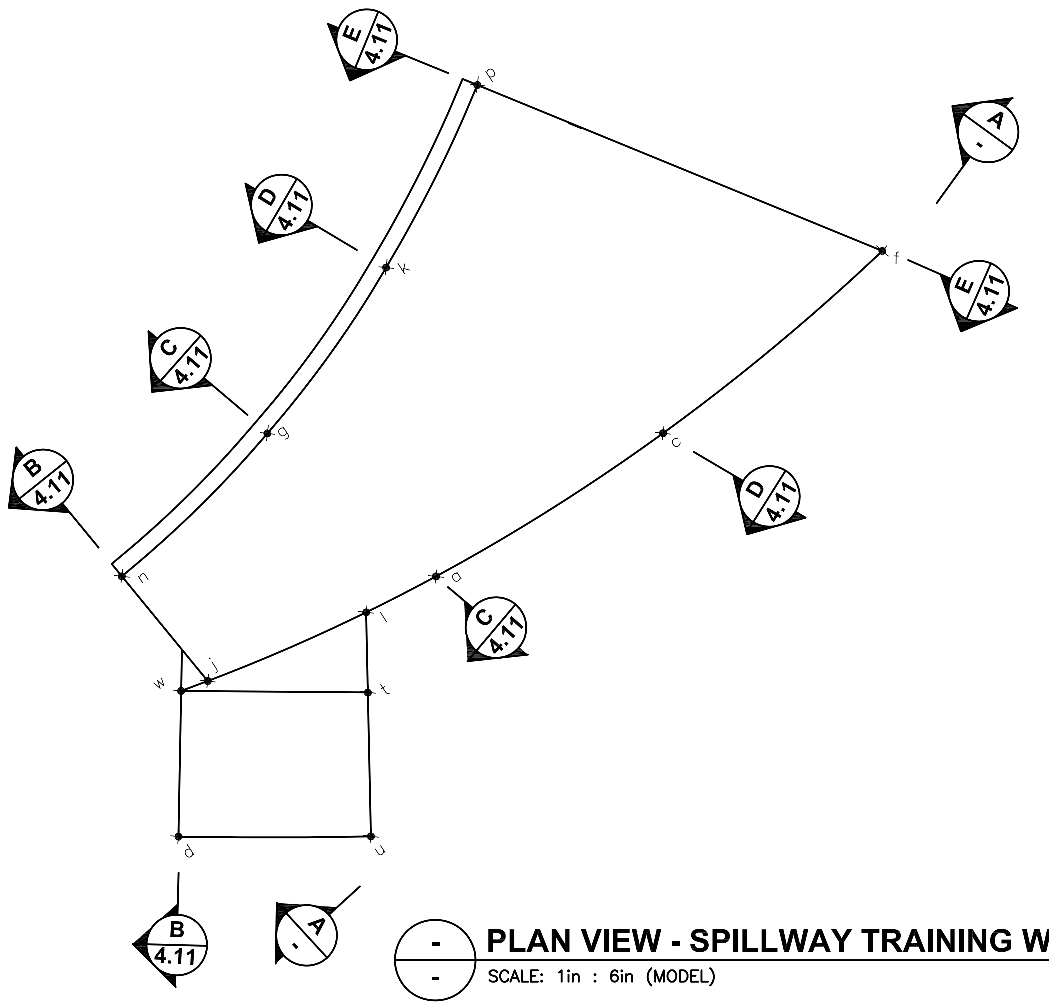
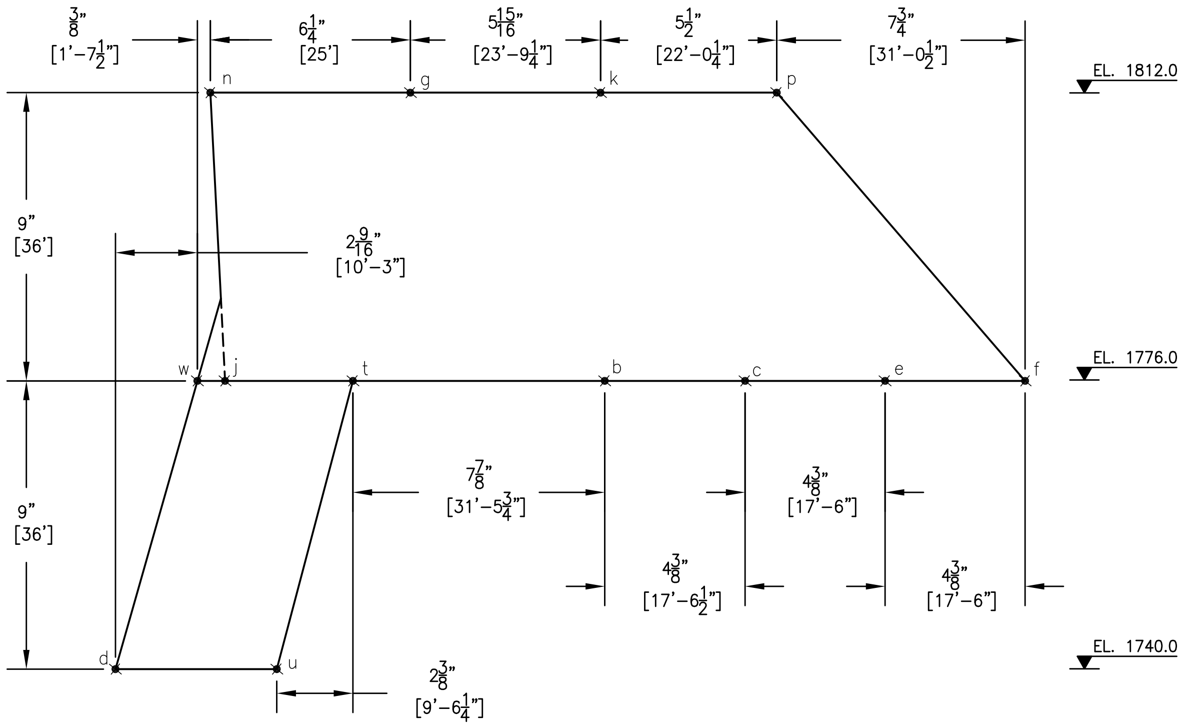
FIGURE 4.9





PLAN VIEW - SPILLWAY TRAINING WALL PART II

SCALE: 1in : 6in (MODEL)



A-A SECTION

SCALE: 1in : 6in (MODEL)

POINT	ELEV.	COORDINATES	
		X	Y
j	1776.0	87.95	78.39
n	1812.0	75.80	90.19
a	1776.0	114.83	94.61
g	1812.0	91.86	109.99
c	1776.0	141.01	115.60
k	1812.0	104.27	132.27
d	1740.0	86.50	58.66
l	1776.0	106.66	89.16
t	1776.0	108.00	79.25
f	1776.0	165.67	141.33
p	1812.0	113.03	156.22
w	1776.0	64.79	76.79
u	1740.0	110.41	61.41
	RAD LENGTH	X	Y
1	140.00'	−24.43	187.94
2	155.00'	−38.89	196.29
3	170.00'	−50.55	202.49
4	235.00'	−19.79	287.24
5	255.00'	−31.25	303.63
6	275.00'	−44.76	318.37
7	600.00'	30.00	656.00

LAYOUT DATA

0 3.0" 6.0" 9.0" 12.0"

DISTANCE IN FEET AND INCHES
SCALE 1in : 6in

NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
2. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET AND INCHES.
3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
4. MODEL SCALE 1:48
5. FABRICATION TOLERANCE = 1/16"

IDAHO POWER COMPANY
OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Model Layout
Spillway Training Wall - South Side Sheet 2
Plan and Section

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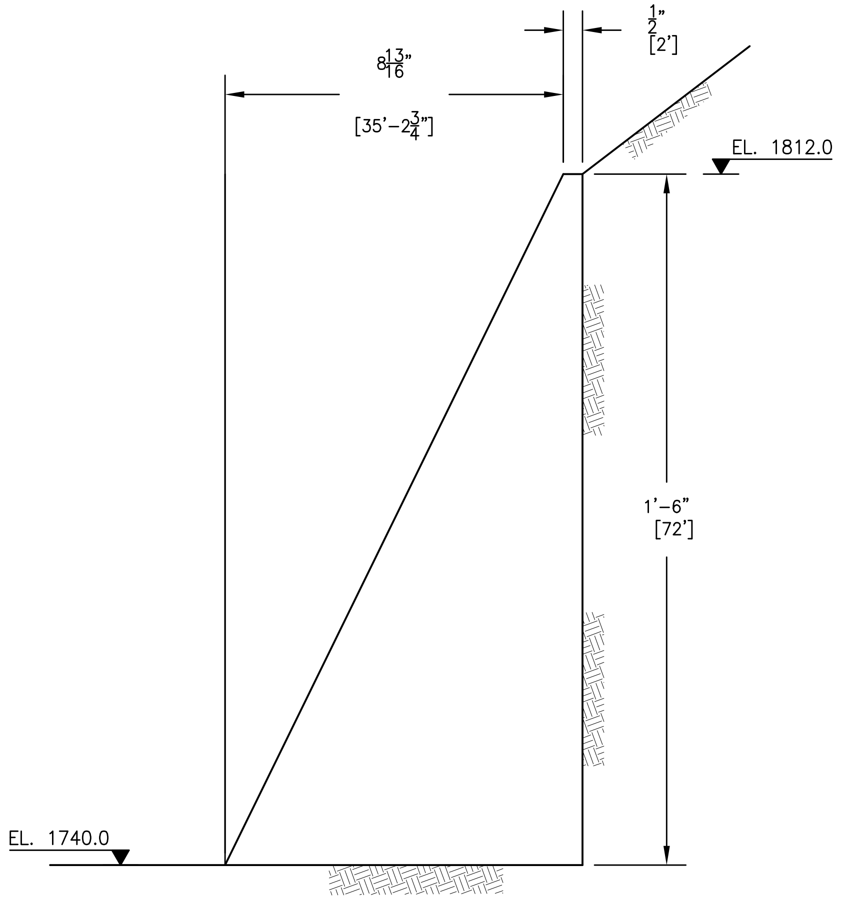
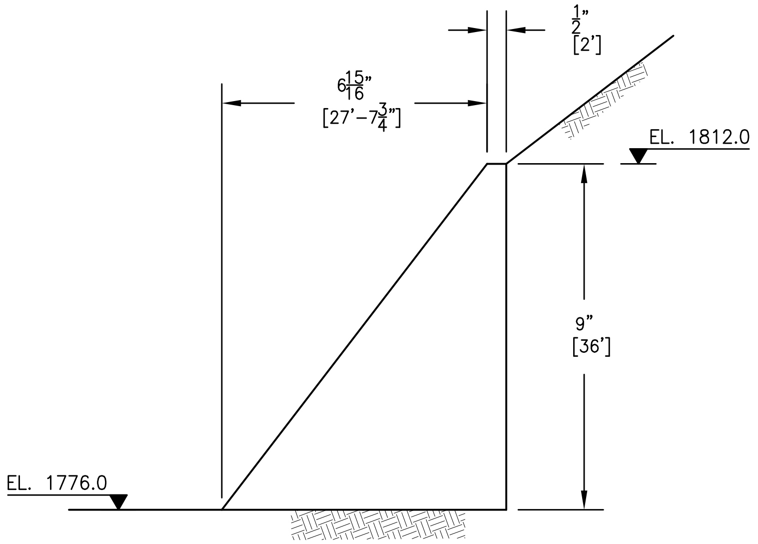
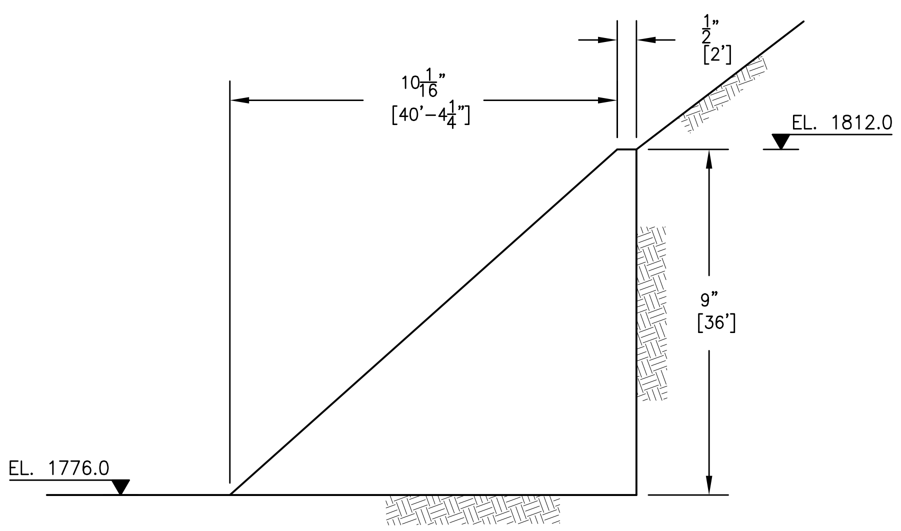
FIGURE 4.10



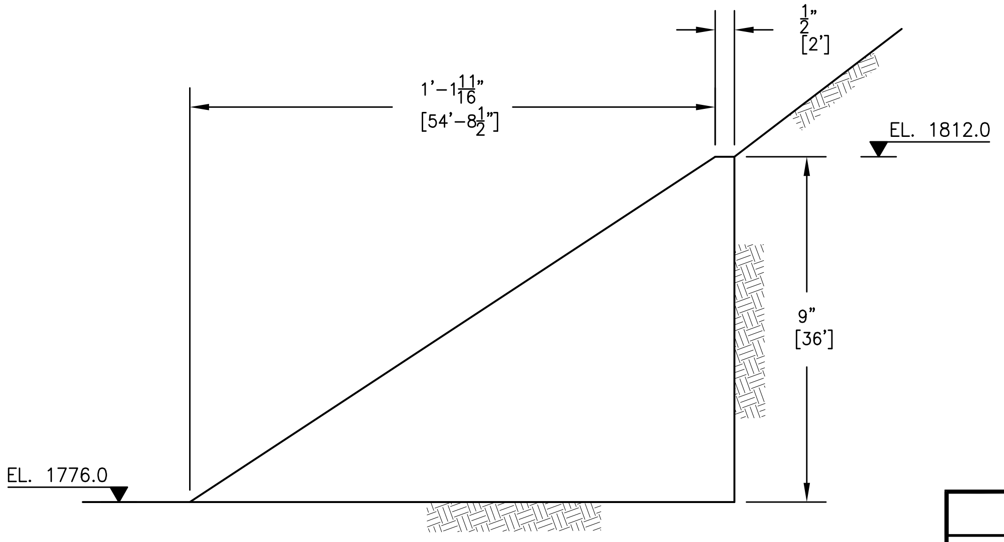
B-B SECTION
4.10
SCALE: 1in : 5in (MODEL)



C-C SECTION
4.10
SCALE: 1in : 5in (MODEL)



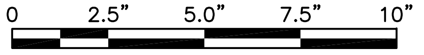
D-D SECTION
4.10
SCALE: 1in : 5in (MODEL)



E-E SECTION
4.10
SCALE: 1in : 5in (MODEL)

NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
2. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET AND INCHES.
3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
4. MODEL SCALE 1:48
5. FABRICATION TOLERANCE = 1/16"



DISTANCE IN FEET AND INCHES
SCALE 1in : 5in

IDAHO POWER COMPANY
OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Model Layout
Spillway Training Wall - South Side Sheet 2
Sections

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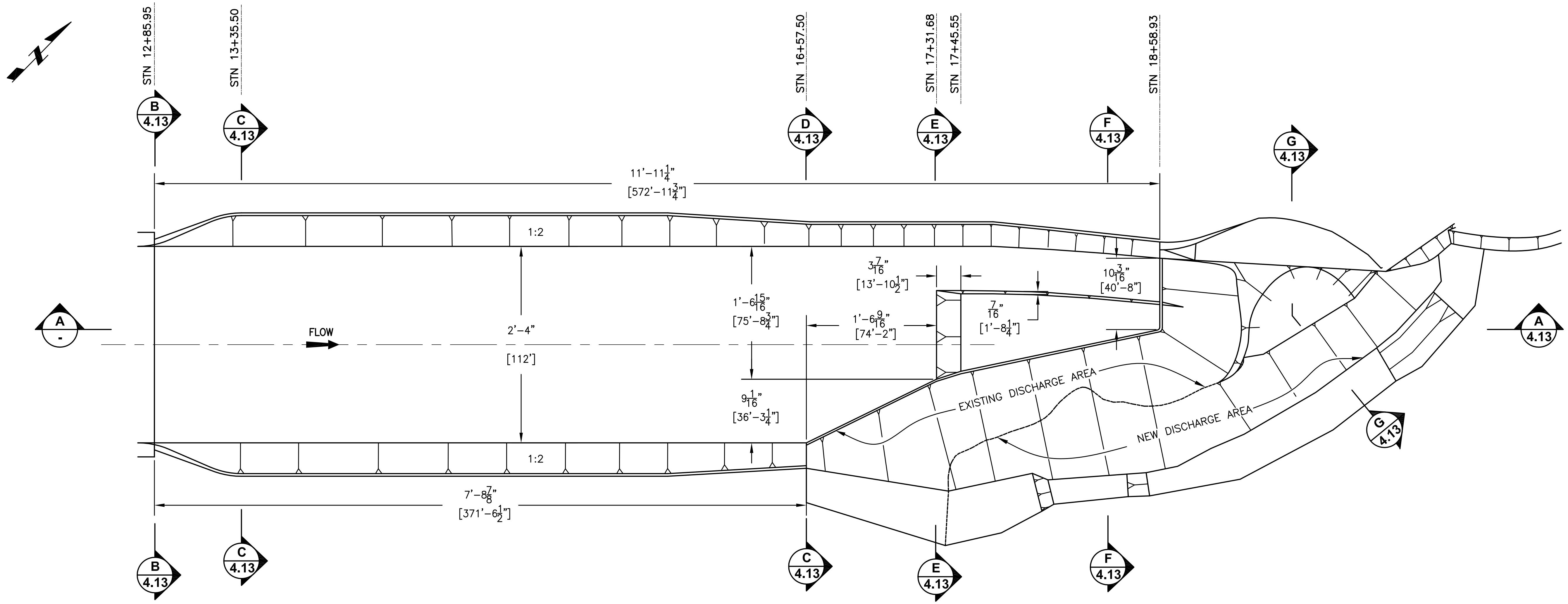
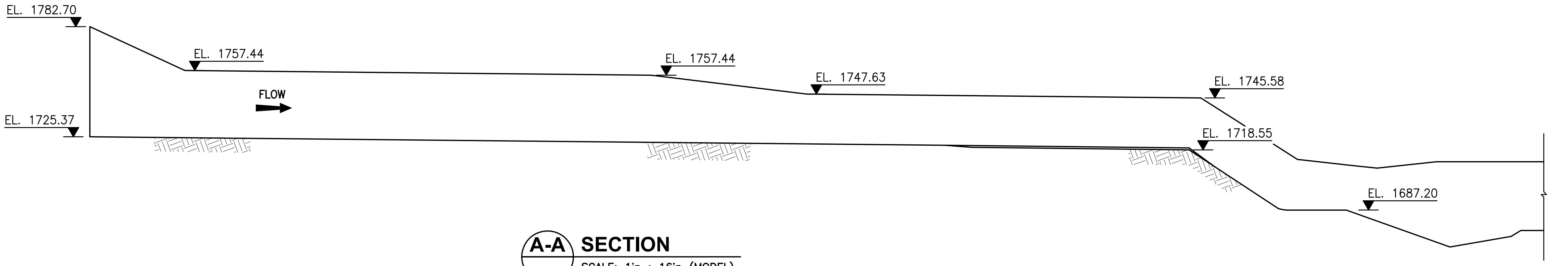
FIGURE 4.11



- PLAN VIEW - SPILLWAY CHUTE

SCALE: 1in : 16in (MODEL)



A-A SECTION

SCALE: 1in : 16in (MODEL)

NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
2. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET AND INCHES.
3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
4. MODEL SCALE 1:48
5. FABRICATION TOLERANCE = 1/16"

0 8" 16" 24" 32"

DISTANCE IN FEET AND INCHES
SCALE 1 in : 16in

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OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Model Layout
Spillway Chute
Plan and Section View

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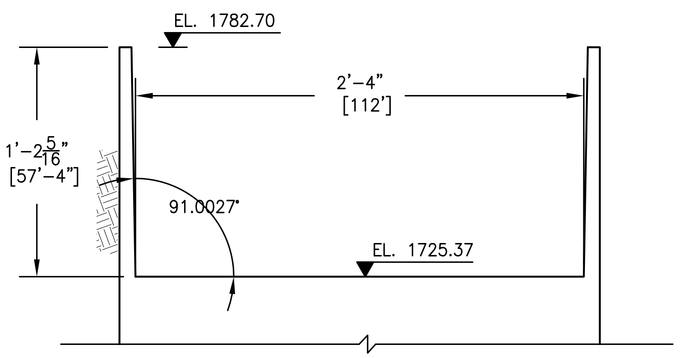
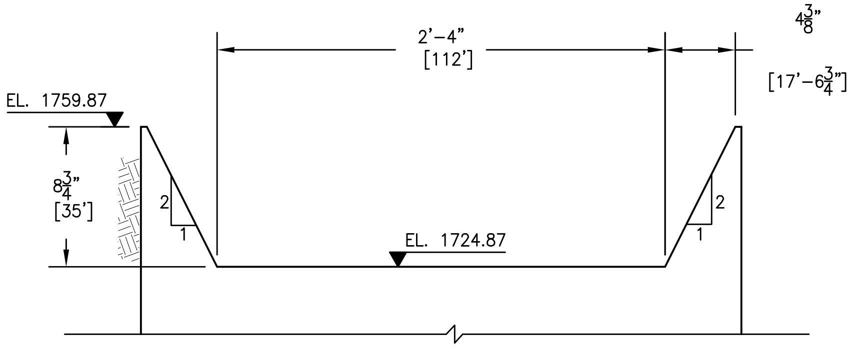
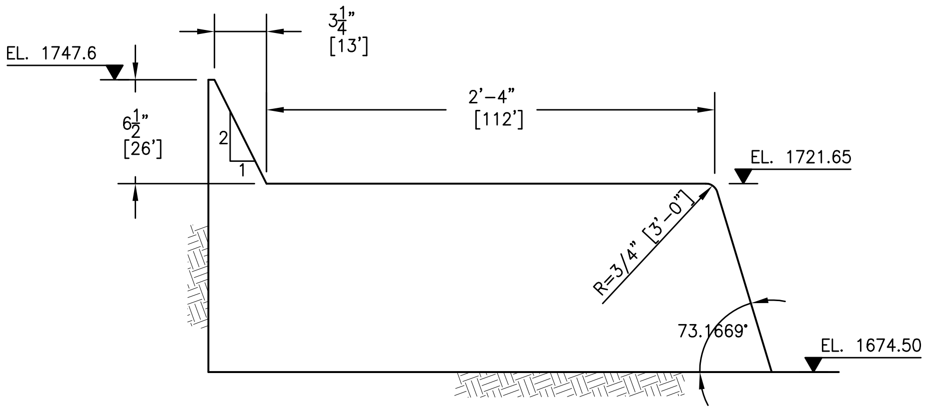
FIGURE 4.12



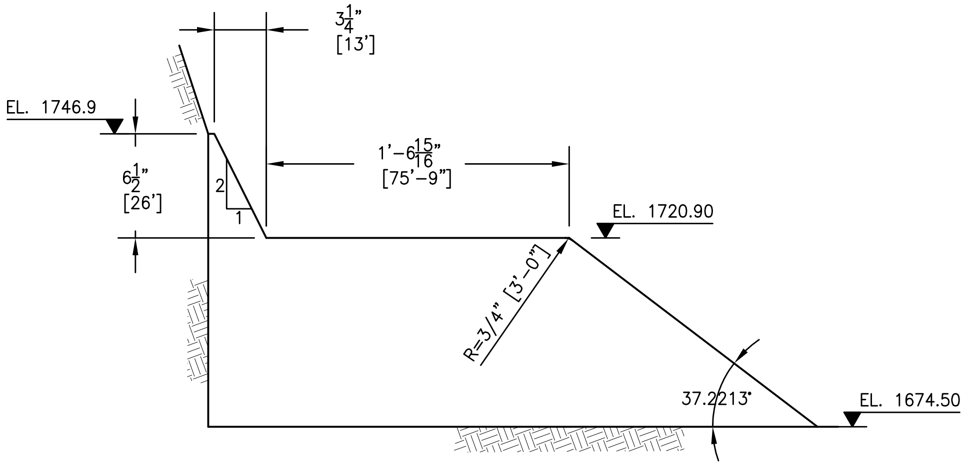
B-B SECTION
4.12 SCALE: 1in : 12in (MODEL)



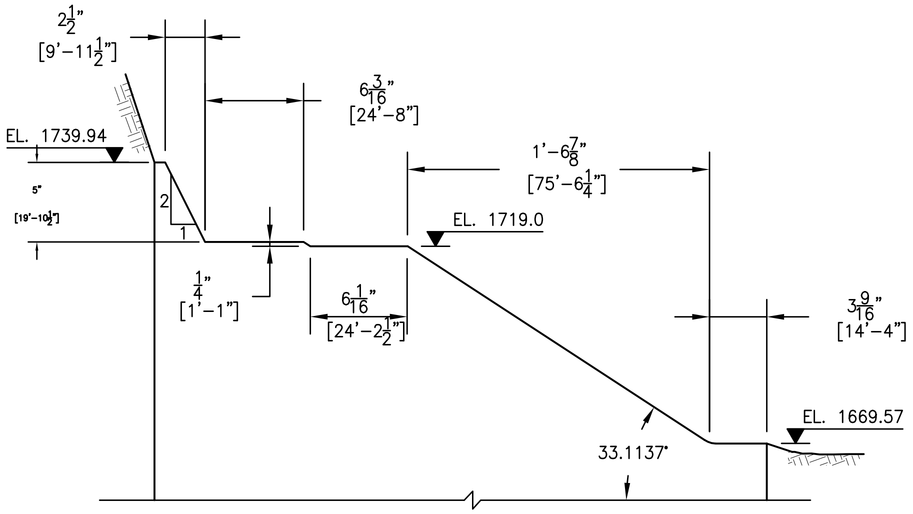
C-C SECTION
4.12 SCALE: 1in : 12in (MODEL)



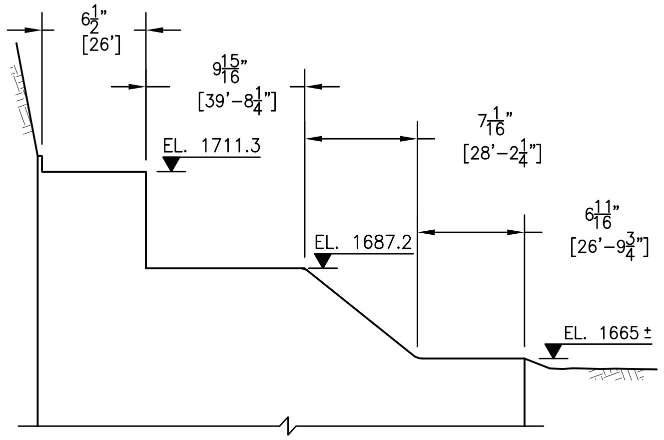
D-D SECTION
4.12 SCALE: 1in : 12in (MODEL)



E-E SECTION
4.12 SCALE: 1in : 12in (MODEL)



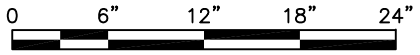
F-F SECTION
4.12 SCALE: 1in : 12in (MODEL)



G-G SECTION
4.12 SCALE: 1in : 12in (MODEL)

NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
2. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET AND INCHES.
3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
4. MODEL SCALE 1:48
5. FABRICATION TOLERANCE = 1/16"



DISTANCE IN FEET AND INCHES
SCALE 1 in : 12in

IDAHO POWER COMPANY
OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Model Layout
Spillway Chute
Sections and Details

21513–015	REV. NO.: 0	DRN. BY: RKJ	Nov–06–07

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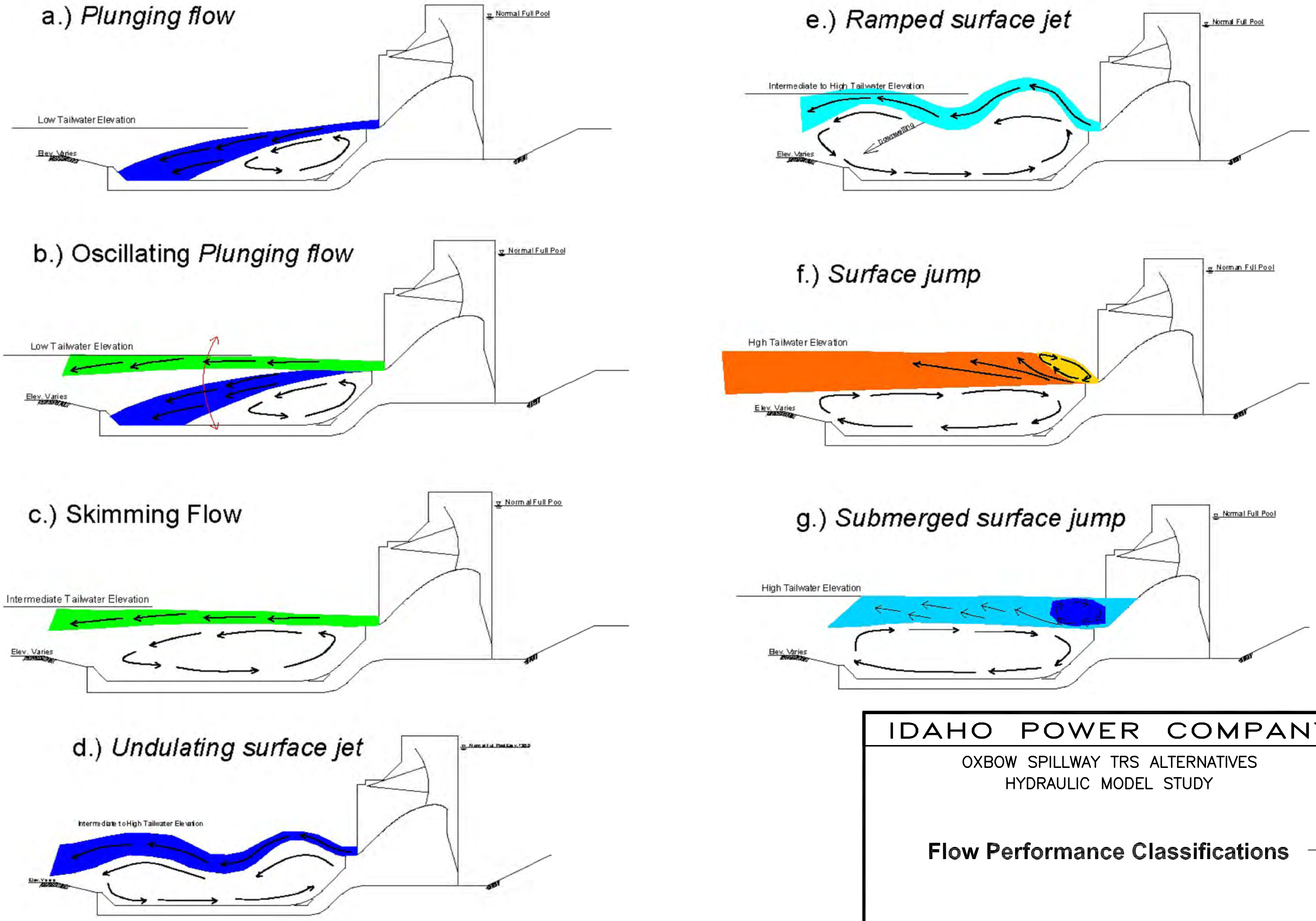
FIGURE 4.13



IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Flow Performance Classifications

21513–8.5x11	REV. NO.: 0	DRN. BY: JAB	OCT–12–07

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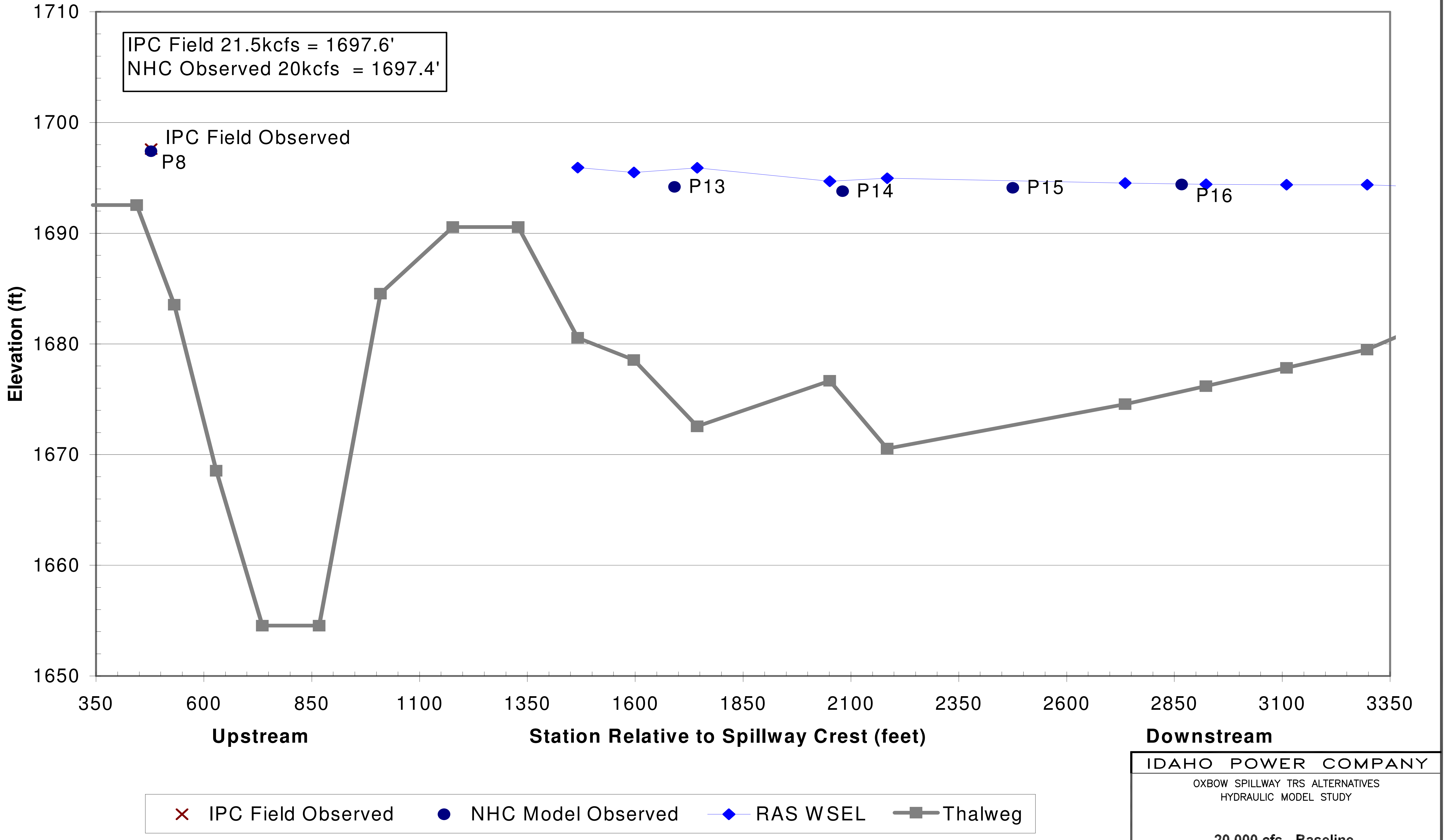
FIGURE 4.14



NOTES:

1. RAS WSEL assuming low powerhouse discharge and low Hells Canyon tailwater, n = 0.030
2. RAS Profile extends to the downstream end of the mobile bed. RAS WSEL calculations upstream of this point are considered unreliable due to multi-dimensional flow effects

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

20,000 cfs - Baseline

Water Surface Elevation Profile Plot

21513–11x17	REV. NO.: 0	DRN. BY: JAB	Oct–11–07

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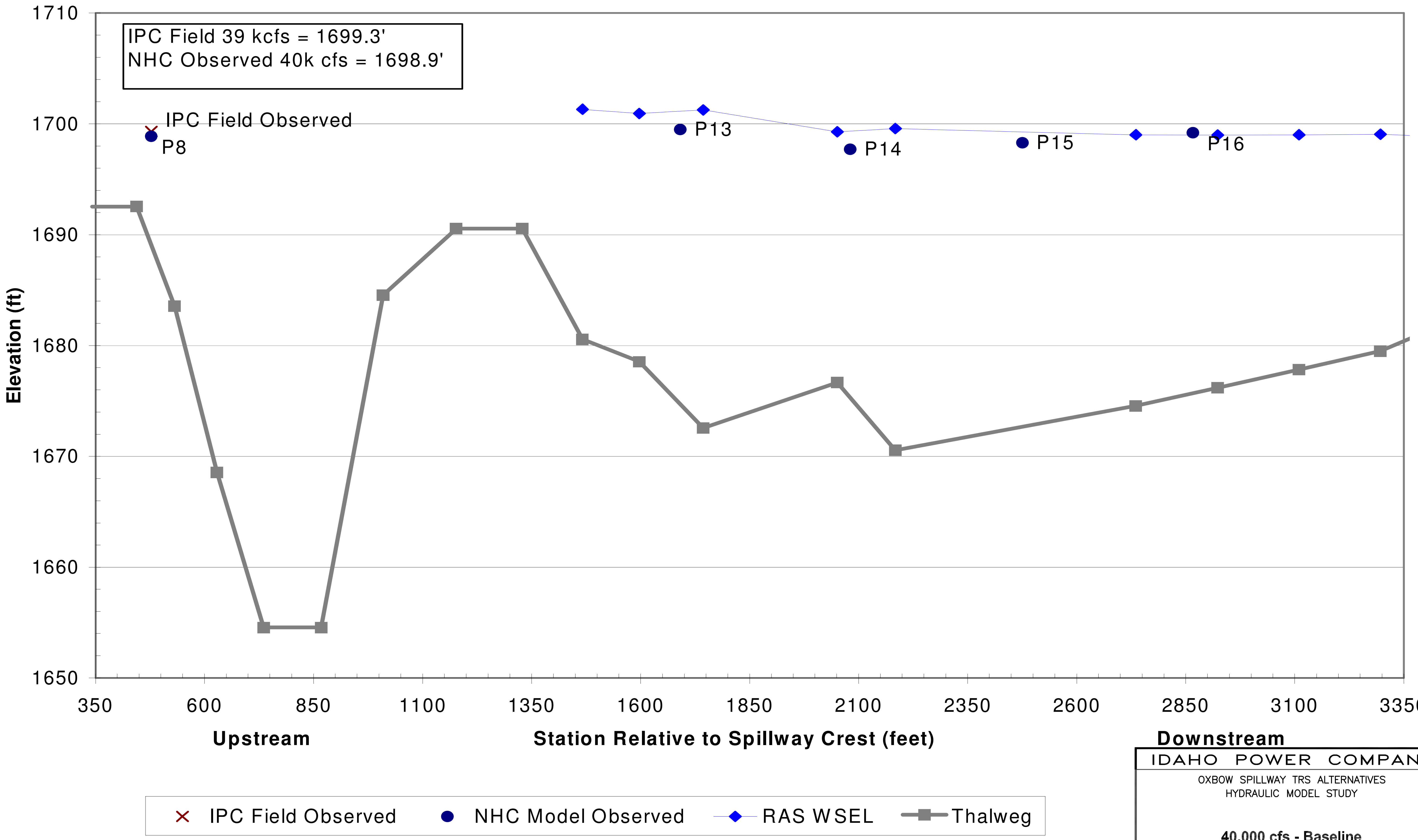
FIGURE 6.1.1



NOTES:

1. RAS WSEL assuming low powerhouse discharge and low Hells Canyon tailwater, n = 0.030
2. RAS Profile extends to the downstream end of the mobile bed. RAS WSEL calculations upstream of this point are considered unreliable due to multi-dimensional flow effects

IDAHO POWER COMPANY
OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

40,000 cfs - Baseline

Water Surface Elevation Profile Plot

21513–11x17	REV. NO.: 0	DRN. BY: JAB	Oct–11–07

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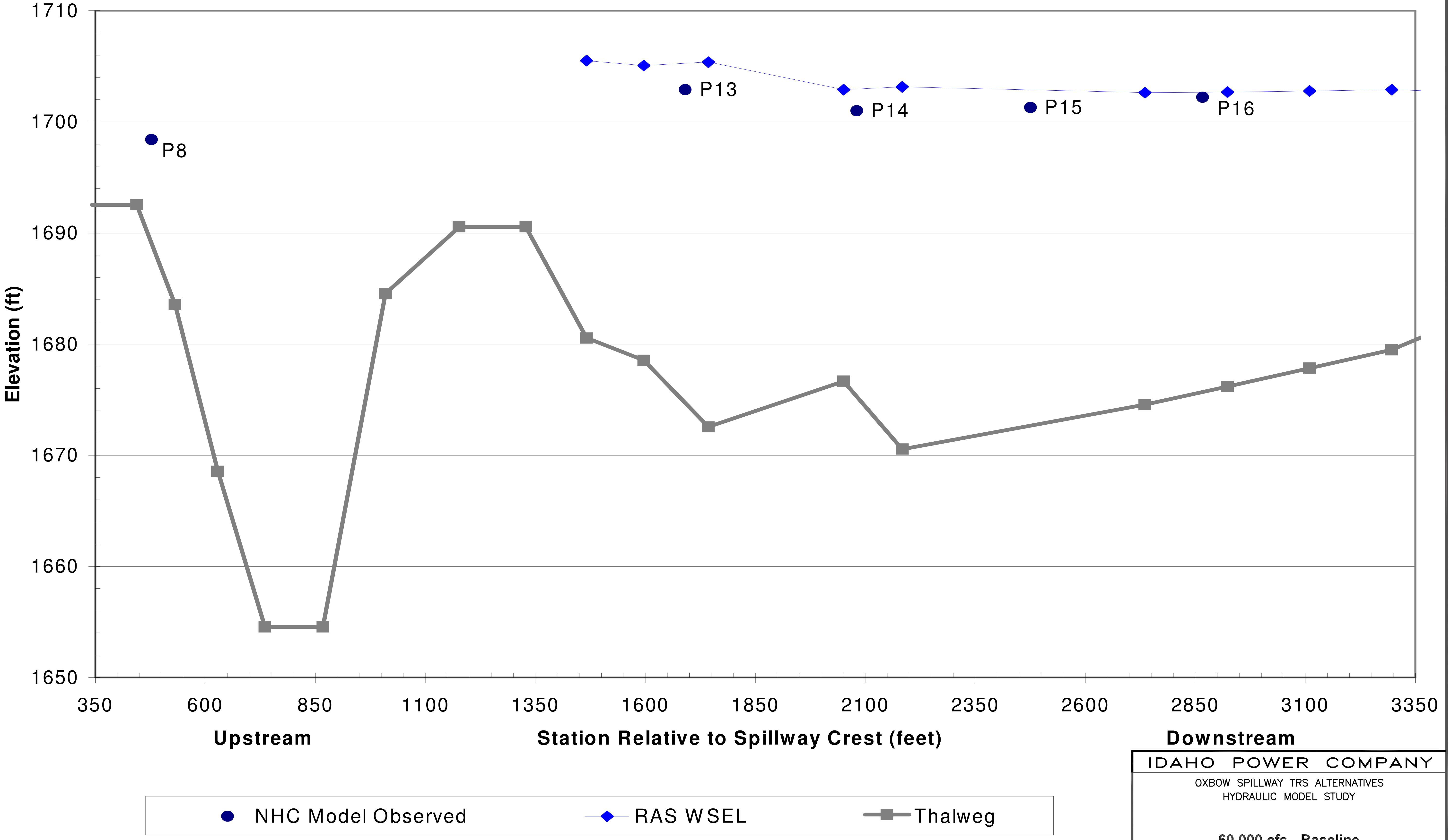
FIGURE 6.1.2



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OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

60,000 cfs - Baseline

Water Surface Elevation Profile Plot

21513-11x17 | REV. NO.: 0 | DRN. BY: JAB | Oct-11-07

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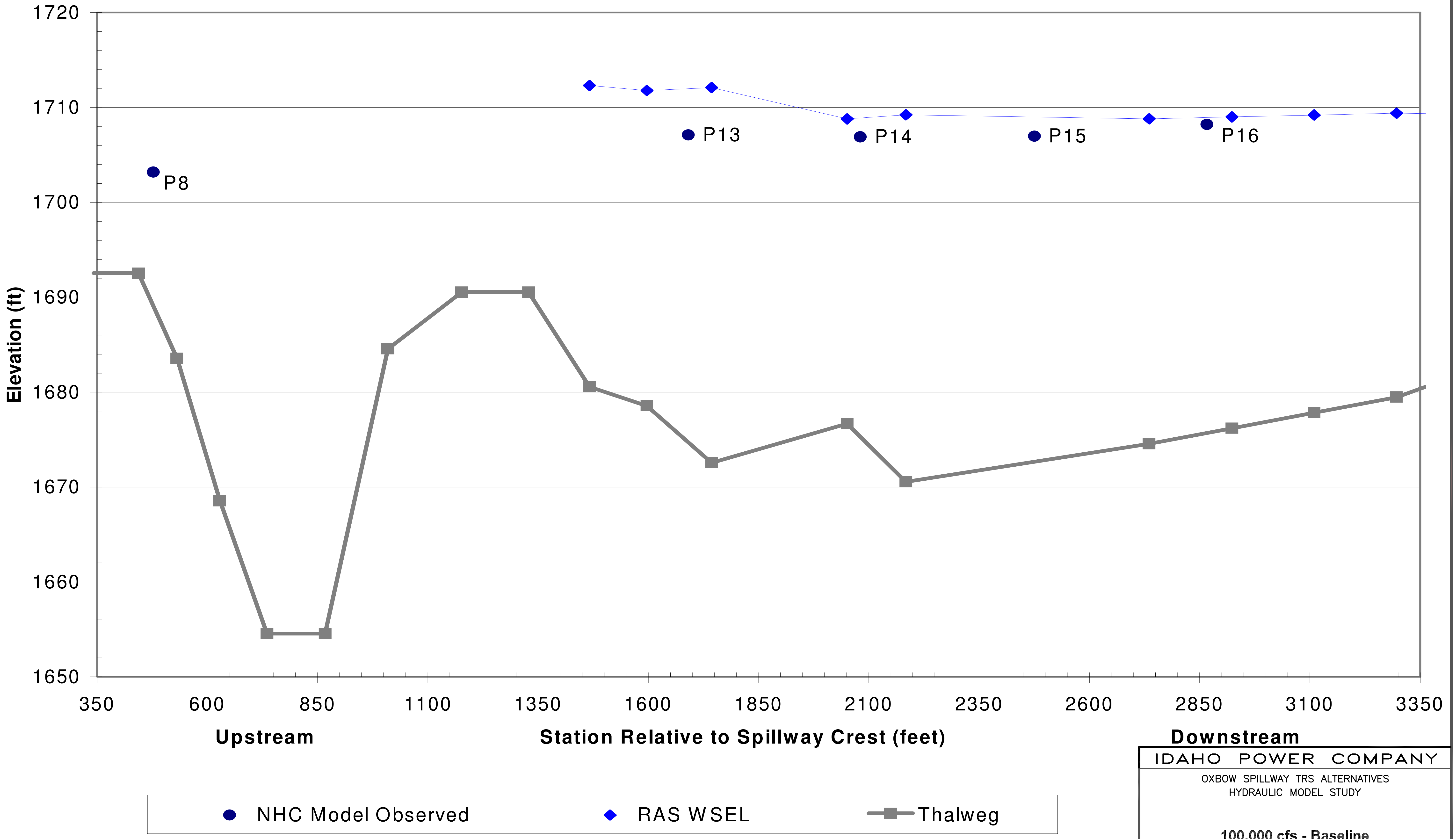
NOTES:

1. RAS WSEL assuming low powerhouse discharge and low Hells Canyon tailwater, n = 0.030
2. RAS Profile extends to the downstream end of the mobile bed. RAS WSEL calculations upstream of this point are considered unreliable due to multi-dimensional flow effects

FIGURE 6.1.3



NOTES:

1. RAS WSEL assuming low powerhouse discharge and low Hells Canyon tailwater, n = 0.030
2. RAS Profile extends to the downstream end of the mobile bed. RAS WSEL calculations upstream of this point are considered unreliable due to multi-dimensional flow effects

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

100,000 cfs - Baseline

Water Surface Elevation Profile Plot

21513–11x17	REV. NO.: 0	DRN. BY: JAB	Oct–11–07

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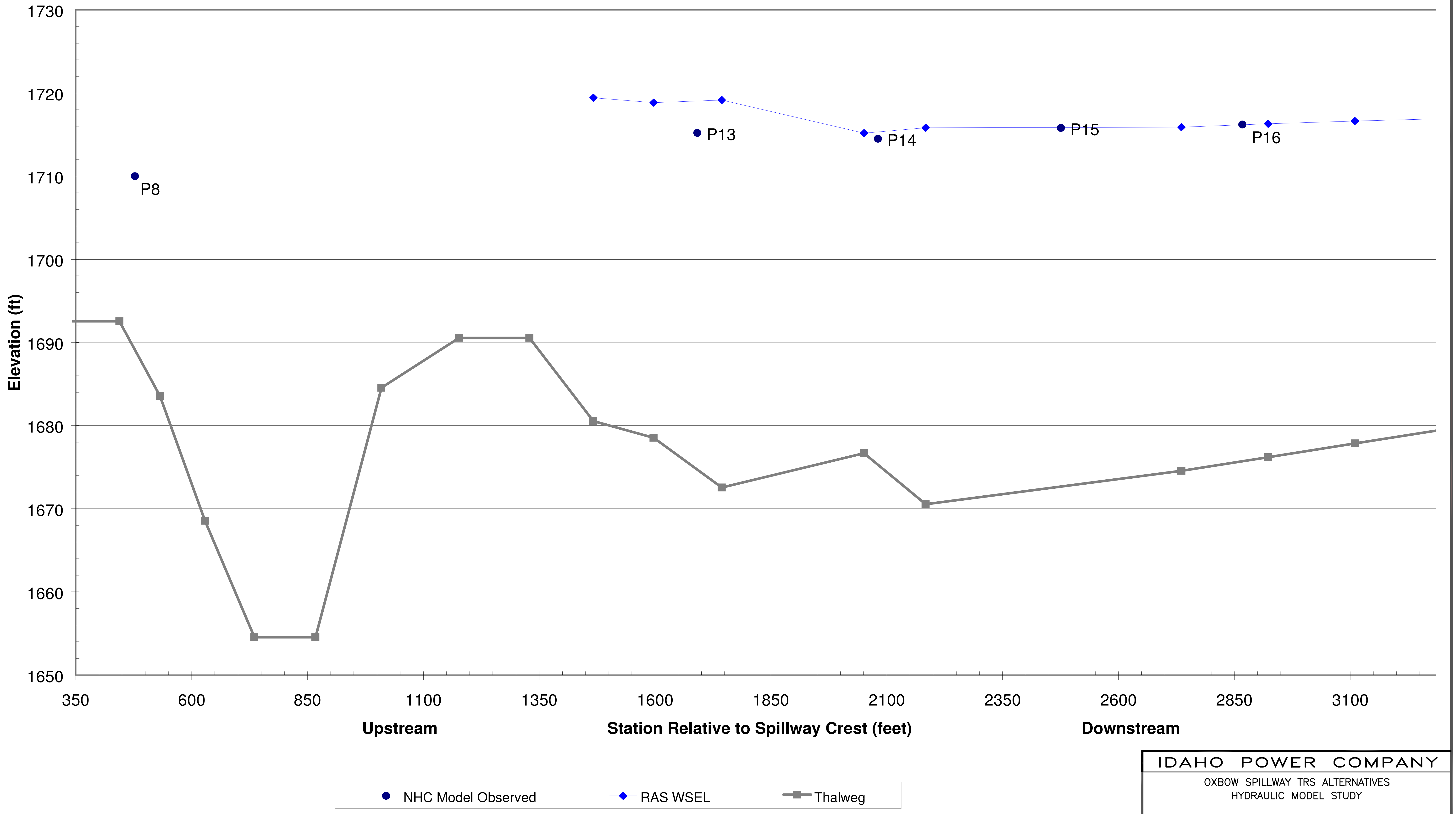
FIGURE 6.1.4



IDAHO POWER COMPANY
OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

150,000 cfs - Baseline

Water Surface Elevation Profile Plot

21513–11x17	REV. NO.: 0	DRN. BY: JAB	Oct–11–07

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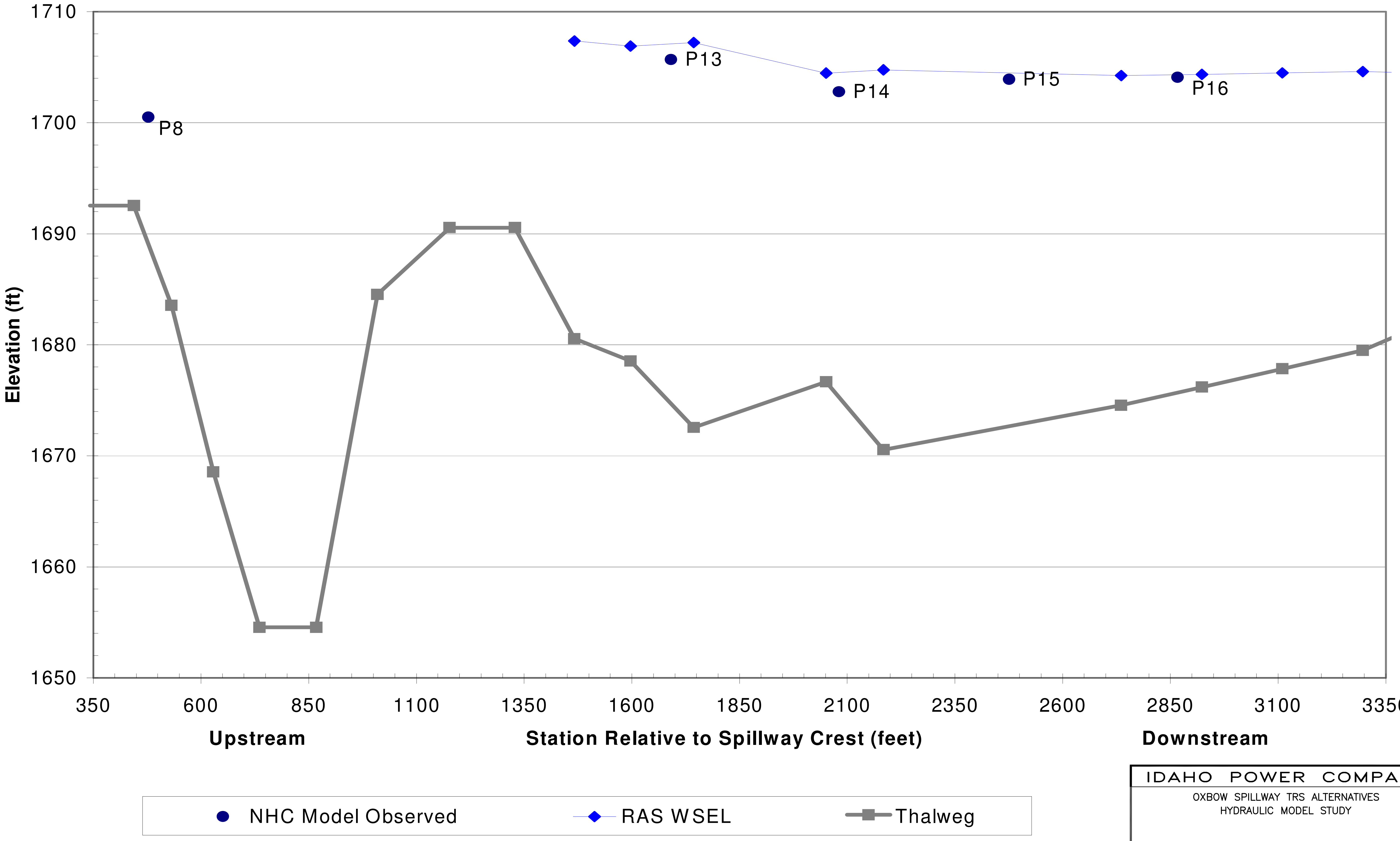
NOTES:

1. RAS WSEL assuming low powerhouse discharge and low Hells Canyon tailwater, n = 0.030
2. RAS Profile extends to the downstream end of the mobile bed. RAS WSEL calculations upstream of this point are considered unreliable due to multi-dimensional flow effects

FIGURE 6.1.5



IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

70,000 cfs - Baseline - Erosion Test
Water Surface Elevation Profile Plot

21513-11x17	REV. NO.: 0	DRN. BY: JAB	Oct-11-07

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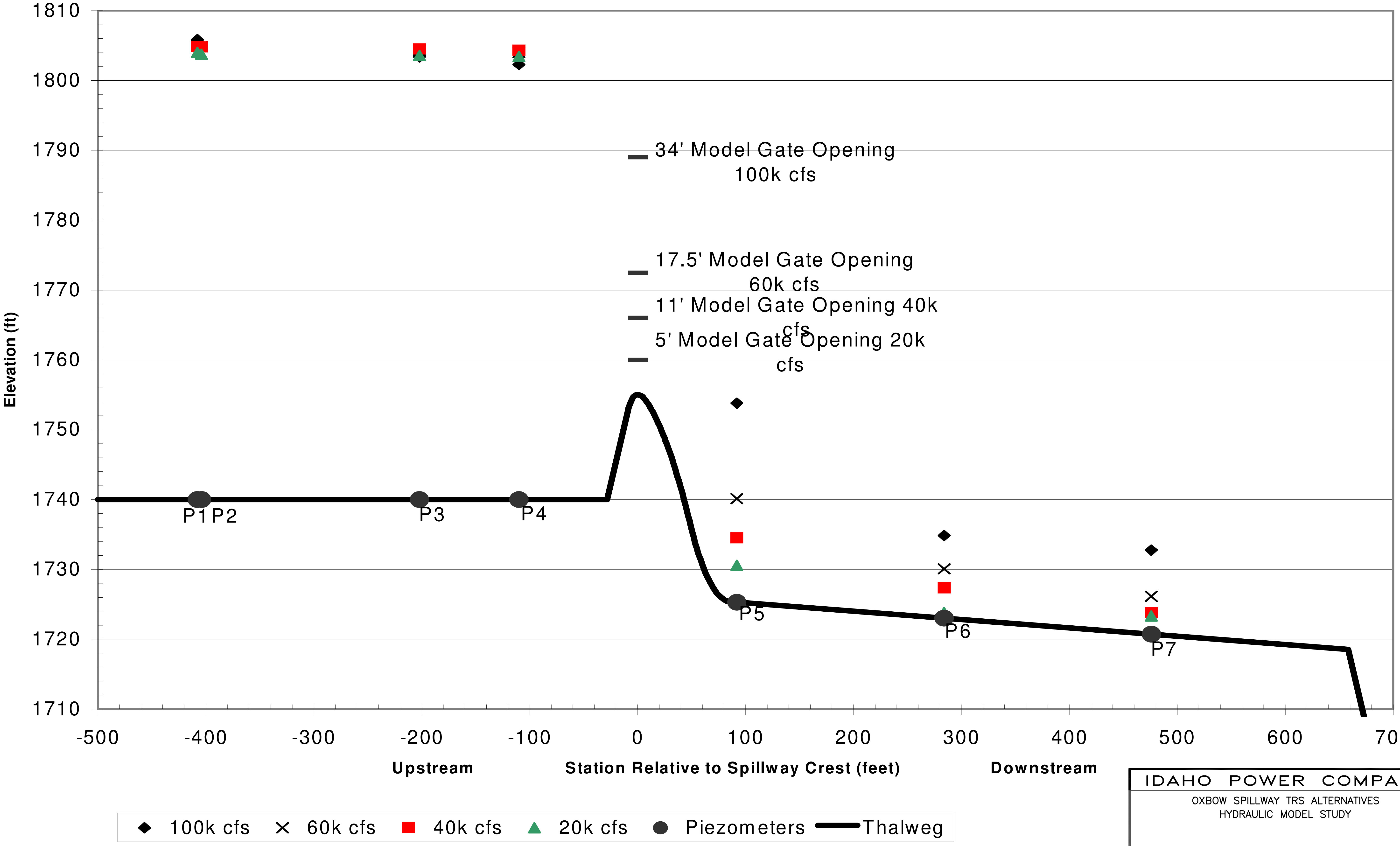
NOTES:

1. RAS WSEL assuming low powerhouse discharge and low Hells Canyon tailwater, n = 0.030
2. RAS Profile extends to the downstream end of the mobile bed. RAS WSEL calculations upstream of this point are considered unreliable due to multi-dimensional flow effects

FIGURE 6.1.6



IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Baseline - Forebay and Chute
Water Surface Elevation Profile Plots

21513-11x17	REV. NO.: 0	DRN. BY: JAB	Oct-11-07

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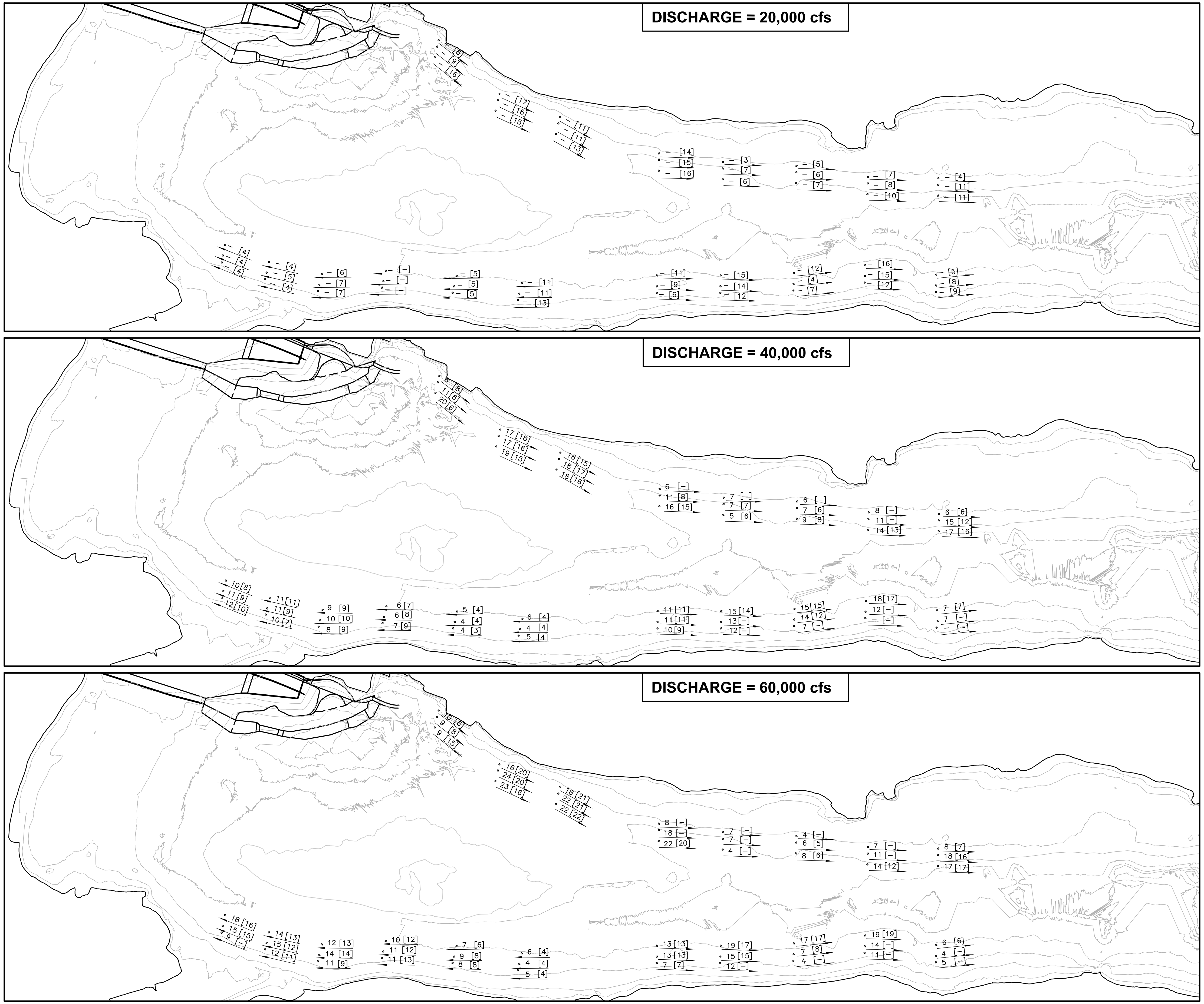
FIGURE 6.1.7



LEGEND

• 20 [18] → MEASUREMENT LOCATION AND FLOW DIRECTION.

20 NEAR SURFACE VELOCITY.
[18] MID-DEPTH VELOCITY.

DISTANCE IN MODEL FEET
(1" = 5')
0 2'-6" 3' 7'-6" 10'
0 120' 240' 360' 480'
DISTANCE IN PROTOTYPE FEET
(1" = 240')

NOTES:

1. ALL VELOCITIES ARE GIVEN IN PROTOTYPE FEET PER SECOND.

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OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

20,000, 40,000 & 60,000 cfs
Near Shore Velocities
Baseline

21513-018	REV. NO.: 0	DRN. BY: JYJ	Nov-15-07

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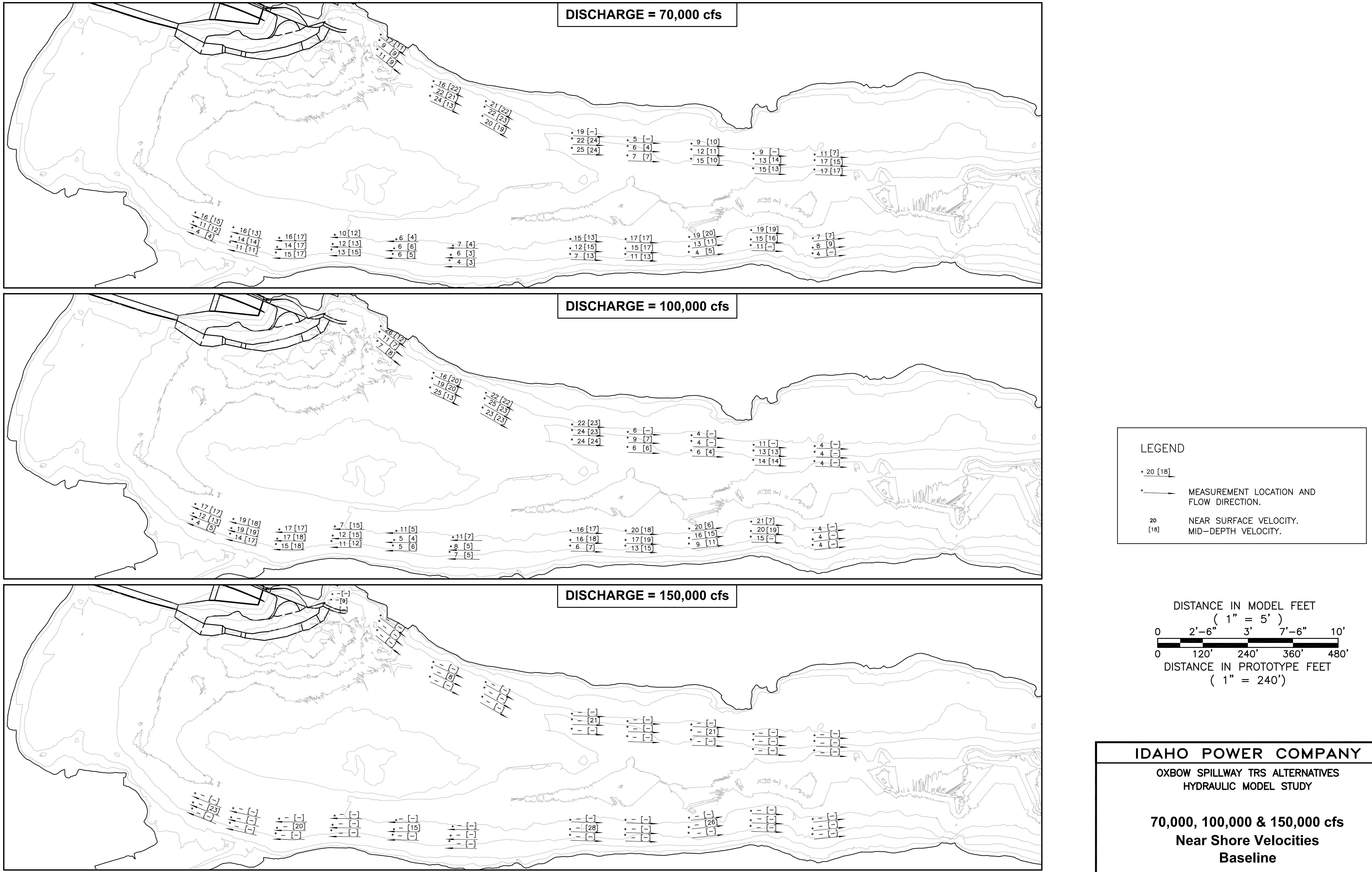
FIGURE 6.1.8



NOTES:

1. ALL VELOCITIES ARE GIVEN IN PROTOTYPE FEET PER SECOND.

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OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

70,000, 100,000 & 150,000 cfs
Near Shore Velocities
Baseline

21513–018	REV. NO.: 0	DRN. BY: JYJ	Nov–15–07

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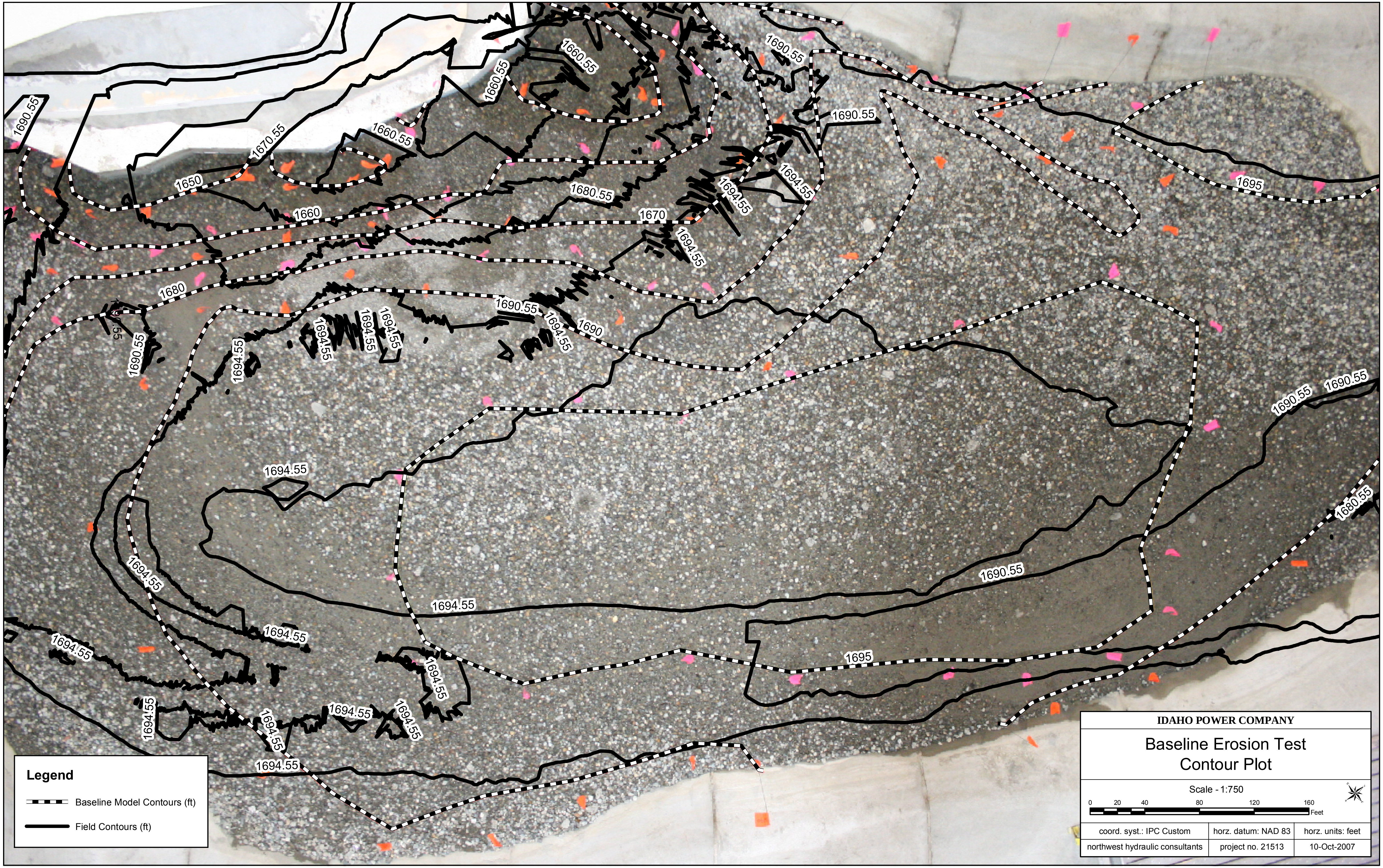
FIGURE 6.1.9



Legend

Baseline Model Contours (ft)

Field Contours (ft)

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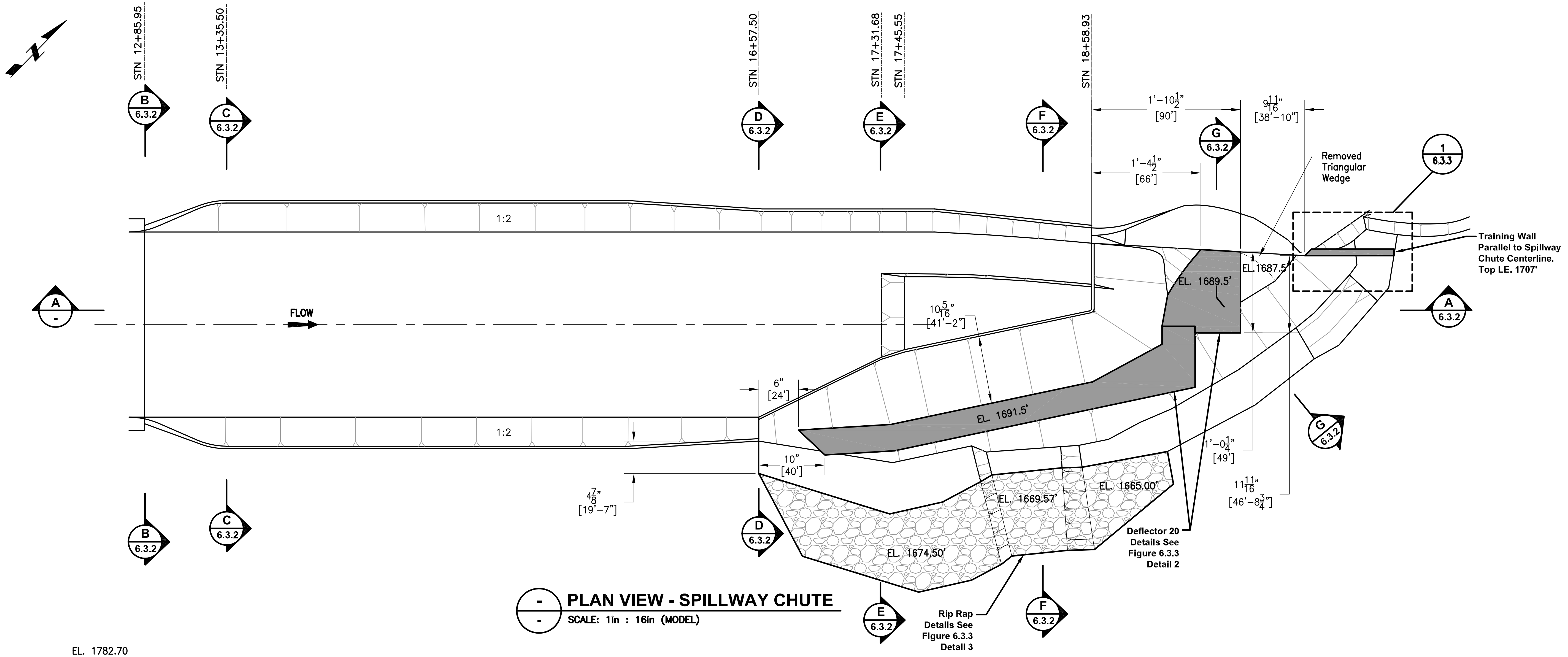
Baseline Erosion Test Contour Plot

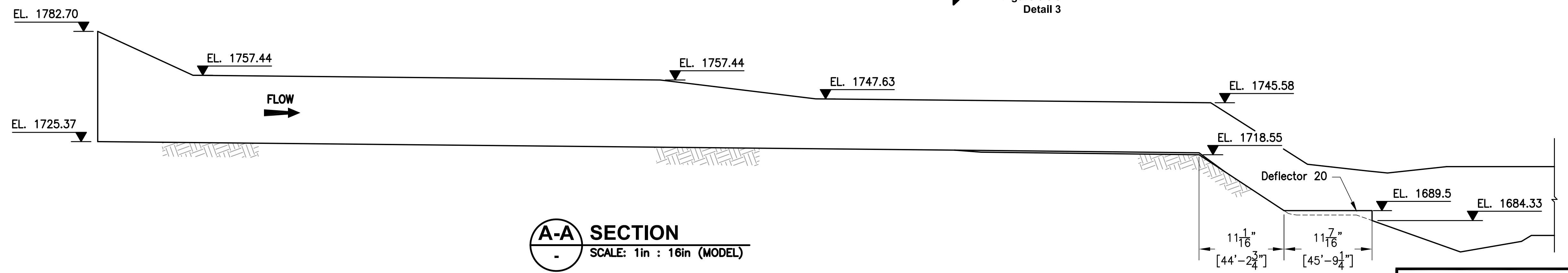
Scale - 1:750

coord. syst.: IPC Custom	horz. datum: NAD 83	horz. units: feet
northwest hydraulic consultants	project no. 21513	10-Oct-2007

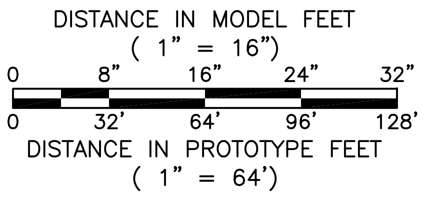
Figure 6.1.10



- **PLAN VIEW - SPILLWAY CHUTE**
- SCALE: 1in : 16in (MODEL)



A-A **SECTION**
- SCALE: 1in : 16in (MODEL)



NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
2. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET AND INCHES.
3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
4. MODEL SCALE 1:48
5. FABRICATION TOLERANCE = 1/16"

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Recommended Design
Spillway Chute and Deflector 20
Plan and Section View

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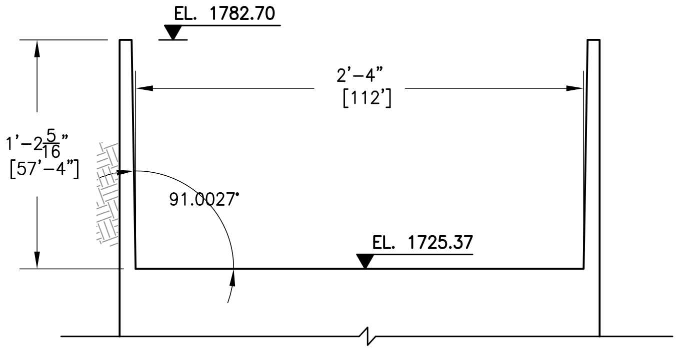
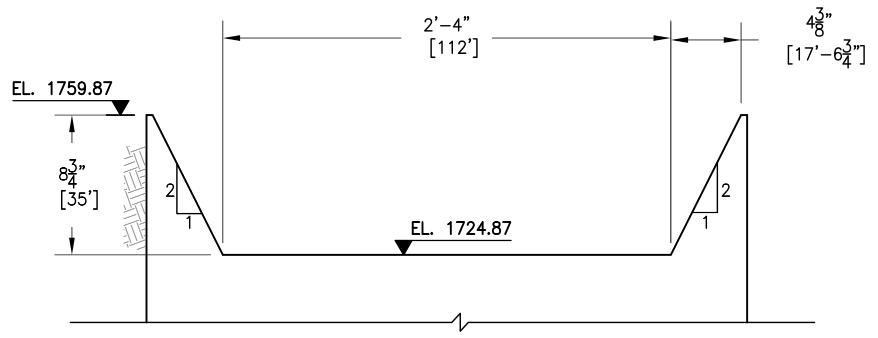
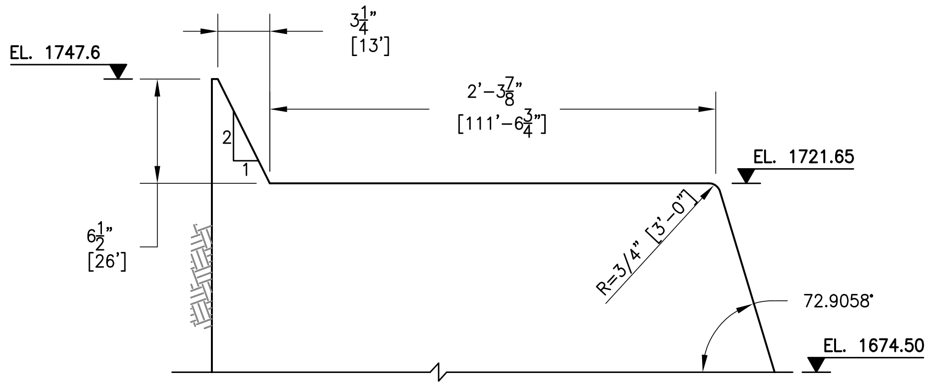
FIGURE 6.3.1



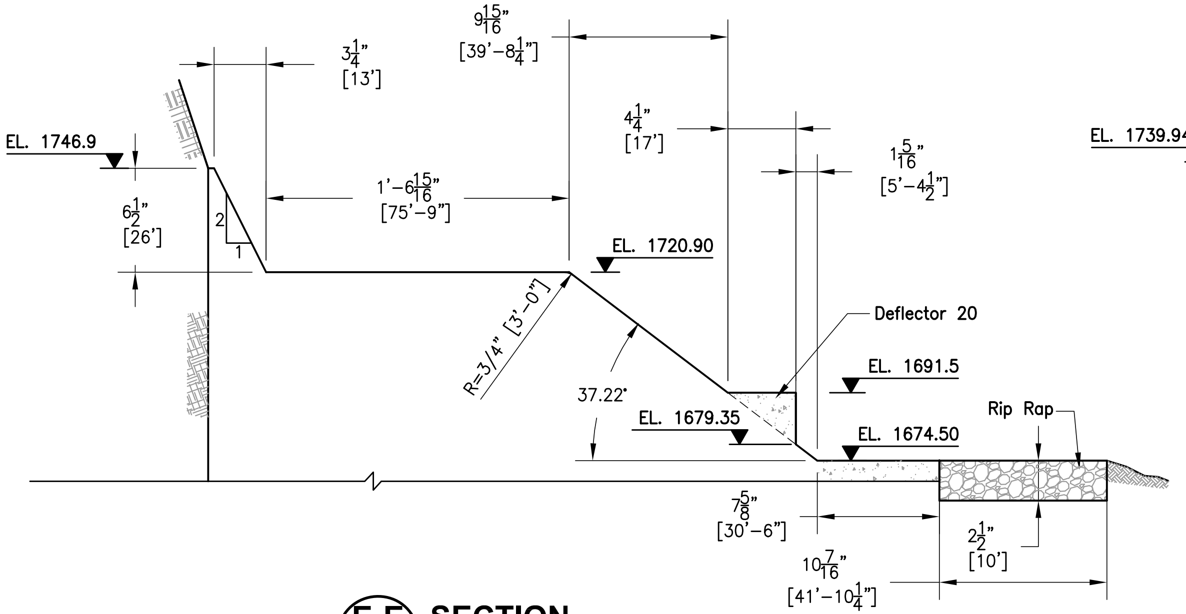
B-B **SECTION**
6.3.1 SCALE: 1in : 12in (MODEL)



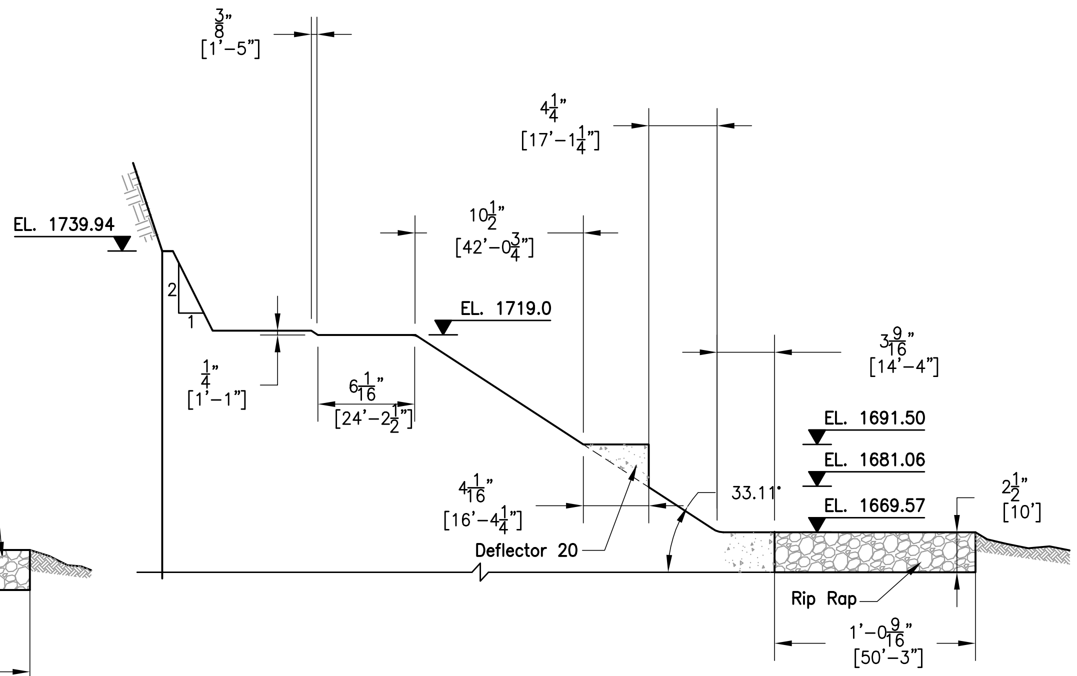
C-C **SECTION**
6.3.1 SCALE: 1in : 12in (MODEL)



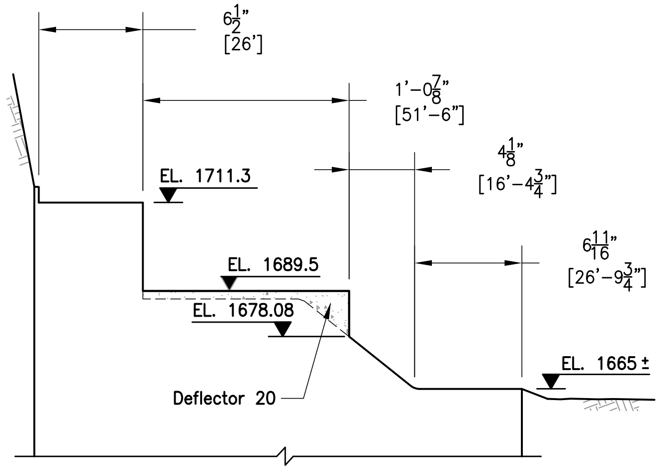
D-D **SECTION**
6.3.1 SCALE: 1in : 12in (MODEL)



E-E **SECTION**
6.3.1 SCALE: 1in : 12in (MODEL)



F-F **SECTION**
6.3.1 SCALE: 1in : 12in (MODEL)

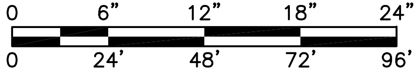


G-G **SECTION**
6.3.1 SCALE: 1in : 12in (MODEL)

NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
2. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET AND INCHES.
3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
4. MODEL SCALE 1:48
5. FABRICATION TOLERANCE = 1/16"

DISTANCE IN MODEL FEET
(1" = 12")



DISTANCE IN PROTOTYPE FEET
(1" = 48')

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OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Recommended Design
Spillway Chute and Deflector 20
Sections and Details

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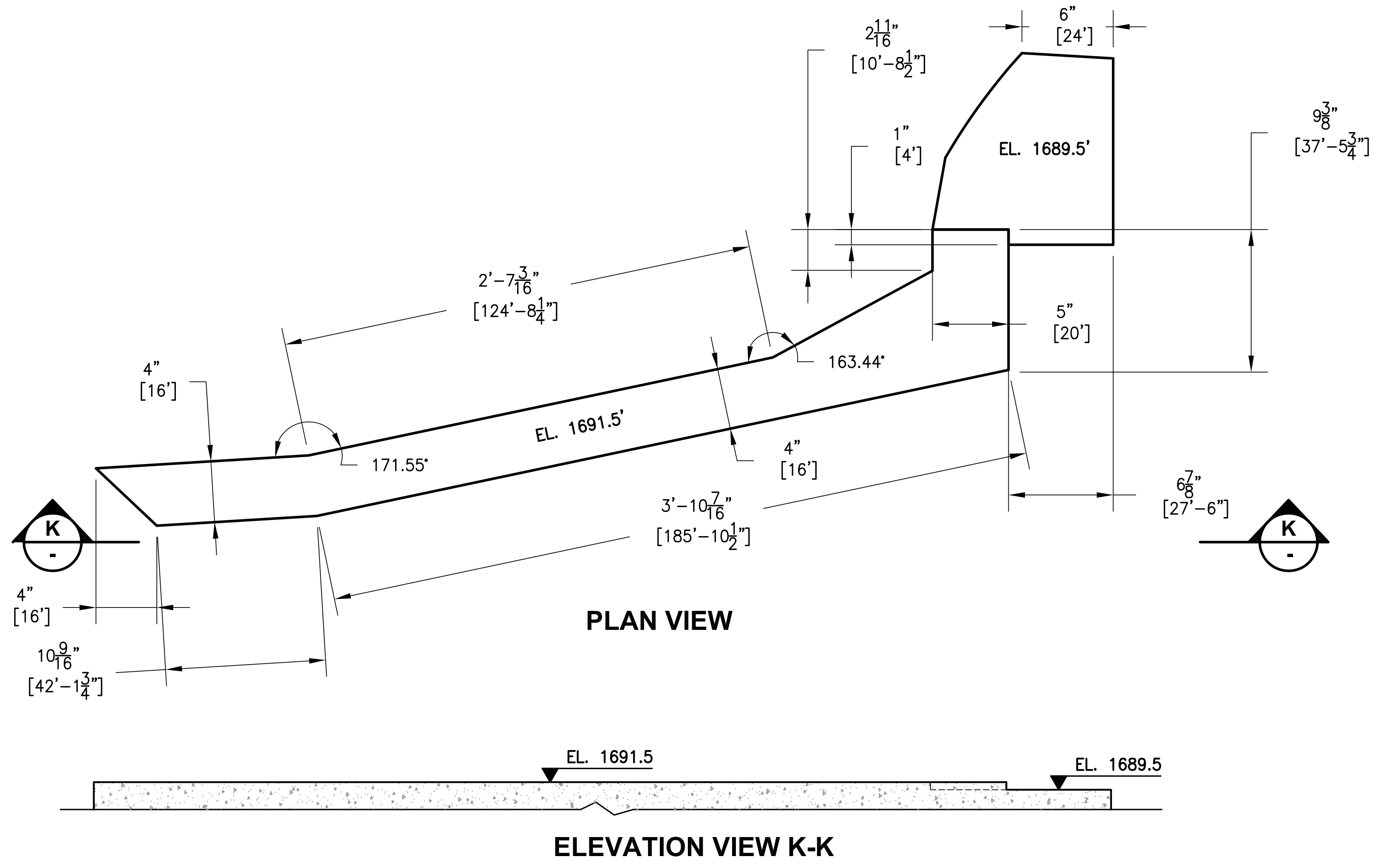
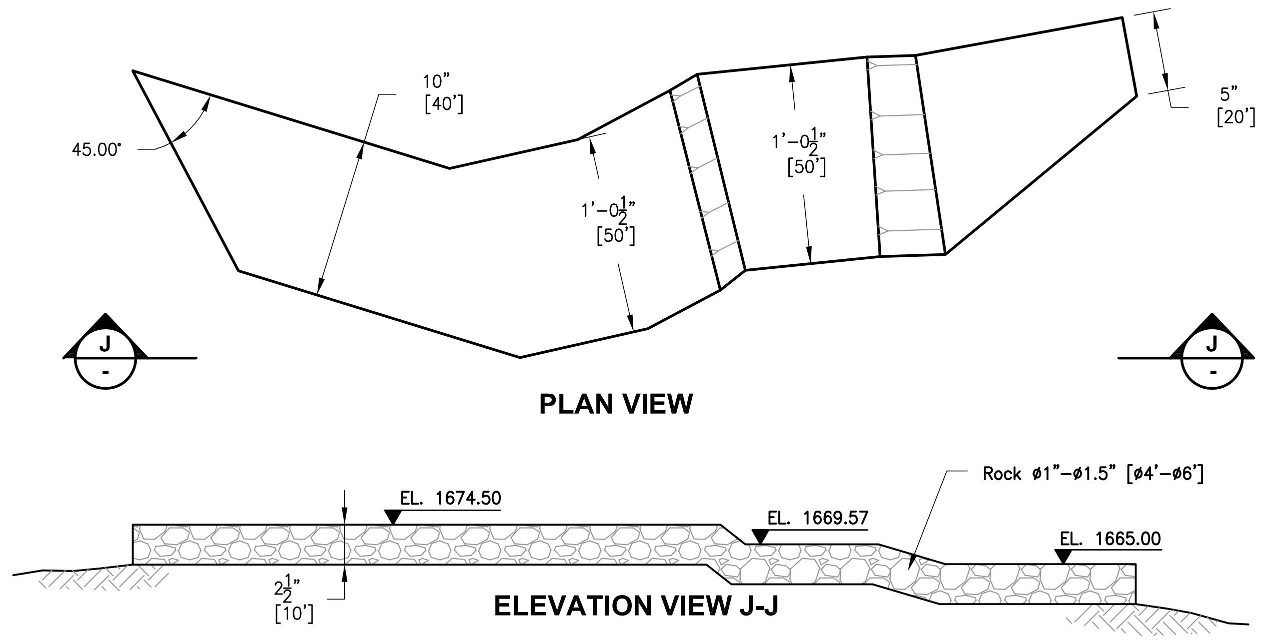
FIGURE 6.3.2



ELEVATION VIEW K-K

2 / 6.3.1 DETAIL - DEFLECTOR 20

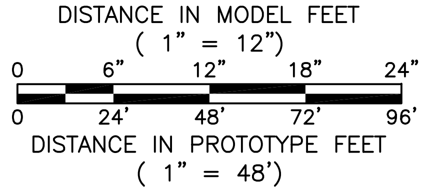
SCALE: 1in : 12in (MODEL)

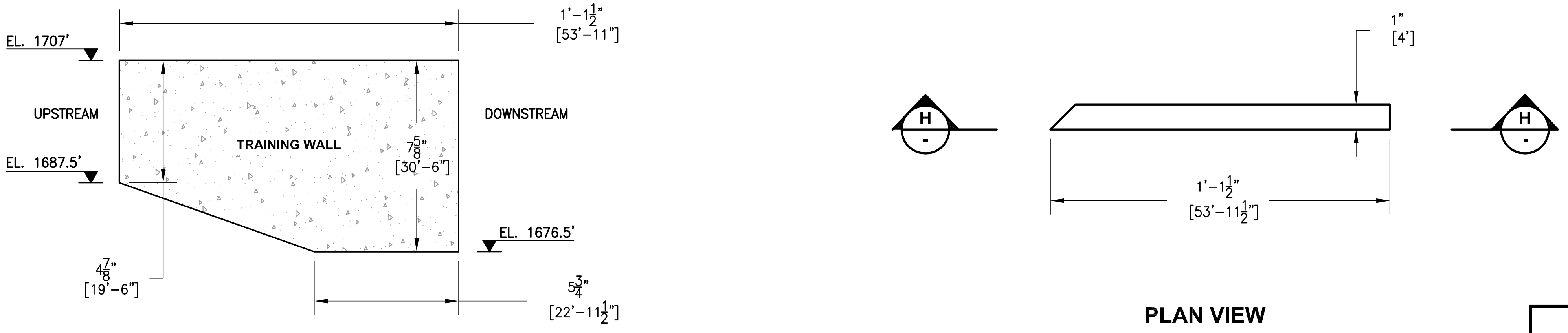


ELEVATION VIEW J-J

3 / 6.3.1 DETAIL - RIP RAP

SCALE: 1in : 12in (MODEL)

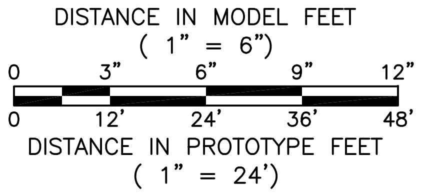




SECTION H-H

1 / 6.3.1 DETAIL- TRAINING WALL

SCALE: 1in : 6in (MODEL)



NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
2. [BRACKETED] DIMENSIONS ARE GIVEN IN PEOTOTYPE FEET AND INCHES.
3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
4. MODEL SCALE 1:48
5. FABRICATION TOLERANCE = 1/16"

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Recommended Design
Deflector 20 with Training Wall and Rip Rap
Plan and Detail

21513–015	REV. NO.: 0	DRN. BY: JYJ	Nov–15–07

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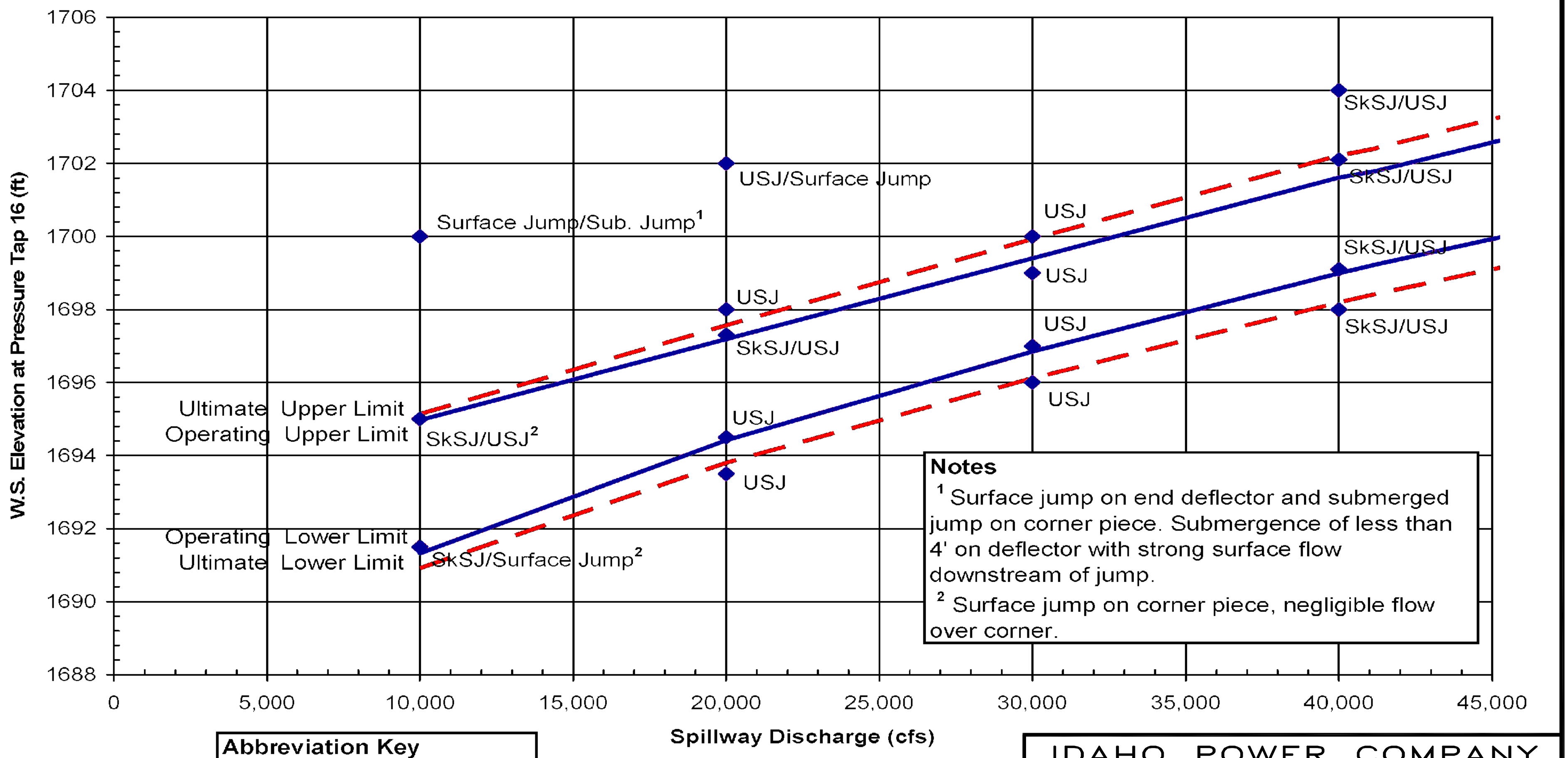
FIGURE 6.3.3

Deflector 20 - End Deflector Performance Curve, 3-Bay Operation, Mobile Bed



Notes

[1] Surface jump on end deflector and submerged jump on corner piece. Submergence of less than 4' on deflector with strong surface flow downstream of jump.

[2] Surface jump on corner piece, negligible flow over corner.

Abbreviation Key

RSJ: Ramped Surface Jet
USJ: Undular Surface Jet
SkSJ: Skimming Surface Jet

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Deflector 20 - Flow Performance Curve
End Deflector
Mobile Bed

21513–8.5x11	REV. NO.: 0	DRN. BY: JAB	OCT–18–07

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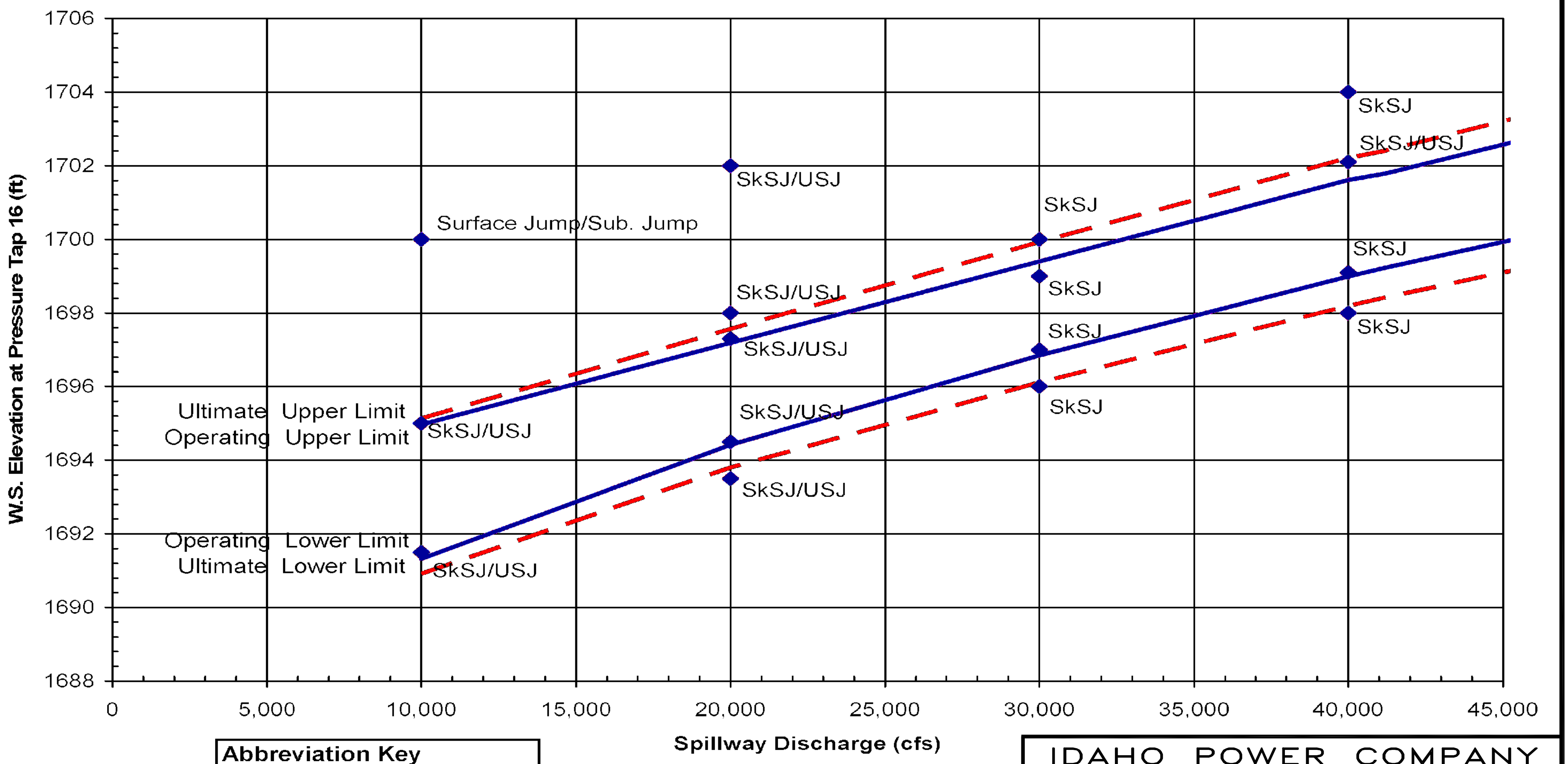
FIGURE 6.3.4

Deflector 20 - Side Deflector Performance Curve, 3-Bay Operation, Mobile Bed



Abbreviation Key
RSJ: Ramped Surface Jet
USJ: Undular Surface Jet
SkSJ: Skimming Surface Jet

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Deflector 20 - Flow Performance Curve
Side Deflector
Mobile Bed

21513–8.5x11	REV. NO.: 0	DRN. BY: JAB	OCT–18–07

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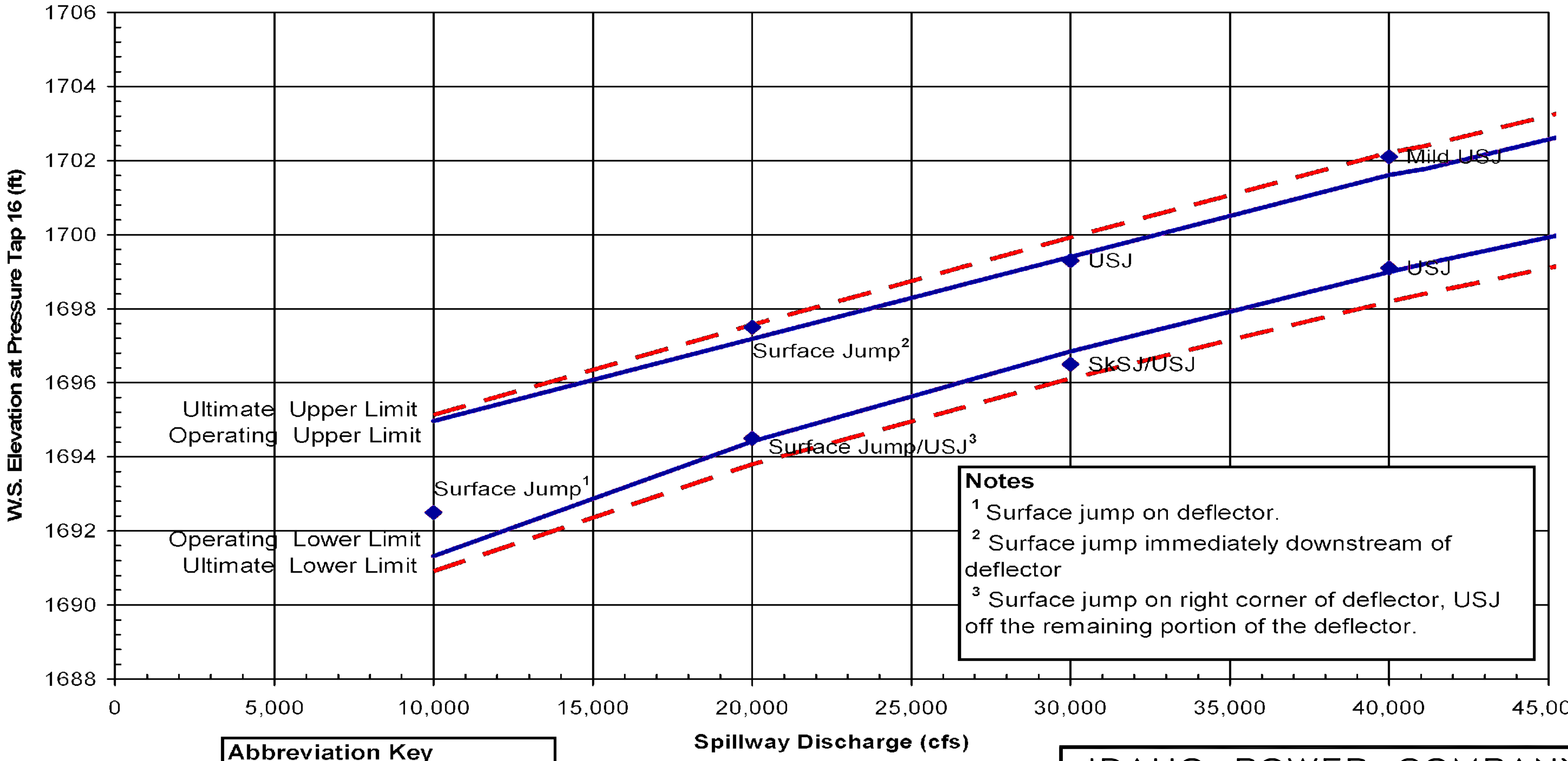
FIGURE 6.3.5

Deflector 20 - End Deflector Performance Curve, 3-Bay Operation, 70 kcfs Fixed Bed



Notes

[1] Surface jump on deflector.

[2] Surface jump immediately downstream of deflector

[3] Surface jump on right corner of deflector, USJ off the remaining portion of the deflector.

Abbreviation Key

RSJ: Ramped Surface Jet
USJ: Undular Surface Jet
SkSJ: Skimming Surface Jet

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

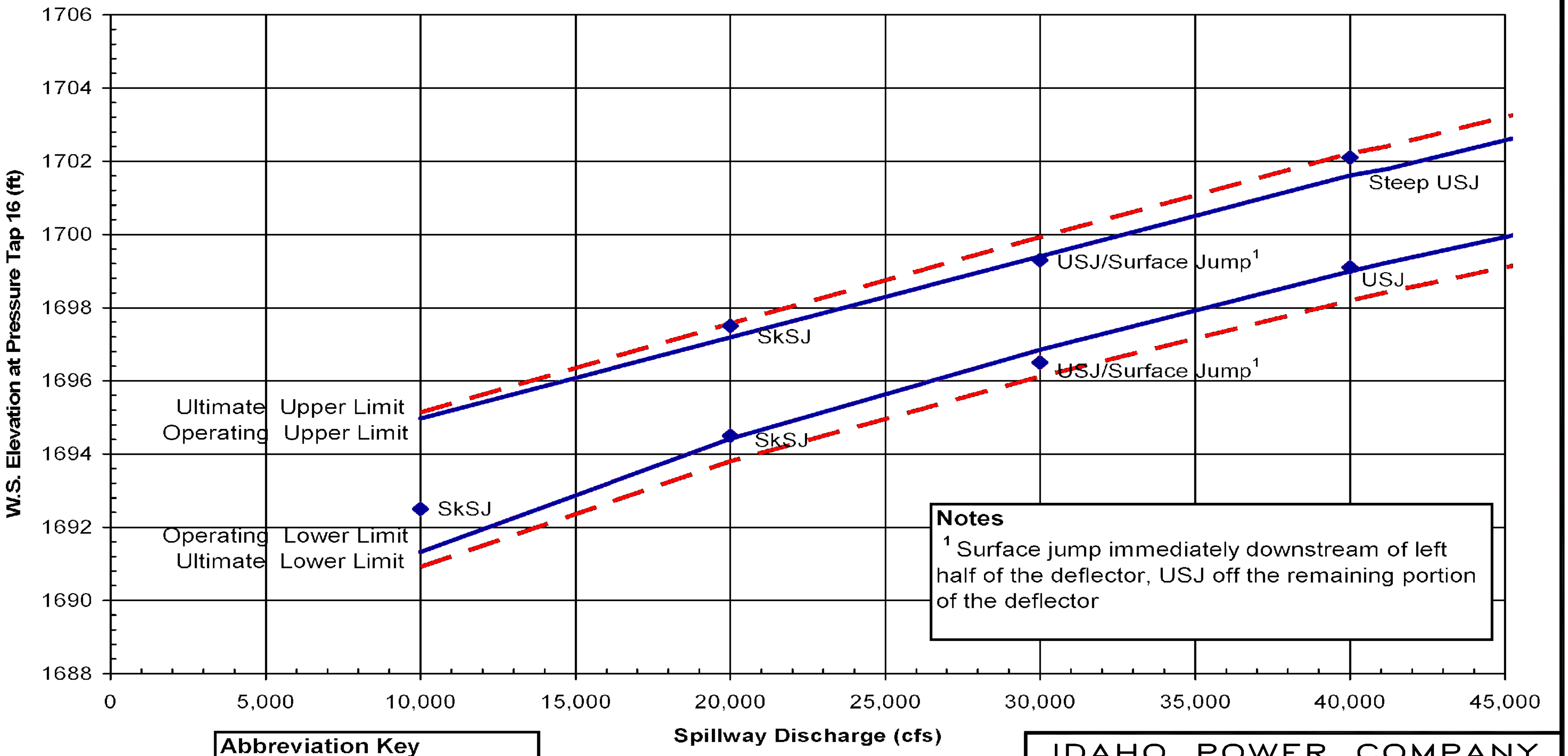
Deflector 20 - Flow Performance Curve
End Deflector
70,000 cfs Fixed Bed

21513–8.5x11	REV. NO.: 0	DRN. BY: JAB	OCT–12–07

northwest hydraulic consultants

FIGURE 6.3.6

Deflector 20 - Corner Portion of Deflector Performance Curve, 3-Bay Operation, 70 kcfs Fixed Bed



Notes

[1] Surface jump immediately downstream of left half of the deflector, USJ off the remaining portion of the deflector

Abbreviation Key
RSJ: Ramped Surface Jet
USJ: Undular Surface Jet
SkSJ: Skimming Surface Jet

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Deflector 20 - Flow Performance Curve
Corner Portion of Deflector
70,000 cfs Fixed Bed

21513–8.5x11	REV. NO.: 0	DRN. BY: JAB	OCT–12–07

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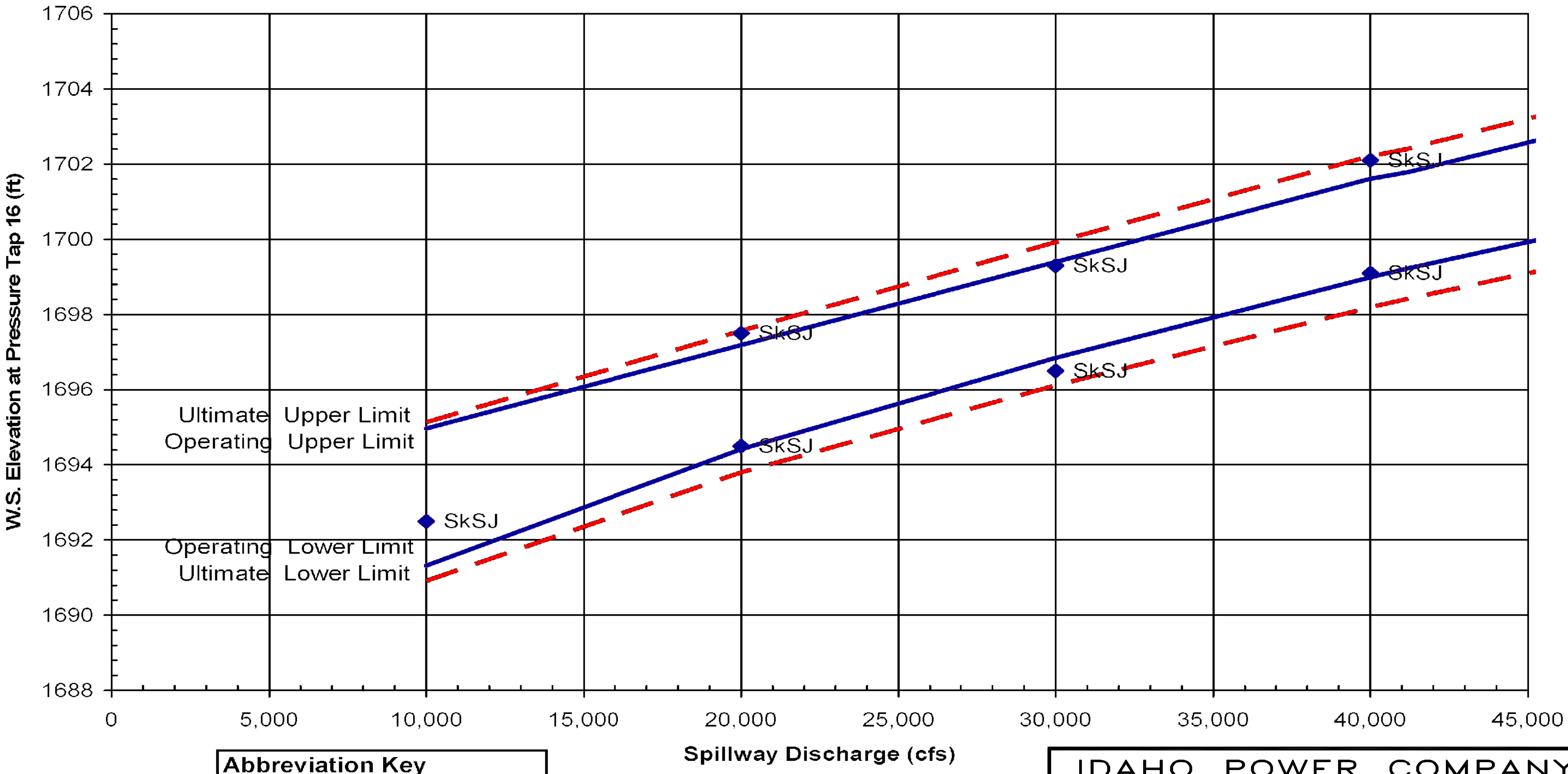
FIGURE 6.3.7

Deflector 20 - Side Deflector Performance Curve, 3-Bay Operation, 70 kcfs Fixed Bed



Abbreviation Key
RSJ: Ramped Surface Jet
USJ: Undular Surface Jet
SkSJ: Skimming Surface Jet

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OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Deflector 20 - Flow Performance Curve
Side Deflector
70,000 cfs Fixed Bed

21513–8.5x11	REV. NO.: 0	DRN. BY: JAB	OCT–12–07

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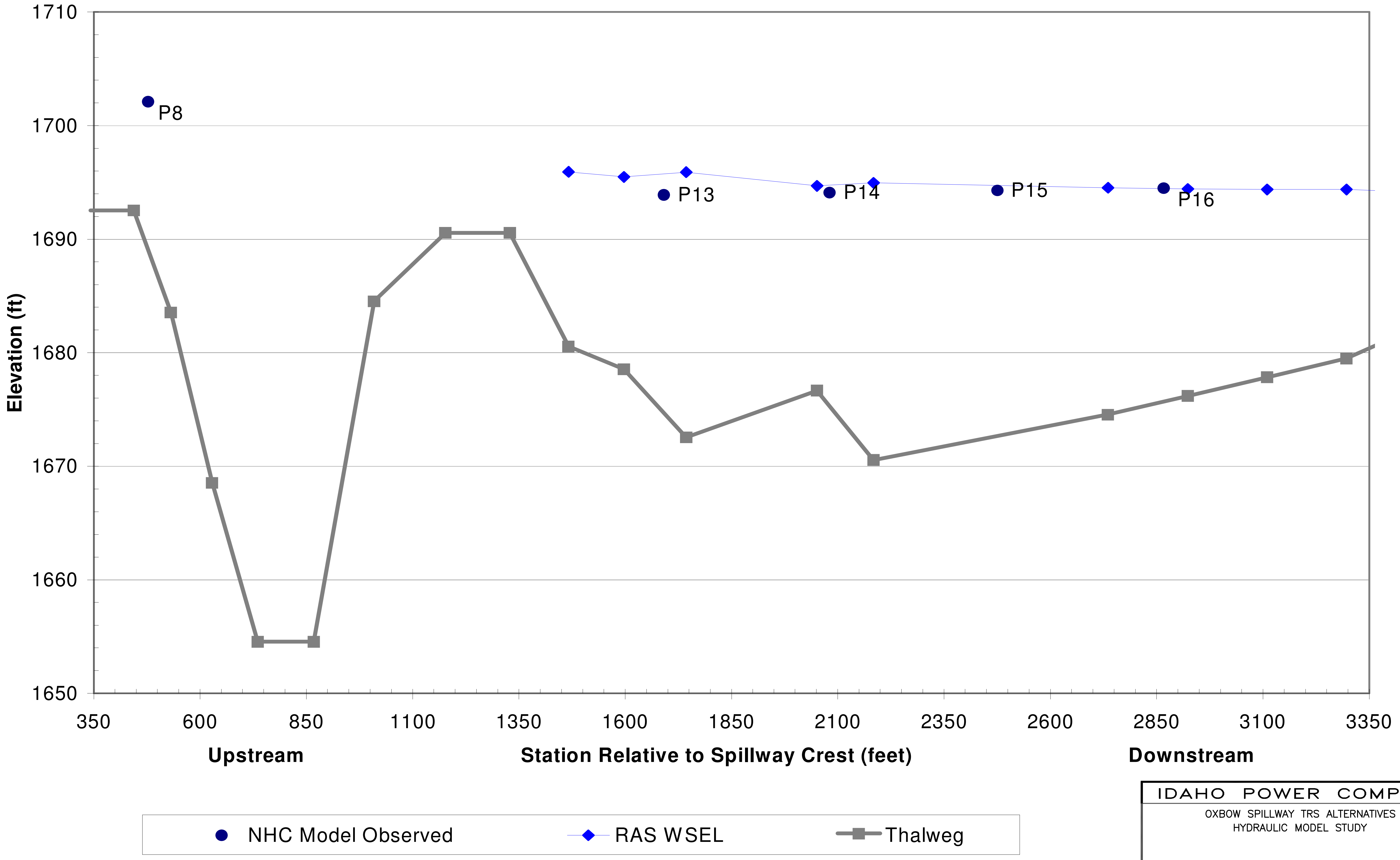
FIGURE 6.3.8



NOTES:

1. RAS WSEL assuming low powerhouse discharge and low Hells Canyon tailwater, n = 0.030
2. RAS Profile extends to the downstream end of the mobile bed. RAS WSEL calculations upstream of this point are considered unreliable due to multi-dimensional flow effects

IDAHO POWER COMPANY
OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

20,000 cfs - Final Documentation
Water Surface Elevation Profile Plot

21513–11x17	REV. NO.: 0	DRN. BY: JAB	Oct–11–07

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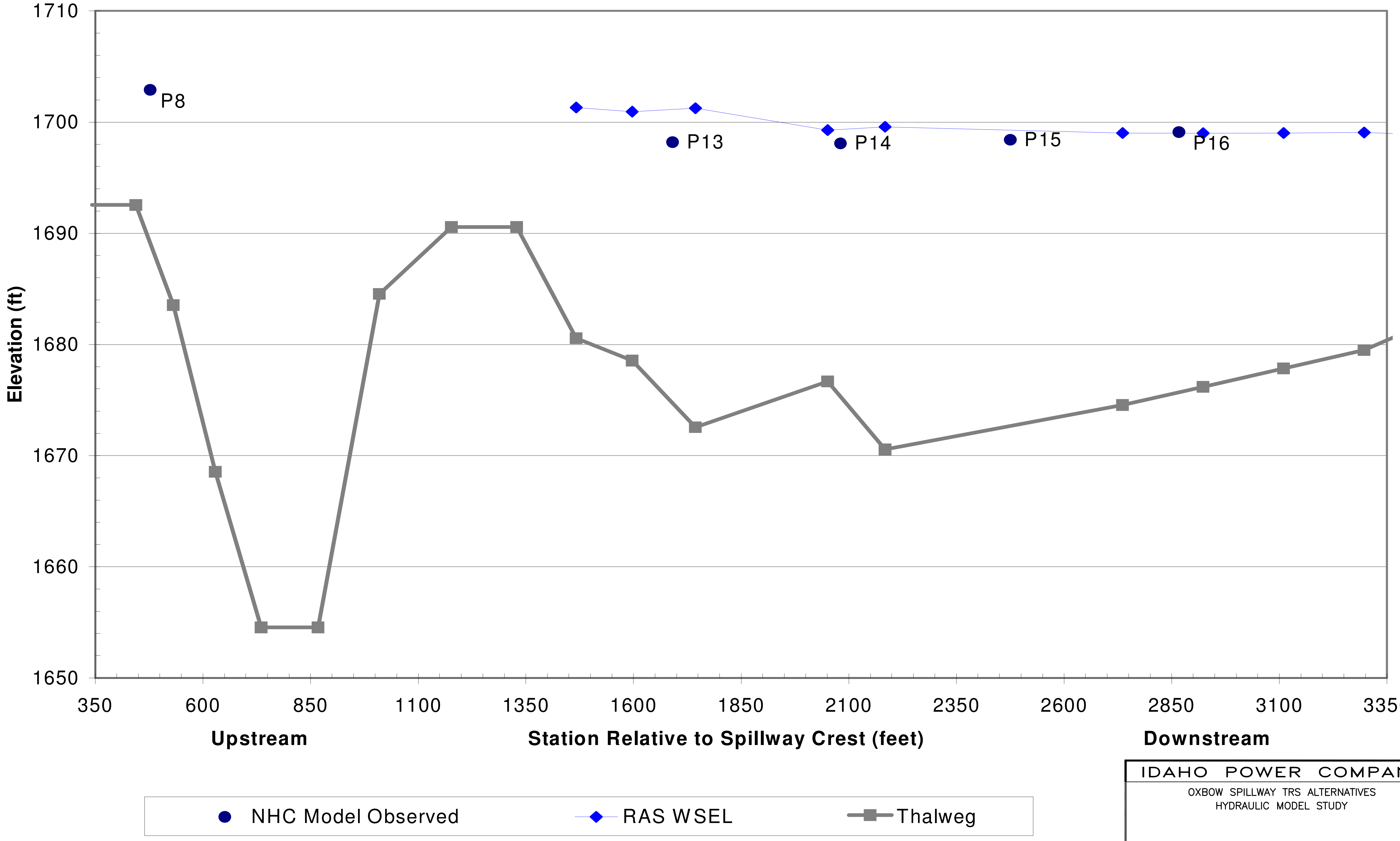
FIGURE 6.3.9



NOTES:

1. RAS WSEL assuming low powerhouse discharge and low Hells Canyon tailwater, n = 0.030
2. RAS Profile extends to the downstream end of the mobile bed. RAS WSEL calculations upstream of this point are considered unreliable due to multi-dimensional flow effects

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

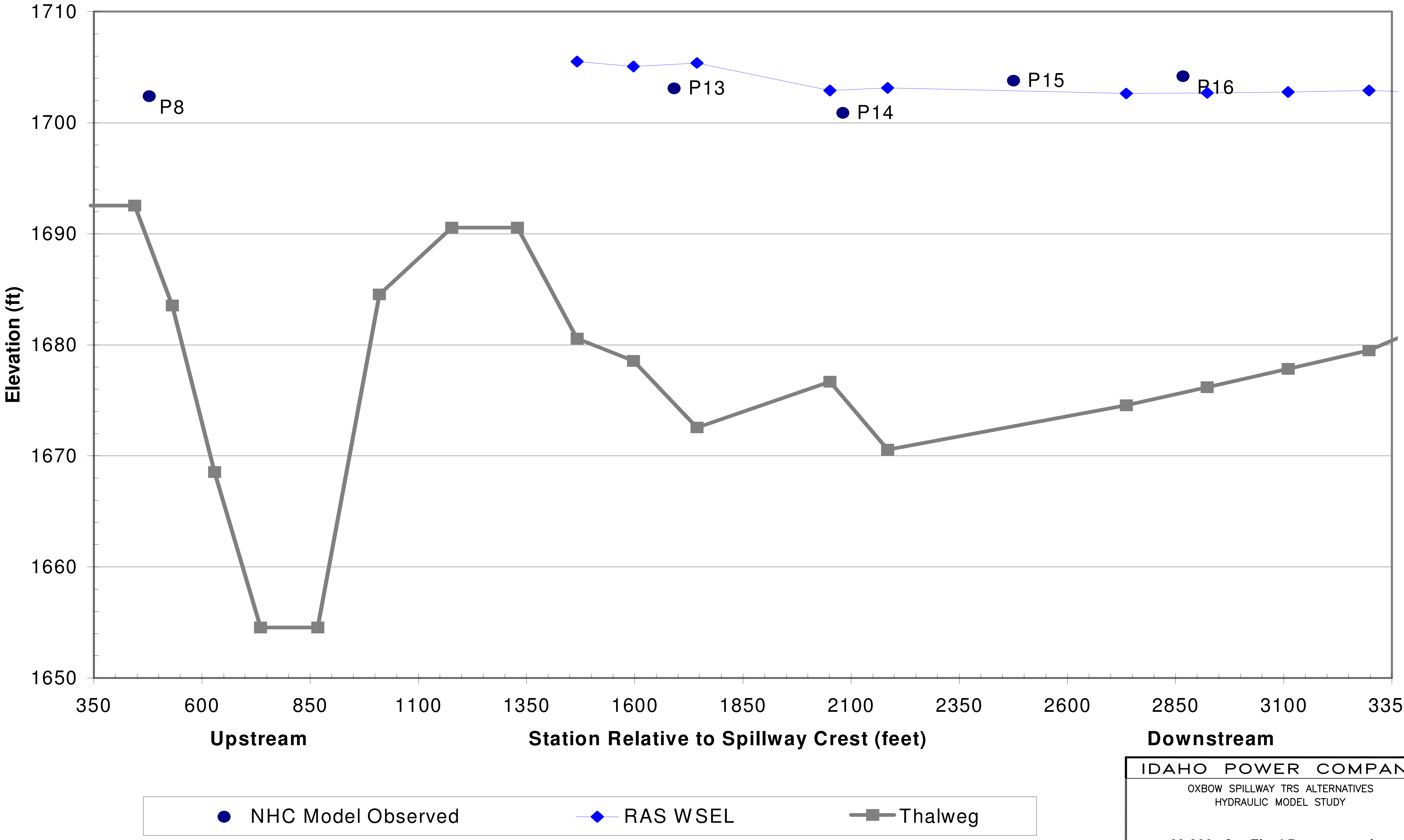
40,000 cfs - Final Documentation

Water Surface Elevation Profile Plot

21513-11x17	REV. NO.: 0	DRN. BY: JAB	Oct-11-07

northwest hydraulic consultants

FIGURE 6.3.10



NOTES:

1. RAS WSEL assuming low powerhouse discharge and low Hells Canyon tailwater, n = 0.030
2. RAS Profile extends to the downstream end of the mobile bed. RAS WSEL calculations upstream of this point are considered unreliable due to multi-dimensional flow effects

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

60,000 cfs - Final Documentation

Water Surface Elevation Profile Plot

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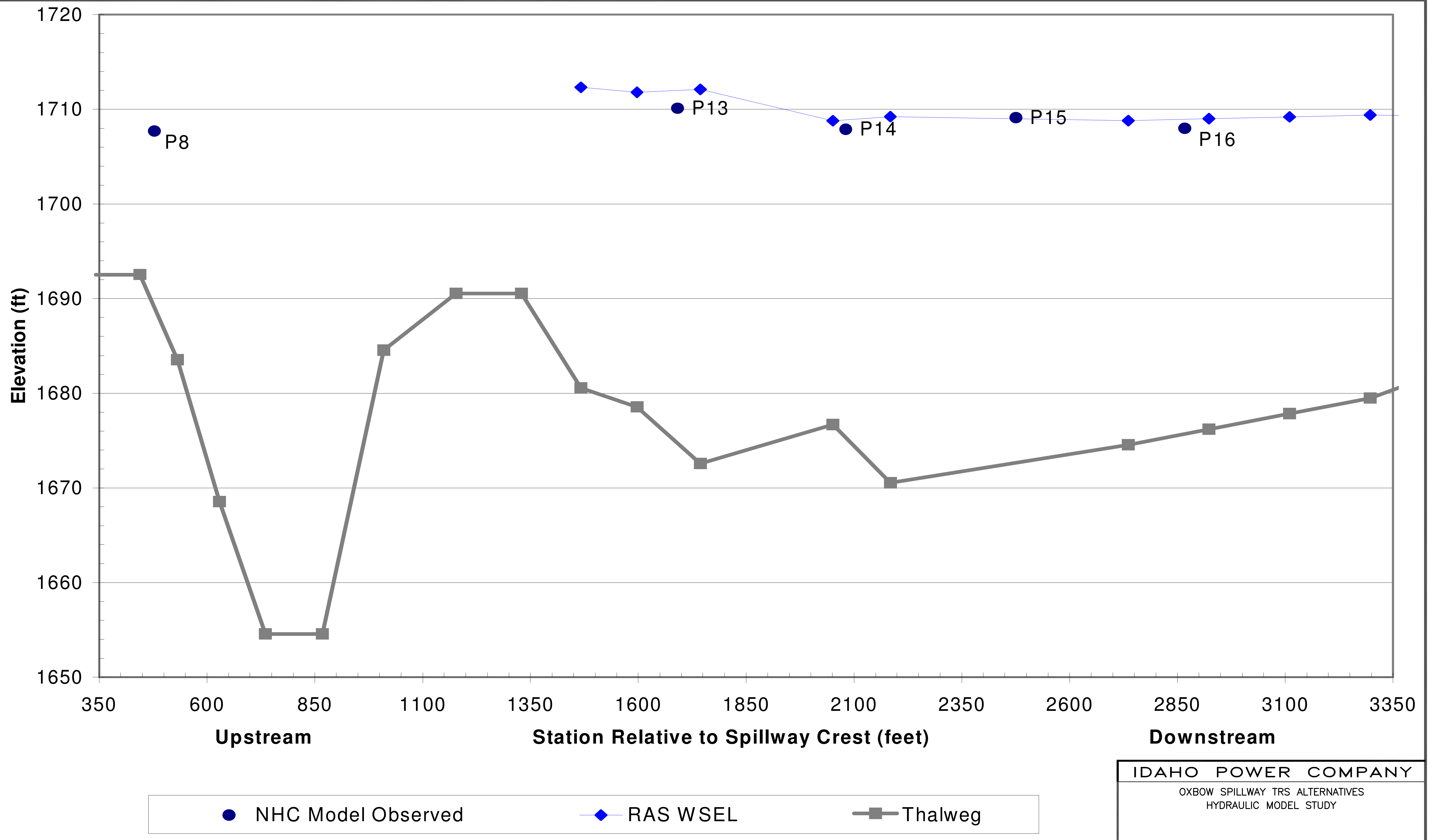
FIGURE 6.3.11



NOTES:

1. RAS WSEL assuming low powerhouse discharge and low Hells Canyon tailwater, n = 0.030
2. RAS Profile extends to the downstream end of the mobile bed. RAS WSEL calculations upstream of this point are considered unreliable due to multi-dimensional flow effects

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OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

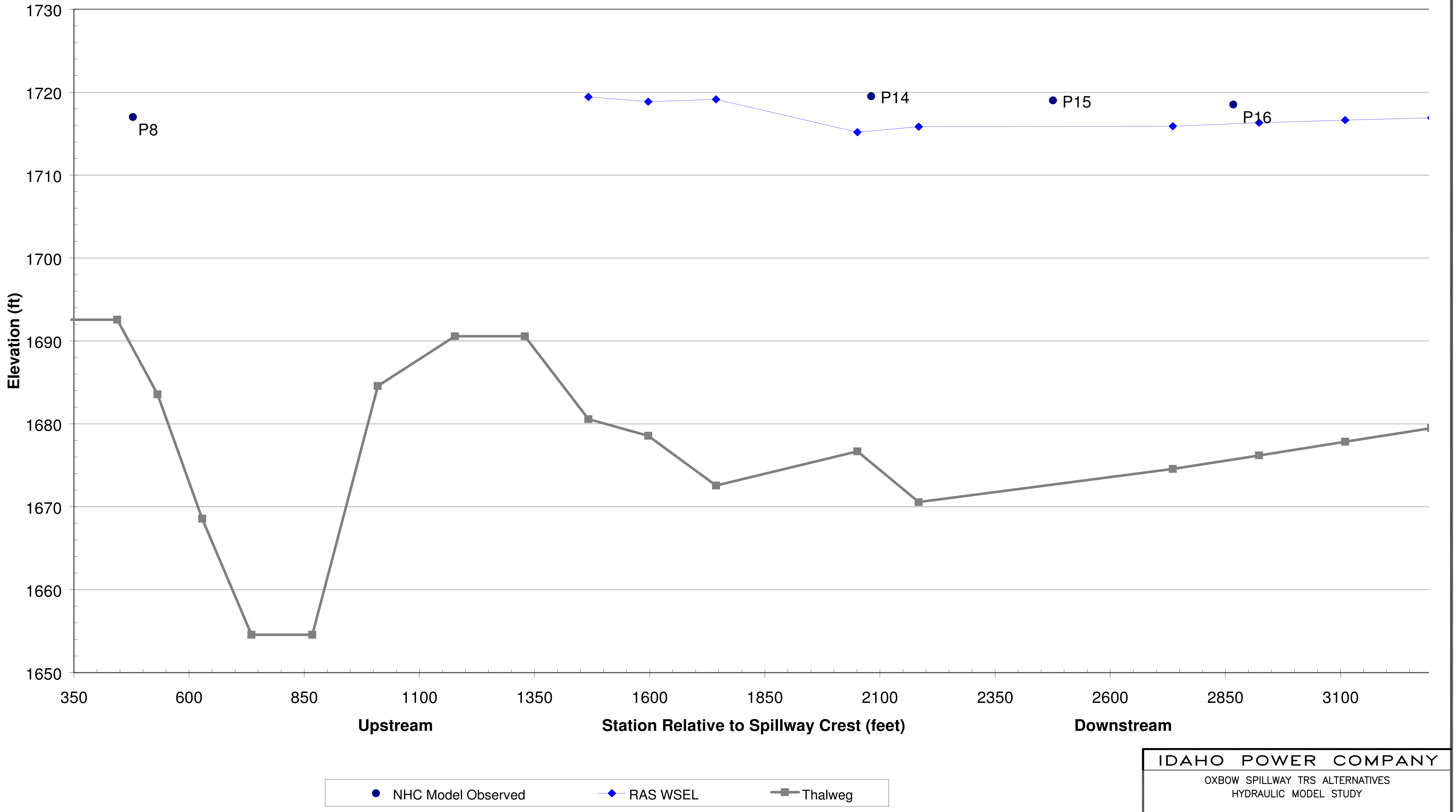
100,000 cfs - Final Documentation

Water Surface Elevation Profile Plot

21513–11x17	REV. NO.: 0	DRN. BY: JAB	Oct–11–07

northwest hydraulic consultants

FIGURE 6.3.12



NOTES:

1. RAS WSEL assuming low powerhouse discharge and low Hells Canyon tailwater, n = 0.030
2. RAS Profile extends to the downstream end of the mobile bed. RAS WSEL calculations upstream of this point are considered unreliable due to multi-dimensional flow effects

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OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

150,000 cfs - Final Documentation

Water Surface Elevation Profile Plot

21513-11x17	REV. NO.: 0	DRN. BY: JAB	Oct-11-07

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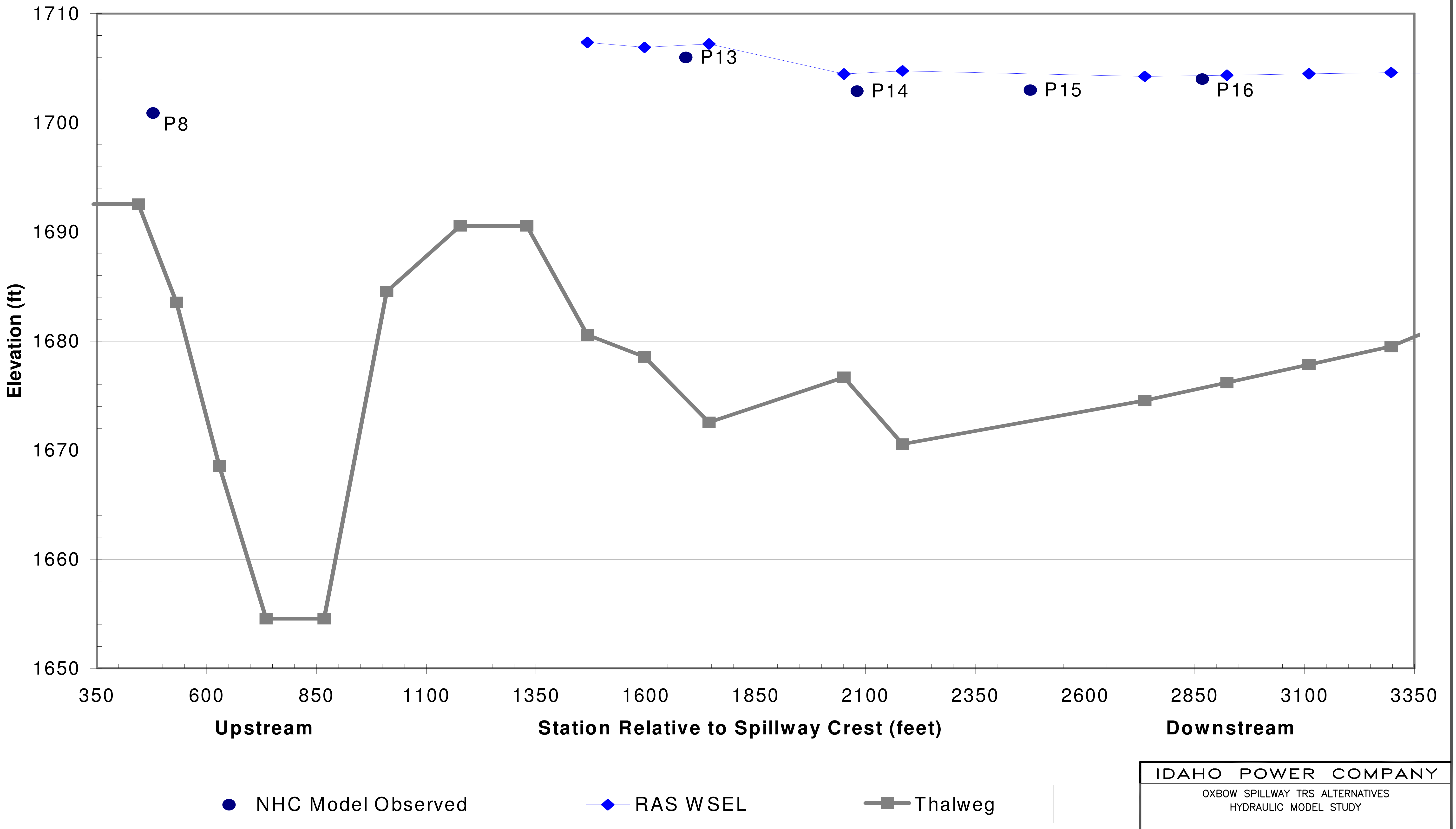
FIGURE 6.3.13



NOTES:

1. RAS WSEL assuming low powerhouse discharge and low Hells Canyon tailwater, n = 0.030
2. RAS Profile extends to the downstream end of the mobile bed. RAS WSEL calculations upstream of this point are considered unreliable due to multi-dimensional flow effects

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OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

70,000 cfs - Final Documentation
Erosion Test
Water Surface Elevation Profile Plot

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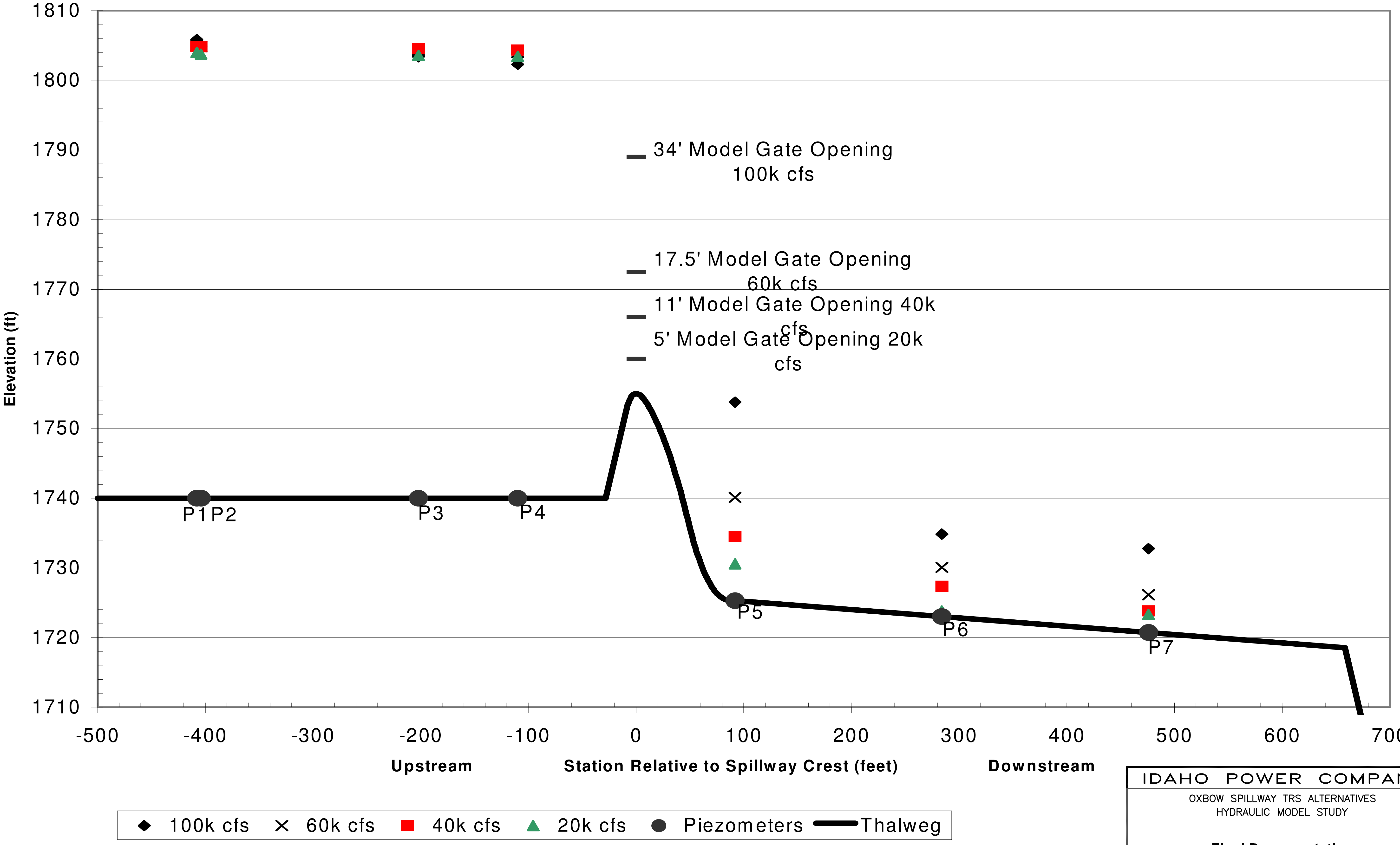
FIGURE 6.3.14



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OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Final Documentation
Forebay and Chute
Water Surface Elevation Profile Plots

21513-11x17	REV. NO.: 0	DRN. BY: JAB	Oct-11-07

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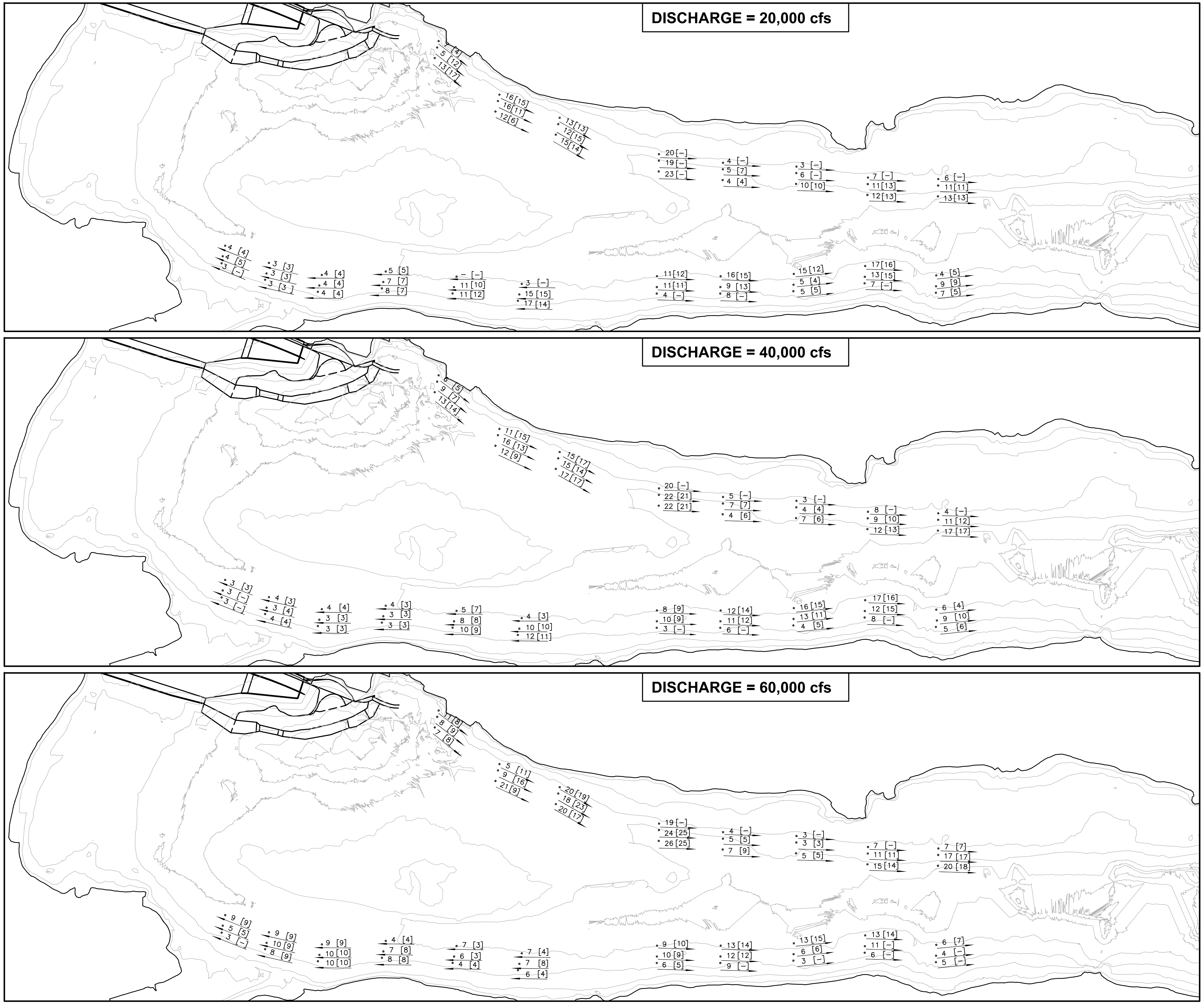
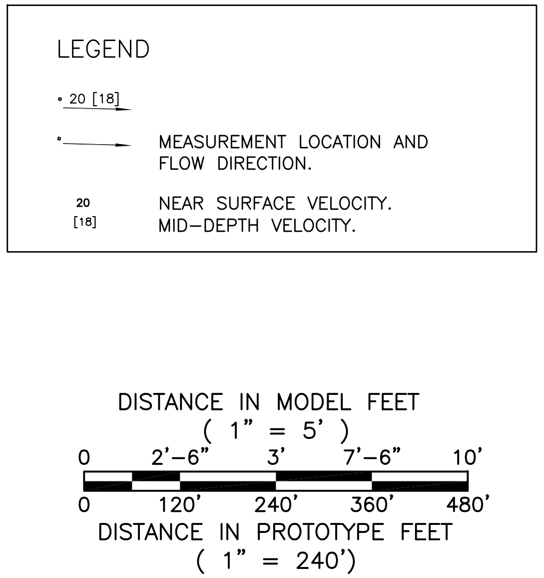
FIGURE 6.3.15





NOTES:

1. ALL VELOCITIES ARE GIVEN IN PROTOTYPE FEET PER SECOND.

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OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

20,000, 40,000 & 60,000 cfs
Near Shore Velocities
Final Documentation

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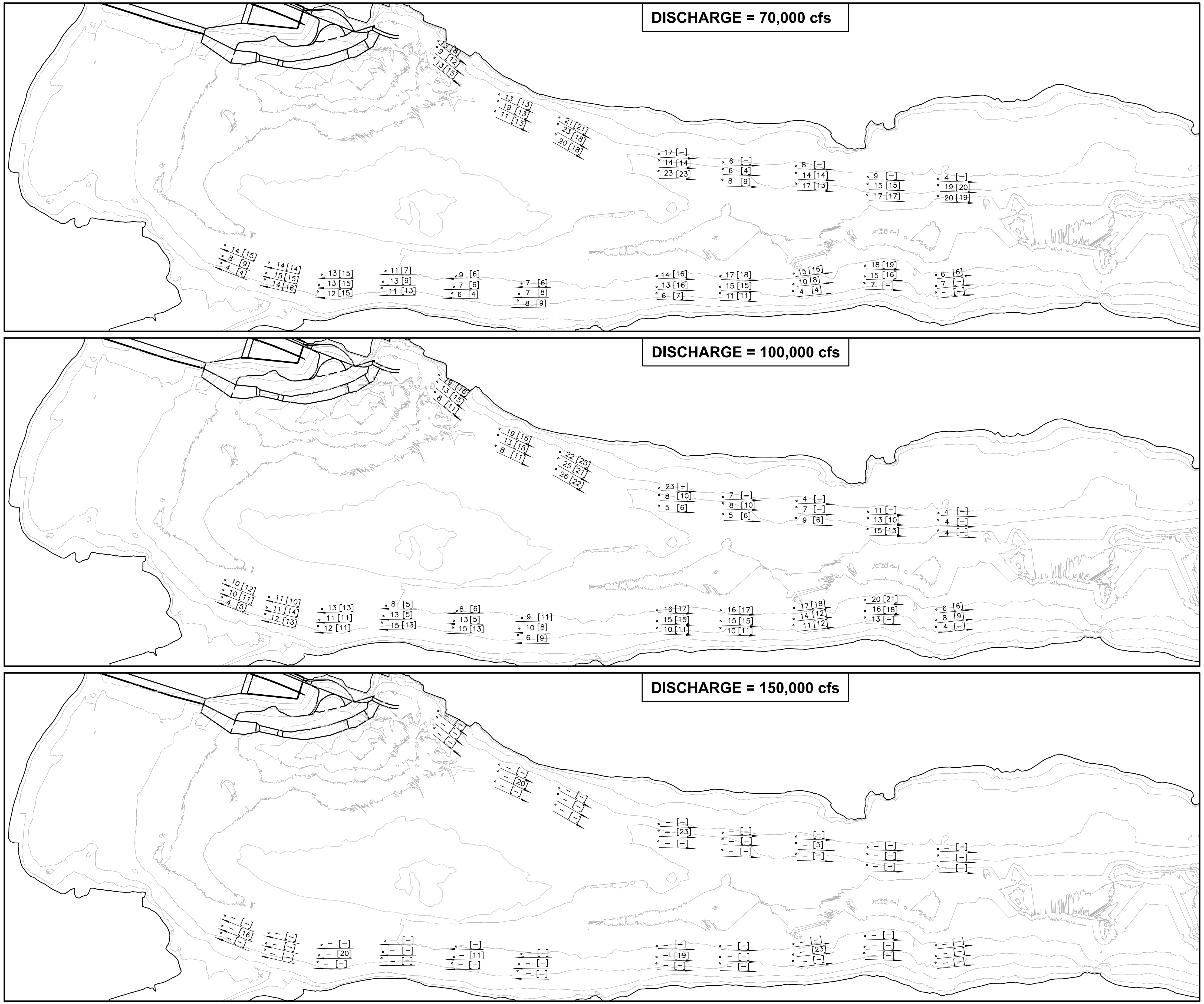
FIGURE 6.3.16



LEGEND

20 [18]

MEASUREMENT LOCATION AND FLOW DIRECTION.

20 NEAR SURFACE VELOCITY.

[18] MID–DEPTH VELOCITY.

DISTANCE IN MODEL FEET
(1" = 5')
0 2'–6" 3' 7'–6" 10'
0 120' 240' 360' 480'
DISTANCE IN PROTOTYPE FEET
(1" = 240')

NOTES:

1. ALL VELOCITIES ARE GIVEN IN PROTOTYPE FEET PER SECOND.

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OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

70,000, 100,000 & 150,000 cfs
Near Shore Velocities
Final Documentation

21513–018	REV. NO.: 0	DRN. BY: JYJ	Nov–19–07

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FIGURE 6.3.17

Legend

Deflector 20 Model Contours (ft)

Field Contours (ft)

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Final Documentation Erosion Test
Contour Plot

Scale - 1:750

coord. syst.: IPC Custom	horz. datum: NAD 83	horz. units: feet
northwest hydraulic consultants	project no. 21513	10-Oct-2007

Figure 6.3.18

IDAHO POWER COMPANY

Final Documentation Erosion Test
Baseline Overlay Contour Plot

coord. syst.: IPC Custom	horz. datum: NAD 83	horz. units: feet
northwest hydraulic consultants	project no. 21513	10-Oct-2007

Figure 6.3.19

PHOTOS

Photo 1.1 Layout of Oxbow project.

Photo 1.2 Oregon spillway operating at 100 cfs.

Photo 1.3 Material deposition downstream of spillway.

Photo 4.1 Oxbow physical model with dry mobile bed.

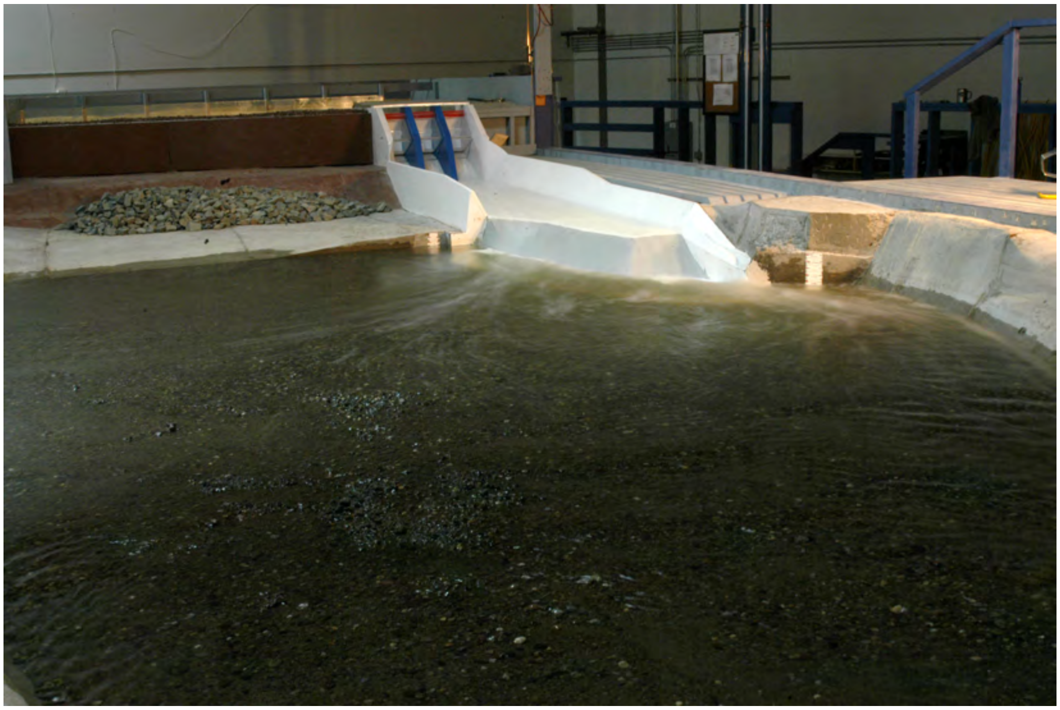

Photo 4.2 Oxbow physical model operating.

Photo 4.3 Oxbow physical model mobile bed, looking overhead..

Photo 6.1.1 Baseline, 20,000 cfs, looking at left bank.

Photo 6.1.2 Baseline, 20,000 cfs, from overhead.

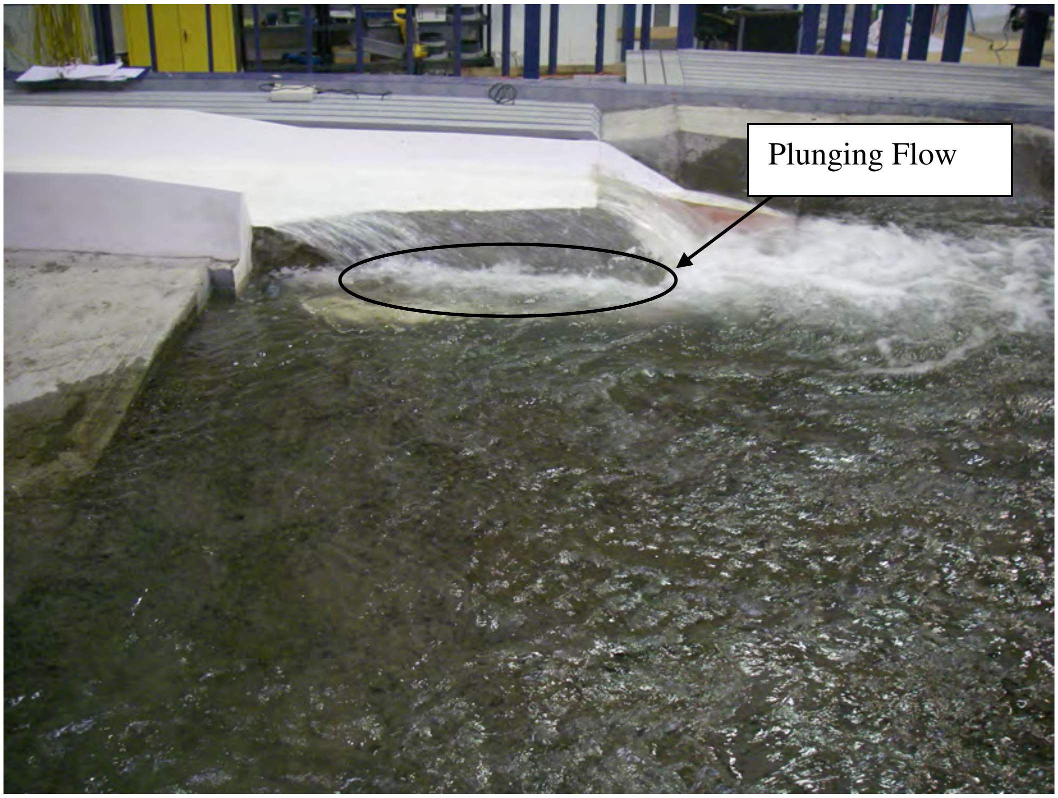

Photo 6.1.3 Baseline, 40,000 cfs, looking at left bank.

Photo 6.1.4 Baseline, 40,000 cfs, from overhead.

Photo 6.1.5 Baseline, 60,000 cfs, looking at left bank.

Photo 6.1.6 Baseline, 60,000 cfs, from overhead.

Photo 6.1.7 Baseline, 100,000 cfs, looking at left bank.

Photo 6.1.8 Baseline, 100,000 cfs, from overhead.

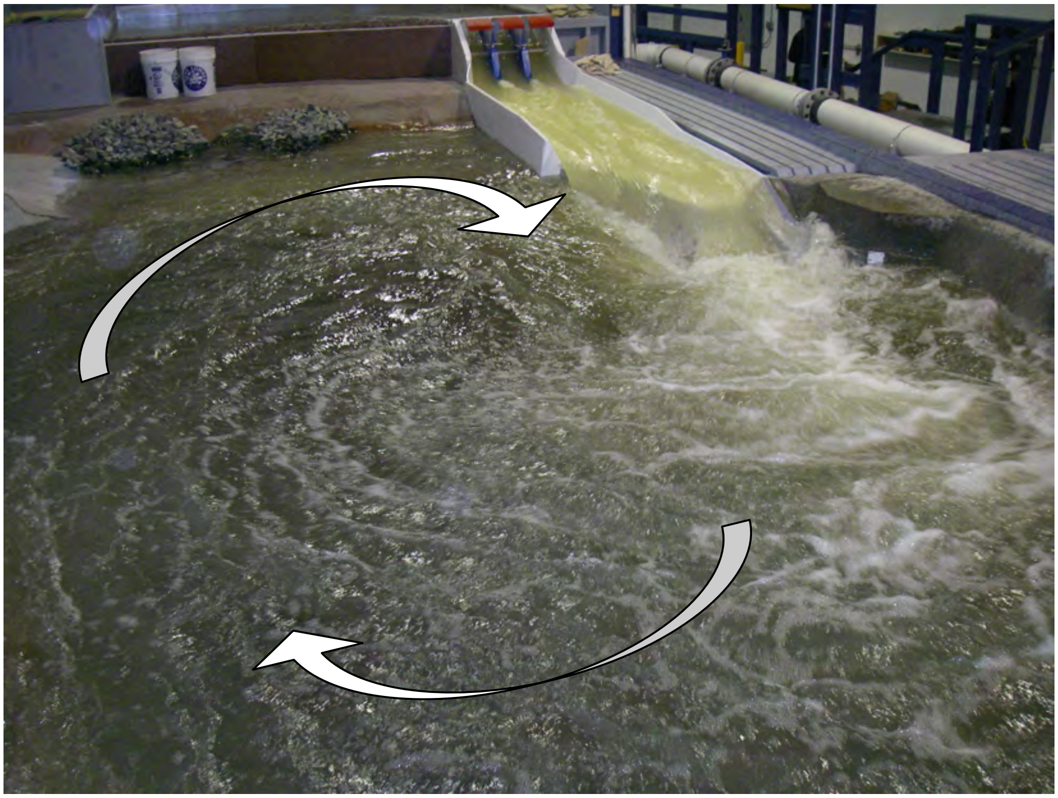

Photo 6.1.9 Baseline, 150,000 cfs, looking at left bank, circulation cell flow pattern shown.

Photo 6.1.10 Baseline, 150,000 cfs, from overhead.

Photo 6.2.1 Generic Deflector Concept 1 - June 6, 2007 Witness Test

Photo 6.2.2 Generic Deflector Concept 2 - June 12, 2007 Witness Test

Photo 6.2.3 Generic Deflector Concept 3 - June 12, 2007 Witness Test

Photo 6.2.4 Deflector 1, 20,000 cfs

Photo 6.2.5 Deflector 2, Dry

Photo 6.2.6 Deflector 3, Dry

Photo 6.2.7 Deflector 4, 20,000 cfs

Photo 6.2.8 Deflector 6, Dry

Photo 6.2.9 Deflector 6, 20,000 cfs

Photo 6.2.10 Deflector 8, Dry

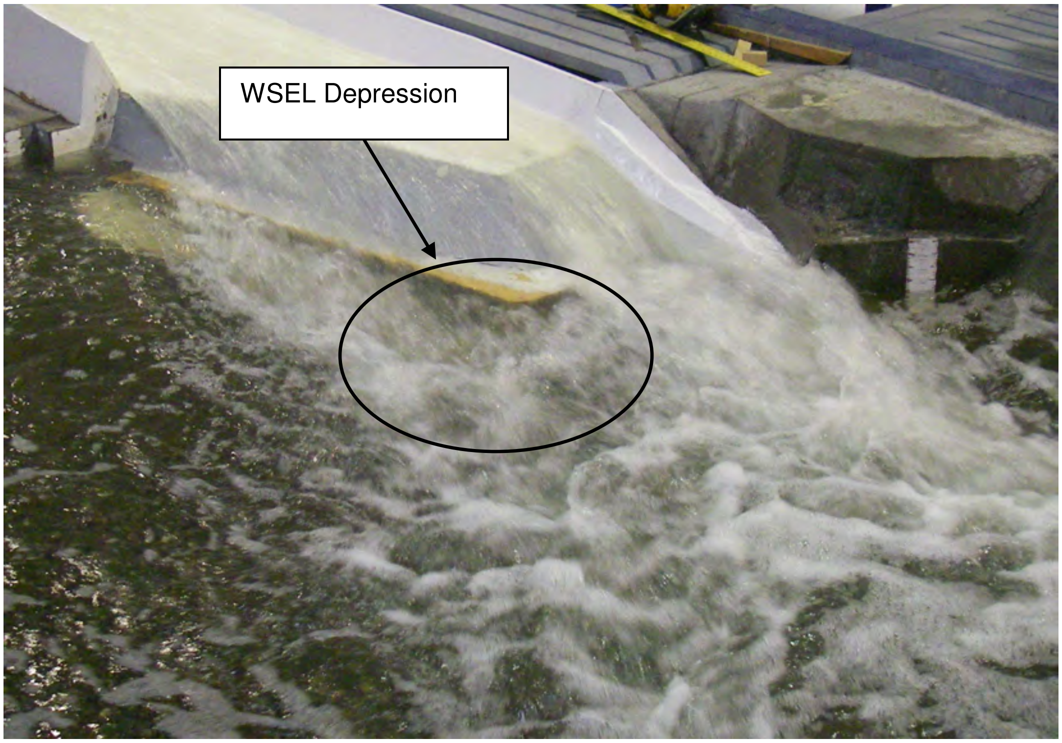

Photo 6.2.11 Localized water surface elevation depression located off northeast corner of the deflector.

Photo 6.2.12 Deflector 14, 40,000 cfs, Low Tailwater, 3-Bay Operation

Photo 6.2.13 Deflector 15, Dry

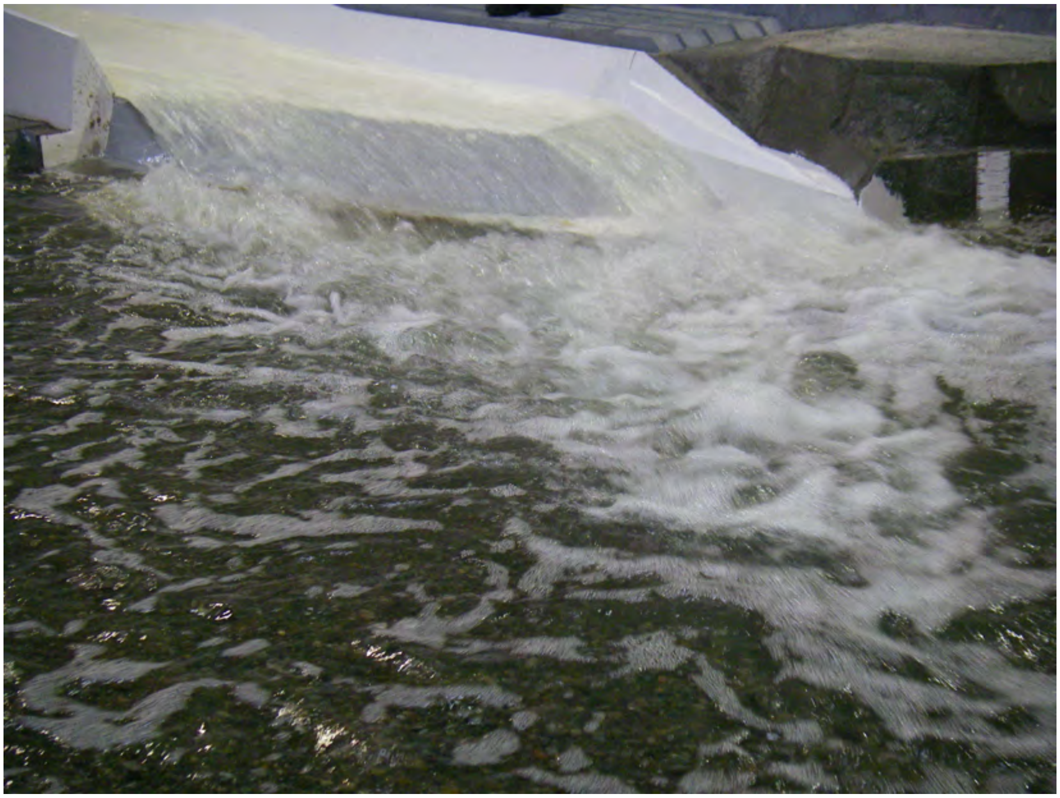

Photo 6.2.14 Deflector 16, 40,000 cfs, Low Tailwater, 2-Bay Operation

Photo 6.2.15 Deflector 17, 20,000 cfs, Low Tailwater, 2-Bay Operation

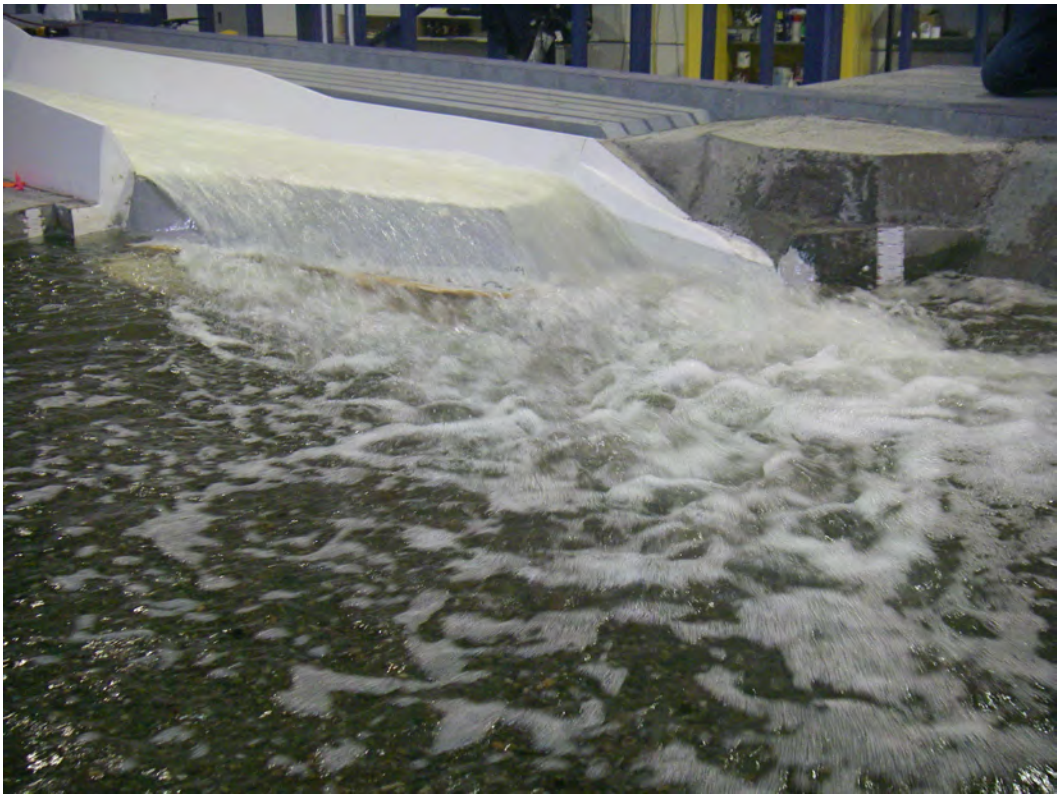

Photo 6.2.16 Deflector 19, 40,000 cfs, Low Tailwater, 3-Bay Operation

Photo 6.2.17 Deflector 20, Dry, Recommended Design

Photo 6.2.18 Deflector 21, Dry

Photo 6.2.19 Deflector 21, 40,000 cfs, Low Tailwater, 3-Bay Operation

Photo 6.2.20 Rip rap test, Deflector 21, 70,000 cfs, 6'-10' rip rap.

Photo 6.2.21 Rip rap test, Deflector 21, 70,000 cfs, 4'-6' rip rap.

Photo 6.2.22 Rip rap test, Deflector 20, 20,000 cfs, 4'-6' rip rap

Photo 6.2.23 Rip rap test, Deflector 20, 40,000 cfs, 4'-6' rip rap.

Photo 6.3.1 Final Documentation, Deflector 20, 20,000 cfs, 1697.2' tailwater.

Photo 6.3.2 Final Documentation, Deflector 20, 40,000 cfs, 1699.1' tailwater.

Photo 6.3.3 Final Documentation, Deflector 20, 60,000 cfs, 1704.2' tailwater.

Photo 6.3.4 Final Documentation, Deflector 20, 100,000 cfs, 1708.4' tailwater.

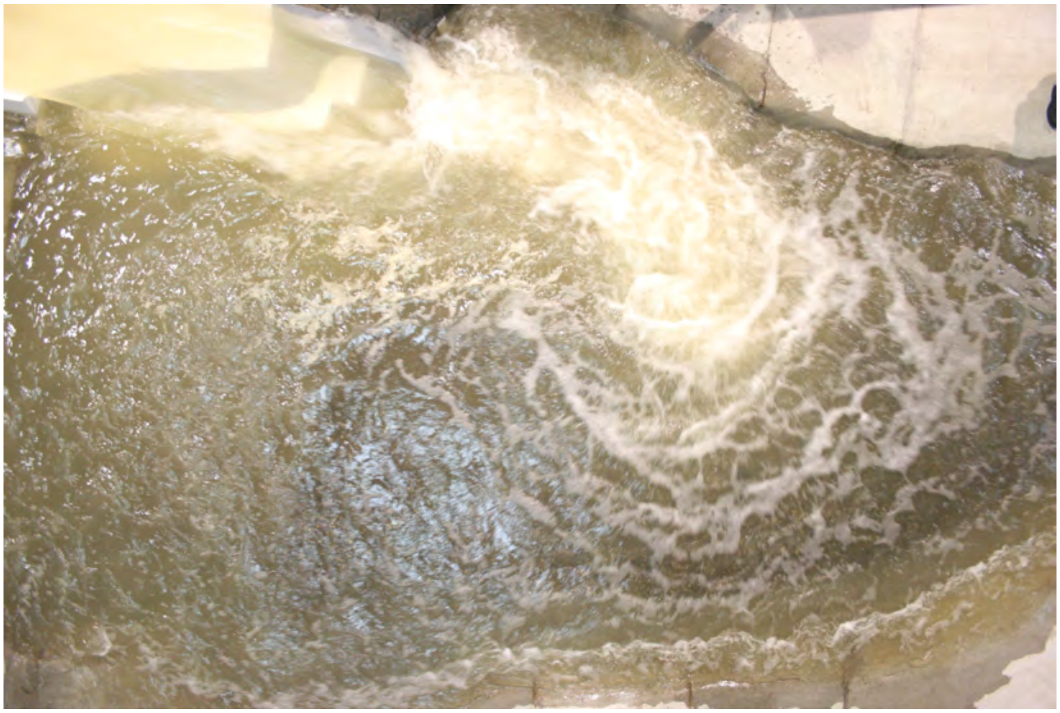

Photo 6.3.5 Final Documentation, Deflector 20, 150,000 cfs, 1718.5' tailwater.

Photo 6.3.6 Final Documentation, Deflector 20, Mobile bed after 70,000 cfs erosion test.

APPENDIX A

APPENDIX A

HEC-RAS NUMERICAL MODEL

A.1 General

Water surface elevation vs discharge data were necessary to estimate the tailwater rating curve at the Oxbow Dam spillway for design of the TRS alternatives and to determine tailwater settings for the downstream control of the physical model. There are no existing water surface elevation vs discharge measurements in the river reach between the Oxbow powerhouse and the Oxbow Dam spillway. The only data available is IPC's Oxbow Powerhouse Tailwater rating curve which is located immediately upstream of the powerhouse. Therefore, the HEC-RAS numerical model was used to evaluate the hydraulic characteristics of the approximately 2.3 mile reach of the Snake River upstream of the Oxbow powerhouse to Oxbow Dam. HEC-RAS is a one-dimensional, steady state-state, numerical model which computes water elevation and velocity at defined locations (cross sections) of a river. The overall channel slope in the modeled reach of the river is about 0.001 ft/ft. The channel is well defined within the steep walls of Hells Canyon with an average channel width of about 400 feet.

A.2 Model Geometry

2-ft contour bathymetry data based on the NAVD88 vertical datum was provided by IPC and used to develop the geometry for the model. Using the HEC-GeoRAS program, 37 channel cross sections placed roughly 500 feet apart were generated from the bathymetric data. Some cross section locations were adjusted to coincide with supplemental surveyed cross sections and to be near selected control point locations. The results of the numerical model were used to provide a downstream control water elevation for the physical model which was constructed to the NGVD29 vertical datum which is 3.45 ft below the NAVD88 vertical datum. The elevations developed from the bathymetric data were therefore adjusted (i.e., lowered by 3.45 ft) to coincide with the vertical datum of the physical model. The layout of the HEC-RAS cross sections on the contour data is shown in Figure A.1.

A.3 Model Calibration

Due to the lack of measured field data from which to estimate channel roughness coefficients for calibration of the numerical model, roughness values (i.e., Manning values) were estimated based on past experience and judgment. The river channel in the reach is well defined and has a small sinuosity. The bed is generally composed of gravels in the 2- to 6-inch range with some larger boulders. Very little vegetation exists on the channel banks and the higher sides of the valley outside of the main channel are characterized by steep rock slopes. Lacking site specific information, Manning roughness values are typically estimated using comparison of photographic information from channels where Manning values have previously been determined. Photographs from the USGS publication "Roughness Characteristics of Natural Channels" by Harry H. Barnes dated 1967 suggest that channels having characteristics comparable to the Snake River in the modeled reach generally have Manning roughness values in the range of about 0.025 to 0.035 with a predominant value on the order of 0.030. Therefore a global Manning value of 0.030 was considered to be the most appropriate and was used to generate the water elevation vs discharge data for use in this study. Manning values of 0.035 and 0.025 were used as a sensitivity check to estimate the upper and lower limits of the computed data.

A.4 Model Downstream Boundary Condition

The downstream boundary of the model is the cross section located at the Oxbow Powerhouse Tailwater Rating Curve. The starting water surface elevations used in the numeric model were based on IPC's rating curve data which plots the water surface elevation upstream of the powerhouse relative to the total river discharge (powerhouse diversion plus spillway release) downstream of the powerhouse. The tailwater elevation upstream of the powerhouse is affected by both the downstream operation of the Hells Canyon Dam pool and the discharge through the Oxbow powerhouse, therefore a unique water elevation vs discharge relationship does not exist at the powerhouse. The Hells Canyon pool elevation normally operates within a 5-ft range and the Oxbow powerhouse release can vary from a little as zero (no units operating) to 28,000 cfs (all four units operating). Figure A.2 is a plot of the existing powerhouse tailwater rating curve data and illustrates the variability of water elevations for a given total river discharge that results from the variable Hells Canyon pool and Oxbow powerhouse discharge conditions. Upper and lower bounds were visually placed on the existing array of data to produce Figure A.3 which is the rating curve data that was used for the downstream boundary in the numerical model.

A.5 Water Surface Profile Computations

The numerical model was used to compute water surface profiles for spillway discharges of 10, 20, 30, 40, 41.2 (TRS design discharge), 60, 70, 100, and 150 kcfs. Two water surface profiles were computed for each spillway discharge to investigate the bounding combinations of tailwaters which were a high Hells Canyon pool elevation combined with a high Oxbow powerhouse discharge and a low Hells Canyon pool elevation combined with a low Oxbow powerhouse discharge. Four possible downstream boundary water elevations exist for any given spillway discharge based on the operating conditions at Hells Canyon and the Oxbow powerhouse but only the high-high and low-low combinations are displayed. For the study the low Oxbow powerhouse release was considered to be 5 kcfs based on review of limited project data and the high powerhouse discharge was 28 kcfs to represent the full powerhouse capacity. The highest and lowest computed water elevations at the Oxbow spillway and the location of the physical model downstream boundary (cross section 11920) from these computations were used as appropriate in design of the TRS alternatives and the physical model study.

As discussed in the Model Calibration section above, computations were also conducted for the upper and lower possible Manning roughness values of 0.025 and 0.035 combined with the respective lower and higher downstream boundary water elevation for each spillway discharge. Therefore a total of thirty-six (36) different HEC-RAS model simulations, as summarized in Table A.1, were made for the study.

Water surface profiles plots for 10, 41.2, 70 and 150 kcfs spillway discharges are displayed in Figures A.4-A.7. The profiles extend from immediately upstream of the Oxbow powerhouse (1172) to downstream of the Oxbow spillway chute where the flow can be assumed to be 1-dimensional (13376). Water surface elevations calculated by the HEC-RAS model further upstream of this point are considered to be unreliable due to the multi-dimensional flow effects. The profile plots highlight that under the low Hells Canyon pool and low Oxbow powerhouse discharge conditions there is a natural control point in the river near cross section 7512 where the channel width and depth constrain flow. Under higher tailwater conditions the effects of this control point are drowned out.

Figures A.8 and A.9 show the potential range of tailwater rating curves for given spillway discharges at cross sections 11920 and 13376, considering the variability of Hells Canyon pool, Oxbow powerhouse discharge and reasonable channel roughness values. In the physical model the rating curves locations correspond to the downstream boundary and the downstream end of the mobile bed respectively. The solid rating curves are considered to represent the most reasonable normal operating conditions (Manning roughness 0.030) while the dashed rating curves represent the overall possible range considering channel roughness uncertainty (Manning roughness 0.025 and 0.035). As reflected by the rating curves, the water elevation at cross section 11920 varies by 3.7-2.4 ft for the operating range and by 5.5-3.8 ft for the overall range. Further upstream at cross section 13376 the water elevation varies by 2.8-1.7 ft for the operating range and by 4.2-3.3 ft for the overall range.

A.6 References

OXBOW DAM SPILLWAY
TRS ALTERNATIVES STUDY
HYDRAULIC MODEL STUDY

TABLE A.1

Numerical Model Simulation Test Plan
Oxbow HEC-RAS Model (D/S Oxbow Dam to U/S of Oxbow Powerhouse)

	Low Hells Canyon Tailwater D/S and Low Oxbow Powerhouse Flow (5,000 cfs)		High Hells Canyon Tailwater D/S and High Oxbow Powerhouse Flow (28,000 cfs)	
10,000 cfs Spillway Discharge				
Discharge U/S Powerhouse (cfs)	10,000	10,000	10,000	10,000
Discharge D/S Powerhouse (cfs)	15,000	15,000	38,000	38,000
Oxbow PH TW Elev	1684	1684	1694.5	1694.5
manning's 'n' value	0.025	0.030	0.030	0.035
20,000 cfs Spillway Discharge				
Discharge U/S Powerhouse (cfs)	20,000	20,000	20,000	20,000
Discharge D/S Powerhouse (cfs)	25,000	25,000	48,000	48,000
Oxbow PH TW Elev	1686	1686	1696	1696
manning's 'n' value	0.025	0.030	0.030	0.035
30,000 cfs Spillway Discharge				
Discharge U/S Powerhouse (cfs)	30,000	30,000	30,000	30,000
Discharge D/S Powerhouse (cfs)	35,000	35,000	58,000	58,000
Oxbow PH TW Elev	1687.7	1687.7	1697.6	1697.6
manning's 'n' value	0.025	0.030	0.030	0.035
40,000 cfs Spillway Discharge				
Discharge U/S Powerhouse (cfs)	40,000	40,000	40,000	40,000
Discharge D/S Powerhouse (cfs)	45,000	45,000	68,000	68,000
Oxbow PH TW Elev	1689.3	1689.3	1699.4	1699.4
manning's 'n' value	0.025	0.030	0.030	0.035
41,200 cfs Spillway Discharge				
Discharge U/S Powerhouse (cfs)	41,200	41,200	41,200	41,200
Discharge D/S Powerhouse (cfs)	46,200	46,200	69,200	69,200
Oxbow PH TW Elev	1689.5	1689.5	1699.5	1699.5
manning's 'n' value	0.025	0.030	0.030	0.035
60,000 cfs Spillway Discharge				
Discharge U/S Powerhouse (cfs)	60,000	60,000	60,000	60,000
Discharge D/S Powerhouse (cfs)	65,000	65,000	88,000	88,000
Oxbow PH TW Elev	1693	1693	1702.9	1702.9
manning's 'n' value	0.025	0.030	0.030	0.035
70,000 cfs Spillway Discharge				
Discharge U/S Powerhouse (cfs)	70,000	70,000	70,000	70,000
Discharge D/S Powerhouse (cfs)	75,000	75,000	98,000	98,000
Oxbow PH TW Elev	1695	1695	1704.5	1704.5
manning's 'n' value	0.025	0.030	0.030	0.035
100,000 cfs Spillway Discharge				
Discharge U/S Powerhouse (cfs)	100,000	100,000	100,000	100,000
Discharge D/S Powerhouse (cfs)	105,000	105,000	128,000	128,000
Oxbow PH TW Elev	1700	1700	1709	1709
manning's 'n' value	0.025	0.030	0.030	0.035
150,000 cfs Spillway Discharge				
Discharge U/S Powerhouse (cfs)	150,000	150,000	150,000	150,000
Discharge D/S Powerhouse (cfs)	155,000	155,000	178,000	178,000
Oxbow PH TW Elev	1711	1711	1715.5	1715.5
manning's 'n' value	0.025	0.030	0.030	0.035

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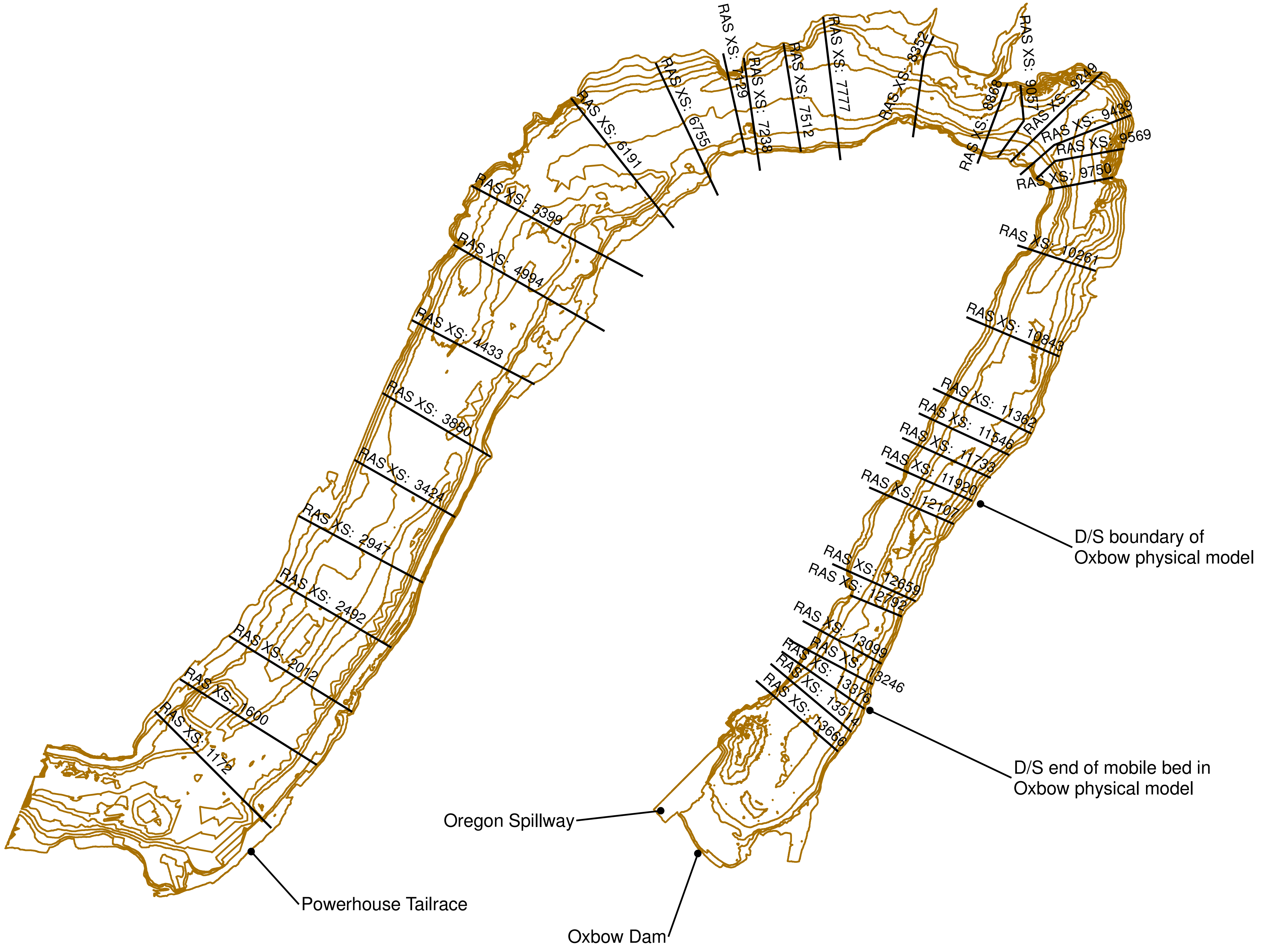
Oxbow HEC-RAS Cross Sections

Scale - 1:10,000

0 250 500 1,000 1,500 2,000 Feet

coord. syst.: IPC Custom	horz. datum: NAD 83	horz. units: feet
northwest hydraulic consultants	project no. 21513	01-Oct-2007



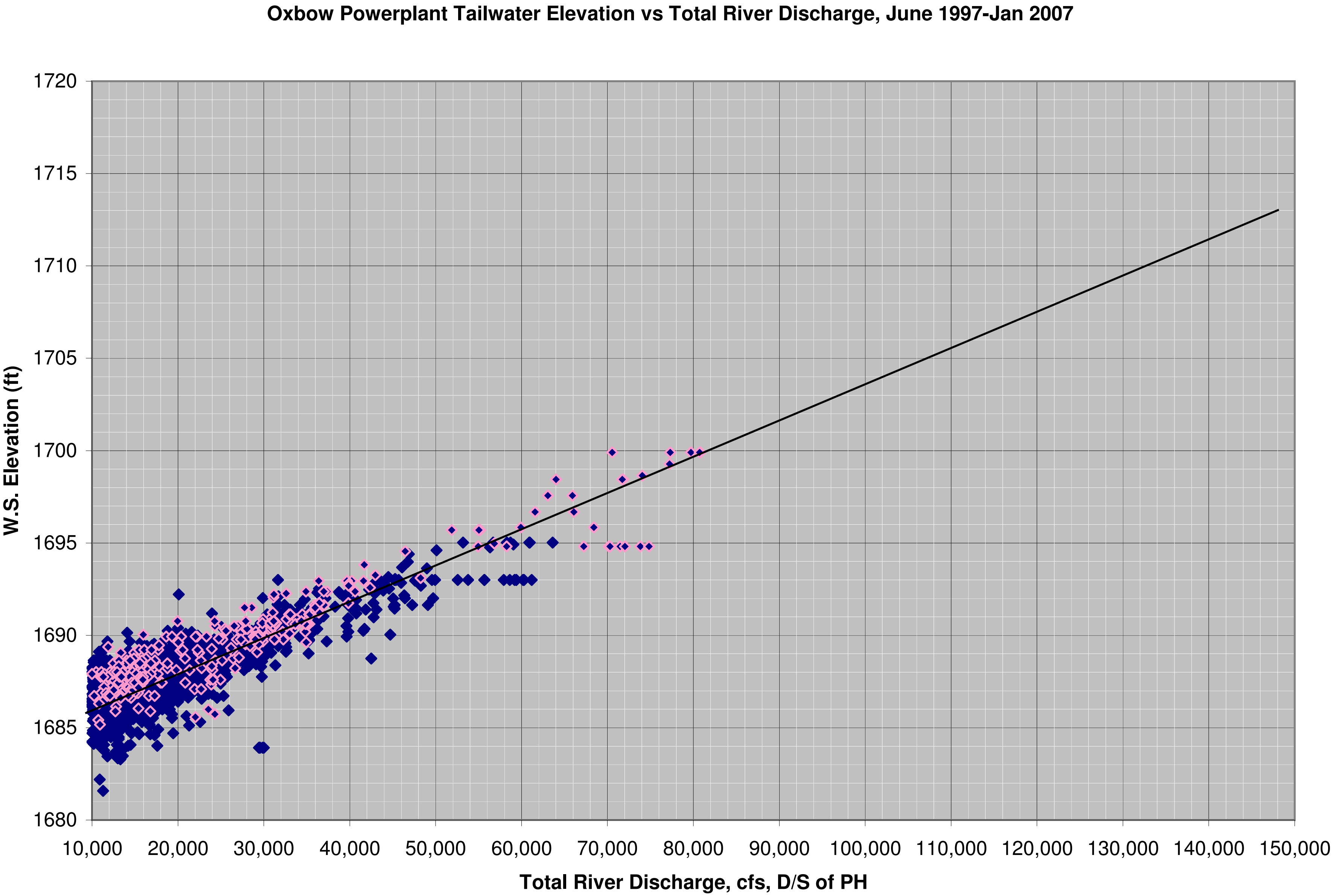
Reference Map

Legend

- HEC-RAS Cross Sections
- 10ft Contours, NAVD88

C:\Projects\21513-Oxbow\GIS\Oxbow 11x17.mxd

Figure A.1



Oxbow Powerplant Tailwater Elevation vs Total River Discharge, June 1997-Jan 2007

Figure A.2

HC normal fb 1683-1688
HC fb ~ 1683/84 for >150,000 cfs

Oxbow Powerhouse TW Rating Curve (U/S of PH)

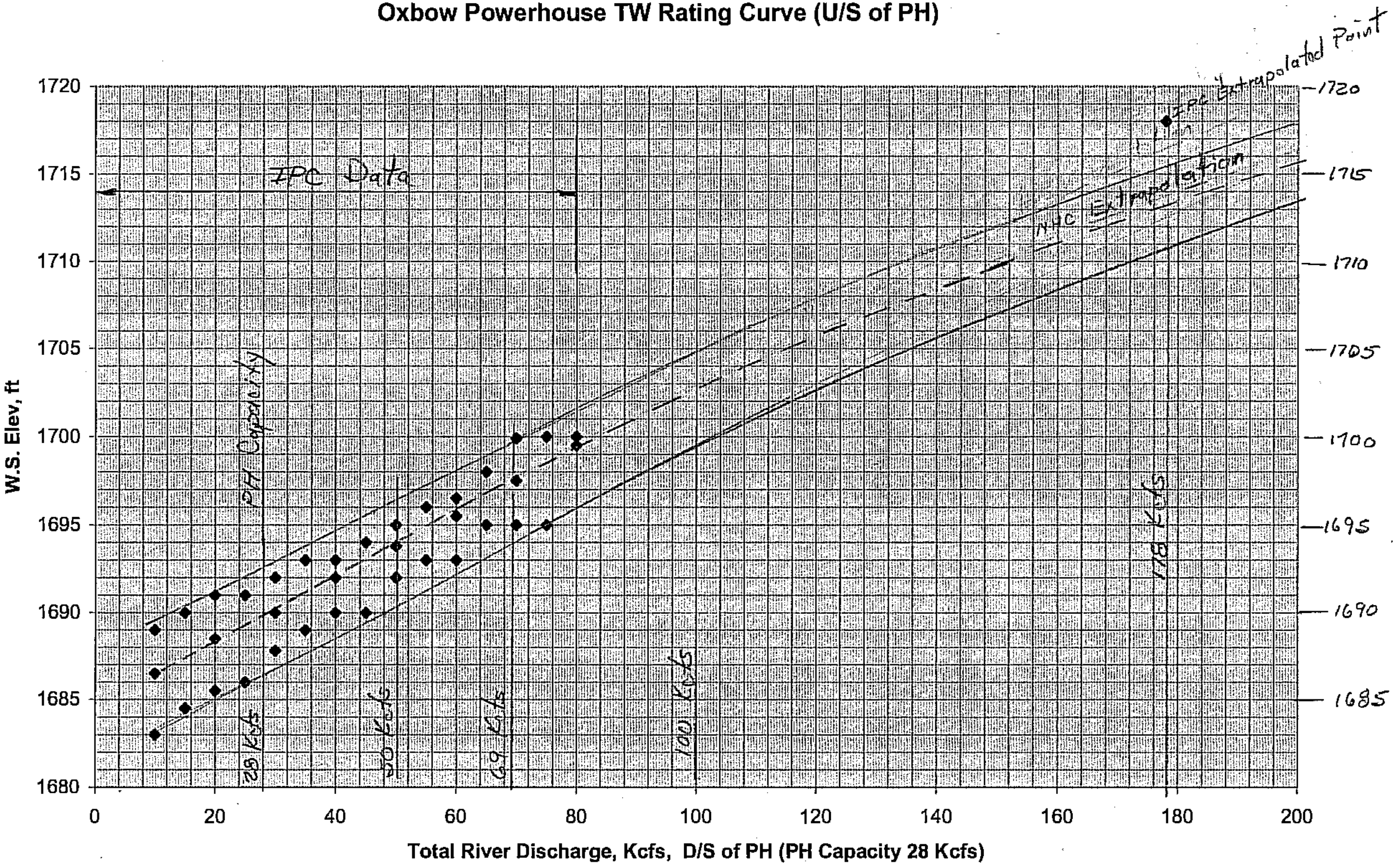


Figure A.3

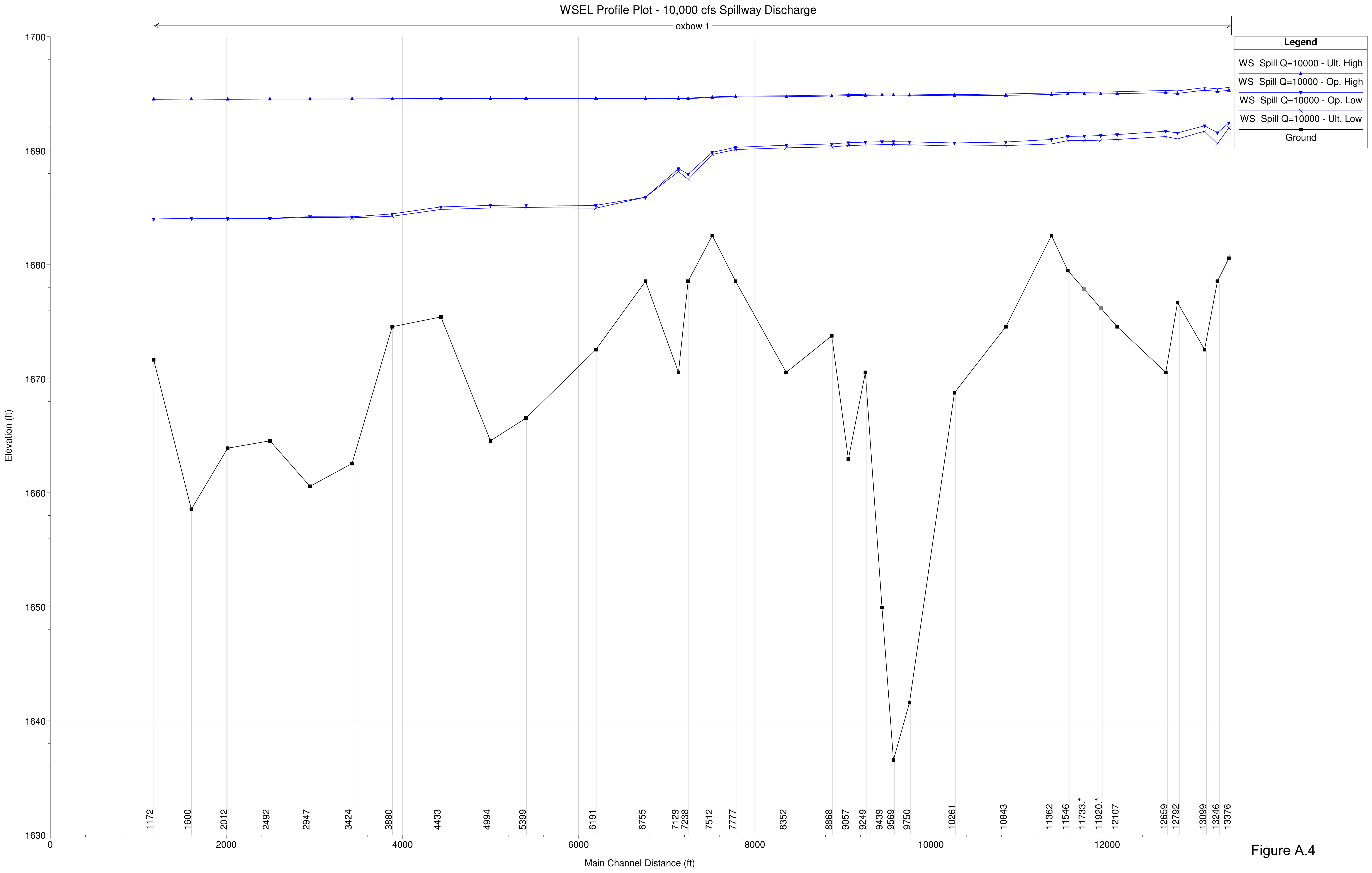
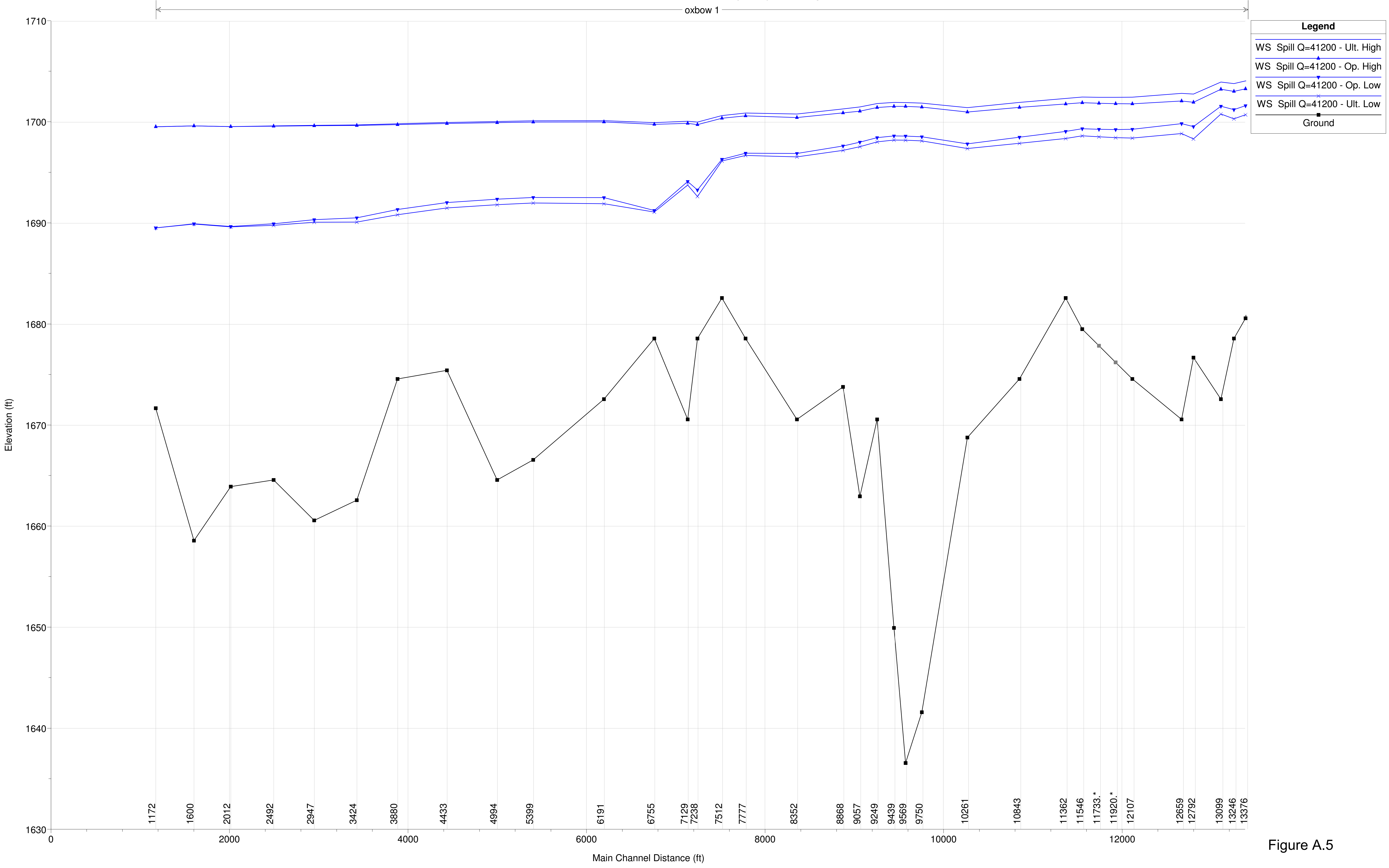
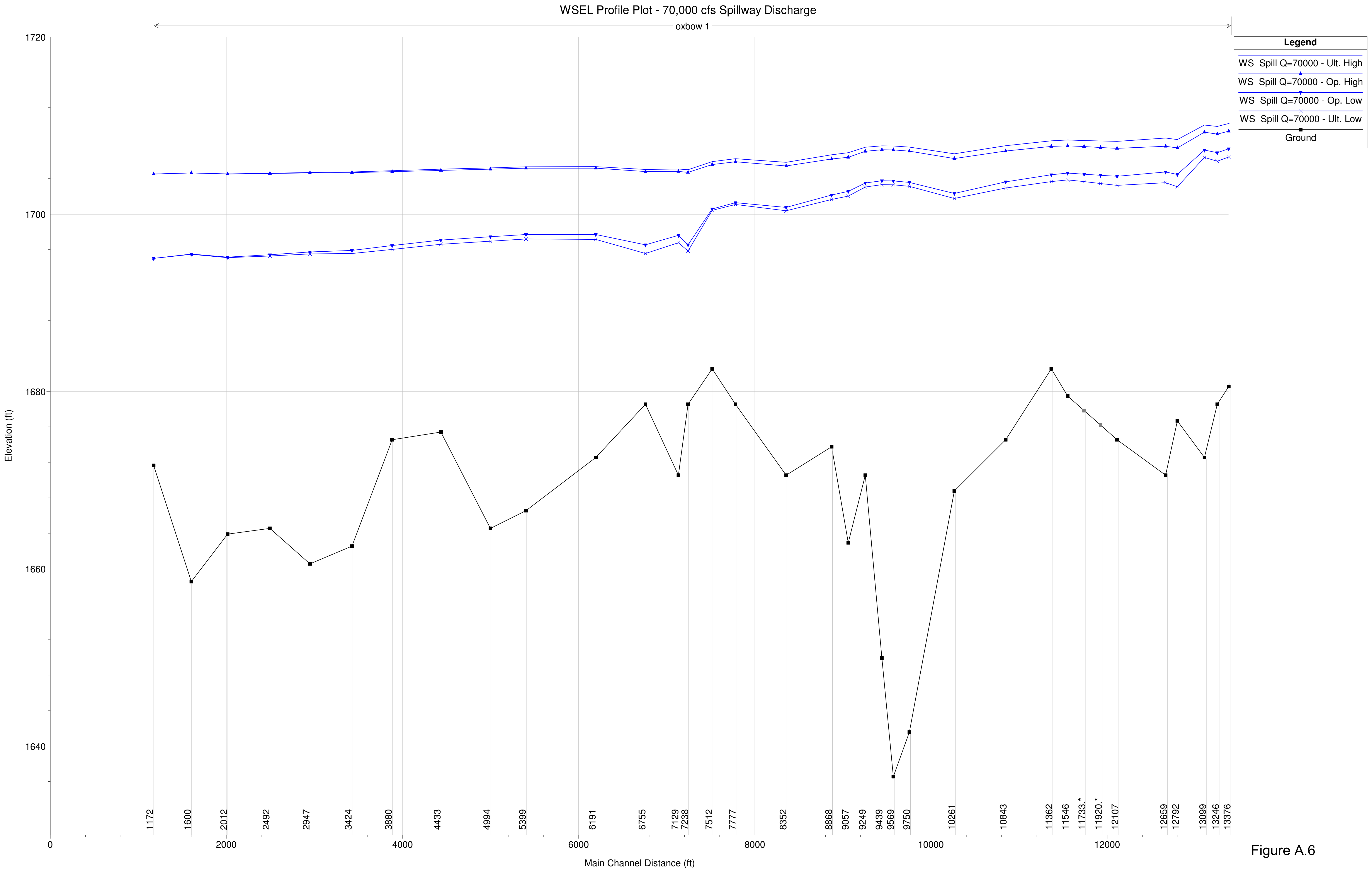

WSEL Profile Plot - 10,000 cfs Spillway Discharge
oxbow 1
Legend
WS Spill Q=10000 - Ult. High
WS Spill Q=10000 - Op. High
WS Spill Q=10000 - Op. Low
WS Spill Q=10000 - Ult. Low
Ground
Elevation (ft)
1700
1690
1680
1670
1660
1650
1640
1630
Main Channel Distance (ft)
0
2000
4000
6000
8000
10000
12000
1172
1600
2012
2492
2947
3424
3880
4433
4994
5399
6191
6755
7129
7238
7512
7777
8352
8868
9057
9249
9439
9569
9750
10261
10843
11362
11546
11733.*
11920.*
12107
12659
12792
13099
13246
13376

Figure A.4



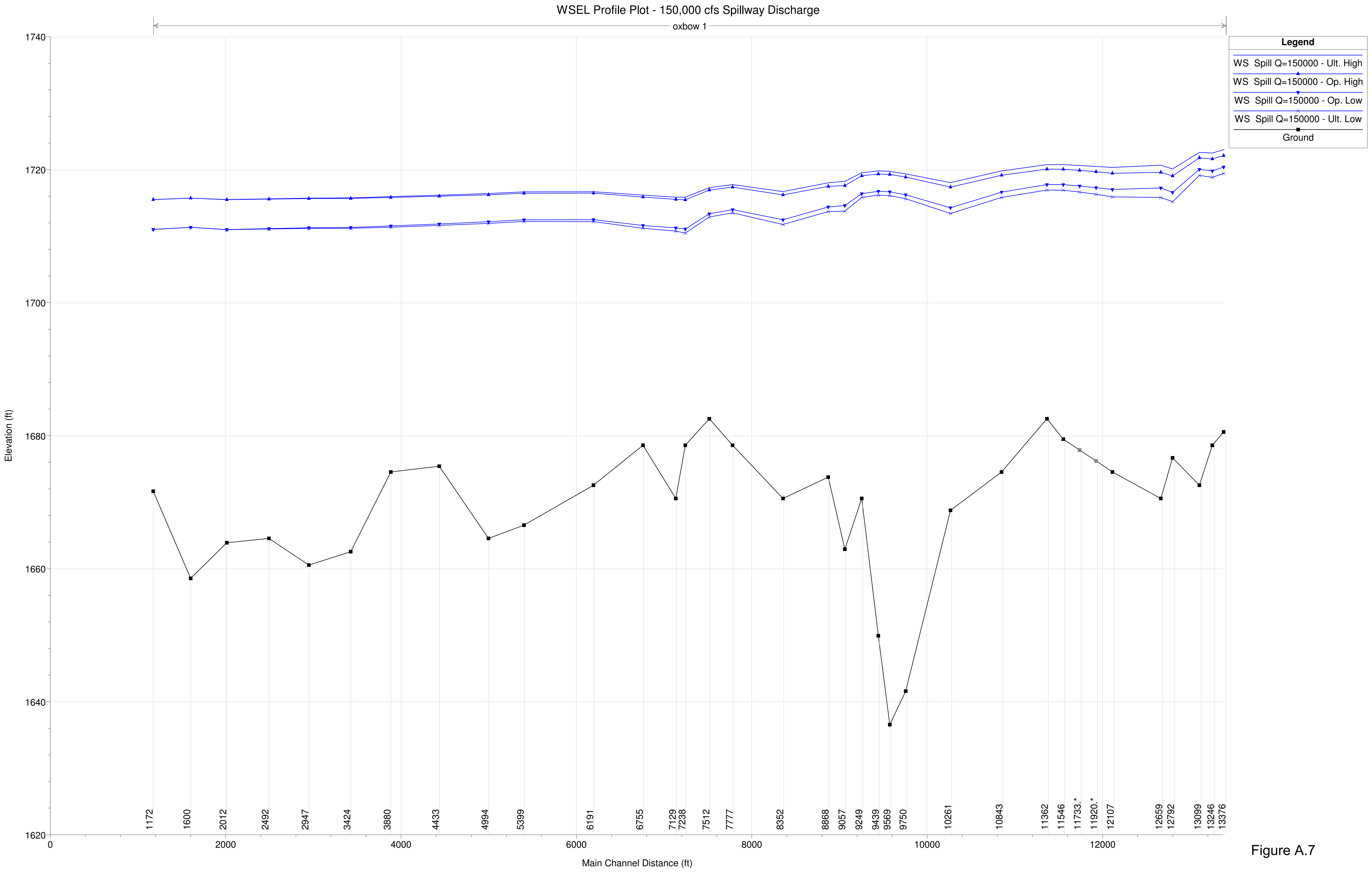
WSEL Profile Plot - 41,200 cfs Spillway Discharge

Figure A.5



WSEL Profile Plot - 70,000 cfs Spillway Discharge
oxbow 1
Legend
WS Spill Q=70000 - Ult. High
WS Spill Q=70000 - Op. High
WS Spill Q=70000 - Op. Low
WS Spill Q=70000 - Ult. Low
Ground
Elevation (ft)
1720
1700
1680
1660
1640
Main Channel Distance (ft)
0
2000
4000
6000
8000
10000
12000
1172
1600
2012
2492
2947
3424
3880
4433
4994
5399
6191
6755
7129
7238
7512
7777
8352
8868
9057
9249
9439
9569
9750
10261
10843
11362
11546
11733.*
11920.*
12107
12659
12792
13099
13246
13376

Figure A.6


WSEL Profile Plot - 150,000 cfs Spillway Discharge
oxbow 1
Legend
WS Spill Q=150000 - Ult. High
WS Spill Q=150000 - Op. High
WS Spill Q=150000 - Op. Low
WS Spill Q=150000 - Ult. Low
Ground
Elevation (ft)
1740
1720
1700
1680
1660
1640
1620
Main Channel Distance (ft)
0
2000
4000
6000
8000
10000
12000
1172
1600
2012
2492
2947
3424
3880
4433
4994
5399
6191
6755
7129
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11920.*
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13099
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13376

Figure A.7

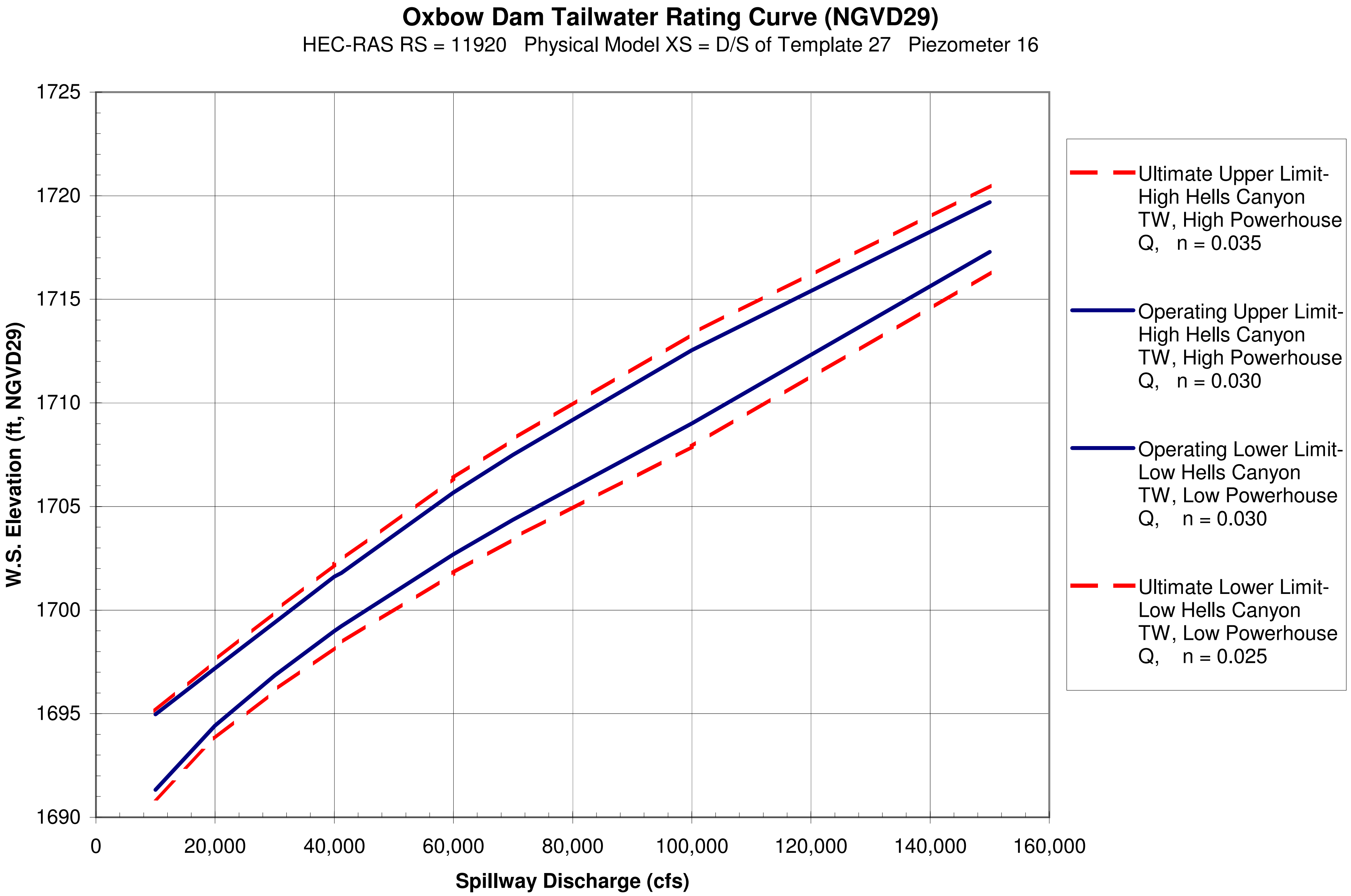
Oxbow Dam Tailwater Rating Curve (NGVD29)
HEC-RAS RS = 11920 Physical Model XS = D/S of Template 27 Piezometer 16
W.S. Elevation (ft, NGVD29)
1725
1720
1715
1710
1705
1700
1695
1690
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
Spillway Discharge (cfs)
Ultimate Upper Limit-High Hells Canyon TW, High Powerhouse Q, n = 0.035
Operating Upper Limit-High Hells Canyon TW, High Powerhouse Q, n = 0.030
Operating Lower Limit-Low Hells Canyon TW, Low Powerhouse Q, n = 0.030
Ultimate Lower Limit-Low Hells Canyon TW, Low Powerhouse Q, n = 0.025

Figure A.8

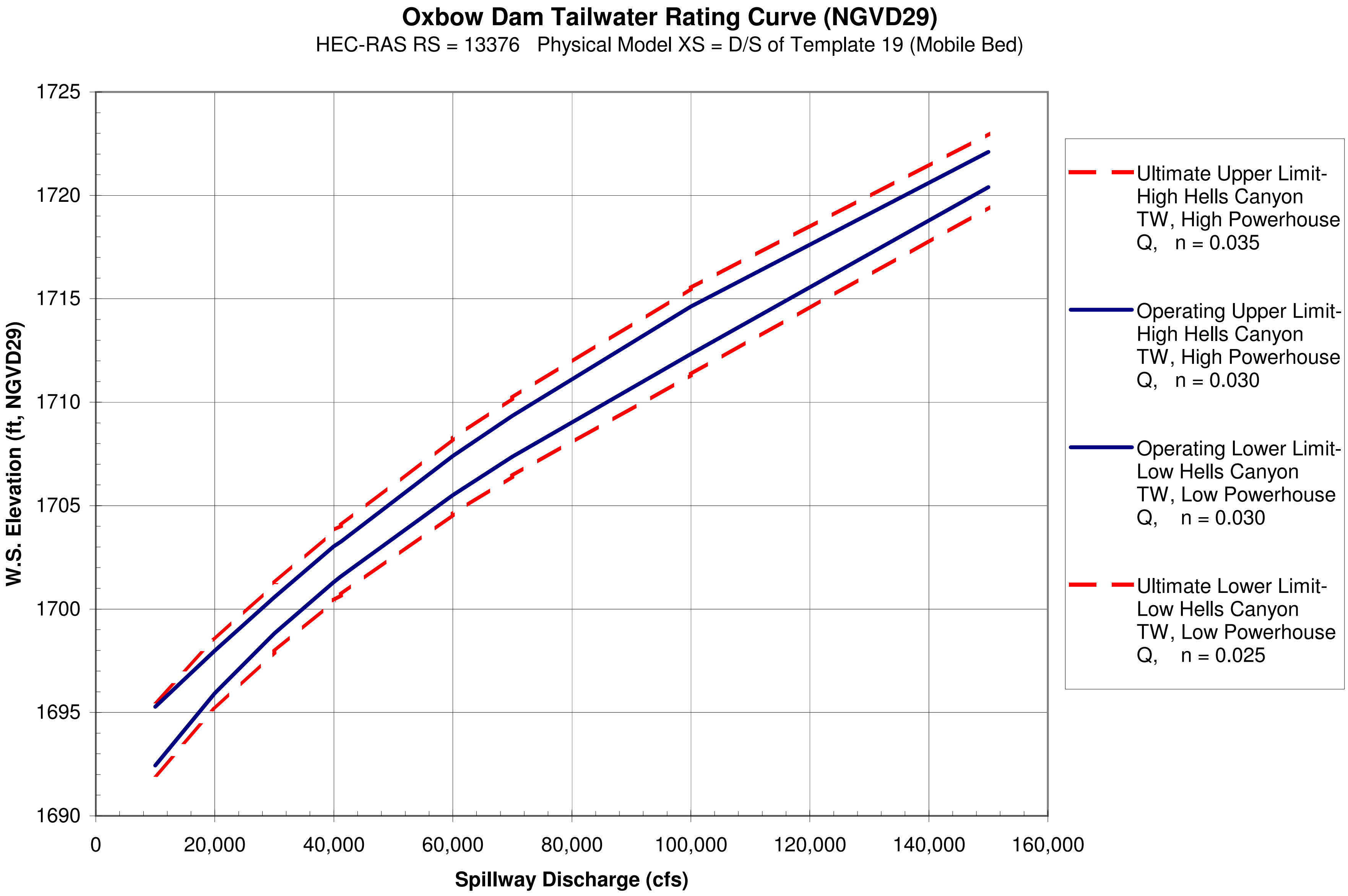
Oxbow Dam Tailwater Rating Curve (NGVD29)
HEC-RAS RS = 13376 Physical Model XS = D/S of Template 19 (Mobile Bed)
W.S. Elevation (ft, NGVD29)
1725
1720
1715
1710
1705
1700
1695
1690
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
Spillway Discharge (cfs)
Ultimate Upper Limit- High Hells Canyon TW, High Powerhouse Q, n = 0.035
Operating Upper Limit- High Hells Canyon TW, High Powerhouse Q, n = 0.030
Operating Lower Limit- Low Hells Canyon TW, Low Powerhouse Q, n = 0.030
Ultimate Lower Limit- Low Hells Canyon TW, Low Powerhouse Q, n = 0.025

Figure A.9

APPENDIX B

nhc
memorandum

northwest
hydraulic
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www.nhcweb.com

To:	**Scott Zimmerman**	Date:	March 16, 2007
From:	**Lisa Larson** **Brian Hughes**	Page:	7
cc:		File:	21513

Re: OXBOW SPILLWAY TRS PROJECT
TRS Alternatives Summary

On February 16, 2007, a brainstorming/kick-off meeting was held to develop a preliminary list of modifications at Oxbow Dam that could potentially reduce Total Dissolved Gas (TDG) concentrations during spill conditions. The following individuals attended this meeting:

Scott Zimmerman, Idaho Power Company (IPC)
Scott Larrondo, IPC
Ralph Myers, IPC
Duncan Hay, Oakwood Consulting
Brian Hughes, Northwest Hydraulic Consultants (**nhc**)
Lisa Larson, **nhc**
Steve Wilhlems, **nhc**
Jim Lencioni, **nhc**
Steve Wittmann-Todd, Jacobs

The discussions and results were documented in meeting minutes taken by **nhc** and provided to IPC. At the conclusion of this meeting, **nhc** was tasked with summarizing the eight alternatives that were discussed during the meeting and recommending three alternatives for developing conceptual designs and physical modeling. This memo summarizes the eight alternatives and provides a recommendation on the three alternatives considered at this time to provide the best opportunity for meeting the TDG objectives. Three other alternatives that may merit some further consideration are also identified.

Oxbow Dam is located on the Snake River at rivermile 272.5. The Oxbow Project consists of the earth and rockfill dam, an intake structure and tunnel, and a powerhouse. The powerhouse and the spillway are separated by a rock ridge in a bend of the Snake River referred to as the Oxbow Bypass. Figure 1 shows the existing Oxbow spillway configuration. The Oxbow operating spillway is located on the left (Oregon) bank of the river looking downstream. The spillway includes three bays controlled by 32-ft wide by 50-ft high tainter gates leading to a 112-ft wide spillway chute. The spillway chute is about 580- ft long and terminates at a steep slope dropping about 30 ft into the downstream river channel. The capacity of the Oxbow operating spillway is 150,000 cfs at pool elevation 1810 ft (PMF condition). There is also a fuseplug spillway located on the right bank that would be activated to pass an additional 150,000 cfs in the event of a PMF.

The flow exiting the spillway chute plunges to depths on the order of 30-50 ft into a largely un-armored plunge pool. As the flow plunges to such depths, entrained air in the water is forced into solution, which increases total dissolved gas (TDG) in the out flowing water. The Idaho Department of Environmental Quality (DEQ) has a state standard of 110 percent maximum TDG concentration when the flow rate is less than the 7Q10, which is referred to herein as the TDG design discharge. The 7Q10 discharge for the Oxbow spillway is 41,000 cfs, representing the highest average seven consecutive day flow with an average recurrence frequency of once in ten years. Under these conditions, velocities and depth at the downstream end of the spillway chute will be in the order of 50 fps and 7.5 ft, respectively, and the unit discharge is 366 cfs per foot.

Based on the collective experience of the group, several alternatives considered to have some potential for reducing TDG concentrations in the tailrace were presented for further consideration. Criteria identified for consideration during the evaluation are documented in the meeting minutes. The importance of each criterion was also ranked from high to low. The highest ranking criteria included: TDG reduction effectiveness, impact to spillway capacity, impact to dam and public safety.

The alternatives identified for further consideration included the following:

1. Standard Stilling Basin Downstream of Spillway Chute with Flow Deflector
2. Standard Stilling Basin Downstream of Widened Spillway Chute with Flow Deflector
3. Flip Bucket, Three Bay Version
4. Flip Bucket, One Bay Version with Dividing Wall
5. Two-Stage Energy Dissipation Structure
6. Stepped Spillway Downstream of Chute
7. Downstream Rock Weir and Ramp
8. Fill in Existing Plunge Pool

The initial discussion of possible alternatives included a number of concepts that could be implemented at locations other than the primary (Oregon side) spillway. However, one of the primary criteria identified by IPC was that only alternatives that could be implemented at the primary spillway should be considered at this time. There were a number of additional primary spillway alternatives discussed in the brainstorming session; however, only the alternatives listed above were considered worthy of more detailed investigation due to either hydraulic or implementation issues.

As noted previously, **nhc** was tasked with developing schematic sketches and a short summary of the hydraulic and total dissolved gas impacts of each alternative. The sketches attached to this memo are schematic and based on a very preliminary level of assessment. They are intended only for illustrative purposes and should not be construed to be of sufficient detail for strict comparative purposes. Without the benefit of the tailwater characteristics to be developed by the HES-RAS modeling, it is not possible to predict actual elevations and dimensions of the various alternatives at this time. Once these characteristics are known and more hydraulic engineering computations are developed, one or more of these alternatives may be found to be impractical.

DISCUSSION OF ALTERNATIVES

Alternative 1 - Standard Stilling Basin Downstream of Existing Spillway Chute with Flow Deflector

This concept is the traditional approach to minimize the "plunging-to-depth" impact of the flow, which has been successfully implemented for TDG reduction at numerous installations elsewhere. As shown in Figure 1-1, a concrete parabolic drop structure leading into a conventional hydraulic jump stilling basin would be constructed at the downstream end of the existing spillway chute. This basin would be designed to dissipate the energy of spillway discharges up to 150,000 cfs. A deflector designed to produce "skimming flow" within the upper 15-20 ft of the tailrace water column would be installed on the parabolic drop to prevent the air entrained water from plunging to depths that presently result in high concentration of TDG. The stilling basin would dissipate the energy associated with the flow exiting from the chute without increasing localized erosion immediately downstream from the chute.

One of the primary disadvantages with this concept is that the unit discharge exiting the spillway chute is about 365 cfs/ft at the TDG design discharge of 41,000 cfs. Past experience with deflectors on relatively high head spillways (high energy off the deflector) has shown that a stable skimming flow regime can not typically be attained with unit discharges in excess of about 200-250 cfs/ft unless the tailwater depth on the deflector exceeds about 20-ft. Tailwater depths on the deflector must be limited to 15-20 ft to prevent forcing of entrained air into solution which would then limit the effectiveness of deflectors to unit discharges of that magnitude. This suggests the physical characteristics of this alternative appear favourable to reducing TDG only up to discharges of about 25,000 cfs, significantly less than the required design discharge of 41,000 cfs. However, the energy of the flow exiting off the deflector at Oxbow may be sufficiently low that a higher unit discharge may produce the skimming flow regime at depths of 15-20 ft with unit discharges in excess of 250 cfs/ft. If this is the case, this alternative may be capable of decreasing TDG levels to approach the 110 percent goal; however, at several projects on the Lower Snake and Columbia Rivers, deflectors were not able to reduce levels to 110 percent. Additional analyses including physical modeling would provide a better indication of the actual levels that appear achievable.

A further reduction in energy at the deflector could be attained by installing relatively small baffle blocks on the chute downstream from the spillway ogee toe designed to increase boundary roughness as opposed to the larger size baffles typically used on baffled chutes to directly dissipate energy. Assuming a Manning roughness value of 0.045, these baffle blocks could reduce the existing 50 fps velocity at the end of the chute to approximately 20 fps at a discharge of 41,000 cfs. This provides a significant reduction in energy and may have a significant improvement on the skimming flow regime effectiveness at Oxbow. Chute velocities would range from about 20-50 fps with a discharge of 41,000 cfs to 30-65 fps at 150,000 cfs; therefore, special consideration would need to be given to cavitation issues in design of the baffles.

Alternative 2: Standard Stilling Basin Downstream of Widened Spillway Chute with Flow Deflector

This concept is identical to Alternative 1 except that the existing spillway chute would be modified to increase the width at the upstream end of the parabolic drop to about 200-ft so that the unit discharge at the TDG design discharge of 41,000 cfs would be on the order of 200 cfs/ft. Figure 1-2 shows a schematic plan and section of this alternative. The advantages with this concept including: (1) an increased potential for attaining the desired skimming flow regime (TDG abatement) at discharges up to 41,000 cfs and (2) decrease in the unit energy entering the stilling basin due to the lower unit discharge and subsequently a reduction in the size and depth of the basin.

The disadvantage of this concept is that specialized designs would be required to effectively and uniformly spread the flow from the 112- ft width that exists immediately downstream of the spillway bays to 200-ft in the relatively short distance available. Guide vanes and/or super elevation of the chute floor are possible methods that could be employed to assist in spreading the flow. The necessary configuration required to effectively spread the flow in a satisfactory manner would need to be developed through testing in the physical model.

Overall this concept would appear to have a greater potential to attain the TDG reduction goal but may have increased costs over Alternative 1. Similar to Alternative 1, meeting the 110 percent standard will be difficult; however, a substantial reduction in TDG may be achieved with this alternative.

Alternative 3: Directional Flip Bucket, Three Bay Version

This concept would consist of a directional flip bucket that would alter the trajectory of the flow exiting from the spillway chute and entering the tailwater pool. Figure 1-3 includes a schematic plan and section of the three bay flip bucket alternative. In addition to the construction of a directional flip bucket, the existing tailwater pool would need to be filled with large rock and/or concrete monolithic units to minimize pool depth at the point of trajectory impact. This design would attempt to create a wide dispersed sheet of water that would expend a considerable amount of energy as the flow spreads and frays; and a large percent of the flow is developed into spray. The basic idea with this concept is to reduce the energy entering the tailwater by allowing the dispersed jet to impact the relatively shallow rock-protected zone providing sufficient tailwater to dissipate the residual energy.

This concept is considered to have a reasonably good potential of meeting the desired TDG objectives provided that a flip bucket configuration can be developed to create the optimum flow trajectory exiting the spillway chute so that the modified tailwater pool would dissipate the residual energy without increasing overall erosion conditions downstream of the dam. Development of such a design would require a trial and error approach in the physical model.

Alternative 4: Directional Flip Bucket, Single Bay Operation with Extended Pier

This alternative is similar in all aspects to Alternative 3 except that the left spillway bay would be isolated by extending the pier between the left bay and the middle bay downstream approximately 100 – 200 ft. Figure 1-4 shows the one bay version of the flip bucket alternative. All of the spillway discharge up to 41,000 cfs would pass through the left bay. There is some thought that this configuration may promote more lateral spreading of the flow across the spillway chute and the flip bucket as a result of a thicker (i.e., deeper) water depth exiting from the isolated bay. However, review of information available at ERDC (U.S. Army Corps of Engineers, Engineer Research and Development Center) and **nhc**'s resources does not necessarily support this premise. Therefore, the actual effectiveness of this lateral spreading concept would have to be studied in a physical model to provide more insight into the effectiveness of the lateral spreading associated with confining the spill to one bay versus three bays.

Alternative 5: Two-Stage Energy Dissipation Structure

This configuration would include construction of a standard hydraulic jump stilling basin immediately downstream of the existing spillway ogee designed to adequately dissipate the energy associated with the TDG discharge of 41,000 cfs. Figure 1-5 shows the two-stage energy dissipation structure option. The existing spillway chute downstream from the stilling basin would be modified (widened and deepened if necessary) to decrease the unit discharge and velocity to about 150 cfs/ft and 12 fps, respectively. A baffled chute would be constructed between the downstream end of the new stilling basin and the tailwater channel. The tailwater channel would be modified as required to create a depth of about 15-ft at the downstream toe of the baffled chute for a discharge of 41,000 cfs.

With the spillway design discharge of 150,000 cfs, the baffled chute control configuration would create a backwater pool that could submerge the existing spillway crest by as much as 10 ft. Such a degree of submergence on the spillway crest is not expected to affect the existing spillway capacity; however this conclusion would need to be confirmed in the physical model.

The TDG reduction benefits associated with this alternative are thought to be somewhat less certain and the construction costs will likely be greater than with most of the other alternatives. To our knowledge, there is limited experience with this type of structure applied to TDG applications; however, the gas exchange characteristics associated with baffles is quite high. In many cases in the Northwest where TDG is an issue, fish passage is also of high concern so baffles are typically eliminated from consideration. Since fish passage is not an issue at Oxbow, consideration of baffles and additional evaluation in a physical model could be conducted. Physical modeling would also provide a means to gain additional information that is not readily available on baffles with high unit discharges.

Alternative 6: Stepped Spillway Extension

For this alternative the existing spillway chute would be modified to expand the flow width to about 400 ft, likely requiring vanes and/or floor super elevation; and, as shown in Figure 1-6, a long (on the order of 300 ft) stepped apron would be constructed between the downstream end of the widened spillway chute and the tailwater channel to dissipate the energy in the spillway flow. The slope of the stepped apron would need to be about 1V:7.5H to prevent the trajectory exiting from the widened spillway chute from separating from the apron. As an alternative, the spillway chute could possibly be further modified by adding baffle blocks or a revised geometry to reduce the velocity at the upstream end of the stepped apron. The stepped apron would only dissipate about 50 percent of the spillway flow energy, therefore a relatively shallow (i.e., 15-20 ft) stilling basin would be required at the downstream toe of the stepped apron.

The cost of this alternative is thought to have a comparable order of magnitude as that of Alternative 5 and the TDG reduction benefit may not be as effective as the other alternatives.

Alternative 7: Downstream Rock Weir and Ramp

In this alternative the downstream river channel would be modified to create a sufficiently long reach of steep rock lined channel (Figure 1-7) to provide a shallow and steep reach to bring the supersaturated TDG spillway flow to equilibrium. This modification would be designed to create a river reach where velocities and depths would be capable of naturally de-gassing the flow. The channel length required is uncertain at this time but would probably need to be at least 1,000 ft long. Assuming that length, preliminary calculations indicated that a sloping rock fill having fill depth of about 20 ft at the upstream end of the 1000-ft long reach (i.e., invert slope of about 2 percent) would create a flow depth of about 8 ft, velocity of about 16 fps and Froude Number of about 1.2 at the TDG design discharge of 41,000 cfs. The backwater pool created by this channel modification would back water up to an elevation estimated to be about 1710 ft at the dam with a discharge of 41,000 cfs (the spillway design discharge water elevation at the downstream toe of the dam is estimated to be about 1730 ft under existing conditions). This backwater impact would be refined after the HEC-RAS model of the Oxbow reach is developed.

A potential significant disadvantage of the alternative is that the channel modification would increase the existing water elevation to some degree at the dam during the spillway design flood. Therefore, an evaluation of the impacts of tailwater elevations greater than the existing condition on stability of the dam embankment will need to be evaluated to determine whether this alternative is feasible from a dam safety standpoint. The required length of the channel modification and the TDG reduction feasibility of this type of alternative should be conducted using a stream gas transfer model before it is constructed in the physical model to ensure viability prior to physical modeling.

Alternative 8: Fill in Existing Plunge Pool

This alternative would consist of filling in the existing plunge pool with a combination of large rock overlain by a relatively thick structural reinforced concrete cap to an elevation of about 1680 ft to reduce the depth of the plunge pool to about 15-20 ft. Past operation has scoured an approximately 50-ft plunge pool in the bedrock that exists; therefore design of any structural fill configuration would need to assure that the design would withstand such erosive action without failing. Design and installation of a durable enough type of fill material or concrete cap design that would satisfactorily resist this high concentration of energy is questionable without some detailed analysis. If a satisfactory design could be developed, the residual energy that would exist would likely create significant erosion both downstream and in the immediate area of the dam embankment. Large concrete monolith units similar to dolos or hexapods that have been successfully used in shore protection works throughout the world would be placed in critical areas to provide erosion control; most notably along the toe of the dam embankment and the shoreline in the more immediate proximity of the jet impact area. These concrete units are uniquely shaped to interlock with one and other and have been constructed in sizes up to about 50 tons each.

A relatively high degree of uncertainty exists that a satisfactory design could be attained; however, this alternative might provide a cost effective method of attaining TDG reduction and may warrant being carried forward to a more conceptual development nature.

RECOMMENDATIONS

At this time, the **nhc** team considers Alternatives 2, 3 and 7 to provide the greatest opportunity to meet the TDG reduction objective at the Oxbow Dam Oregon side spillway without adversely impacting dam safety. However, during the internal review process subsequent to the February 16 meeting, some discussion has surfaced that three other alternatives could also benefit from additional review.

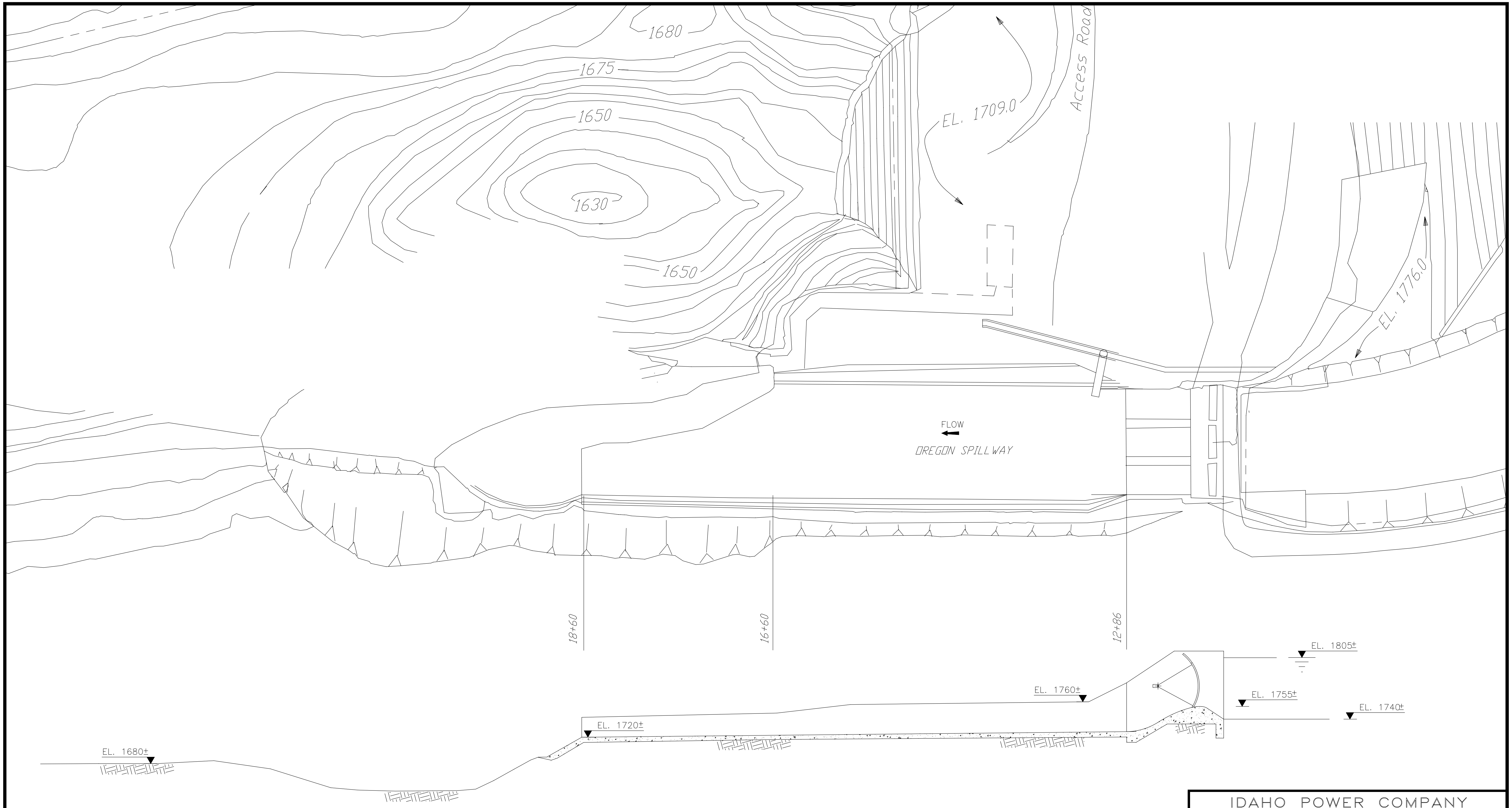
The alternatives that resulted in additional interest during our internal review process included the following:

- Alternative 1 is a variation of Alternative 2 and the two could be considered together. Alternative 1 may be less expensive as it does not require expanding the spillway chute although it would have a deeper stilling basin.

- Alternative 8 was eliminated by consensus during the initial brainstorming meeting as being too uncertain primarily with respect to providing long term durability, but was included in this summary memo as requested. Although this alternative would require a significant amount of fill in the plunge pool along with a robustly designed structural capping and erosion protection along the side slopes of the tailrace area, more detailed analyses could show that this alternative is economical and viable. We note this ITR comment herein for IPC's consideration prior to complete elimination of the concept.

- Alternative 5 was considered to have merit and would be a good fall back alternative if Alternatives 2, 3, or 7 are determined to be unfeasible during the conceptual design process.

After IPC has an opportunity to review this memo and comment on the alternatives presented for additional analyses, and after completion of the HEC RAS numerical modeling to determine tailwater elevation characteristics at the project, a conceptual design of three alternatives will be developed. Once the tailwater characteristics are known and more hydraulic engineering computations are developed, one or more of these alternatives may be found to be impractical. Assuming that the alternatives continue to appear promising during the conceptual design phase, the three alternatives would then be implemented in the physical model for proof of concept. If during the conceptual design stage, any of the three alternatives appear unfeasible, other alternatives could then be considered for implementation in the physical model.



NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET.
2. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.

0 50′ 100′ 150′ 200′

DISTANCE IN FEET
SCALE 1in : 100ft

IDAHO POWER COMPANY

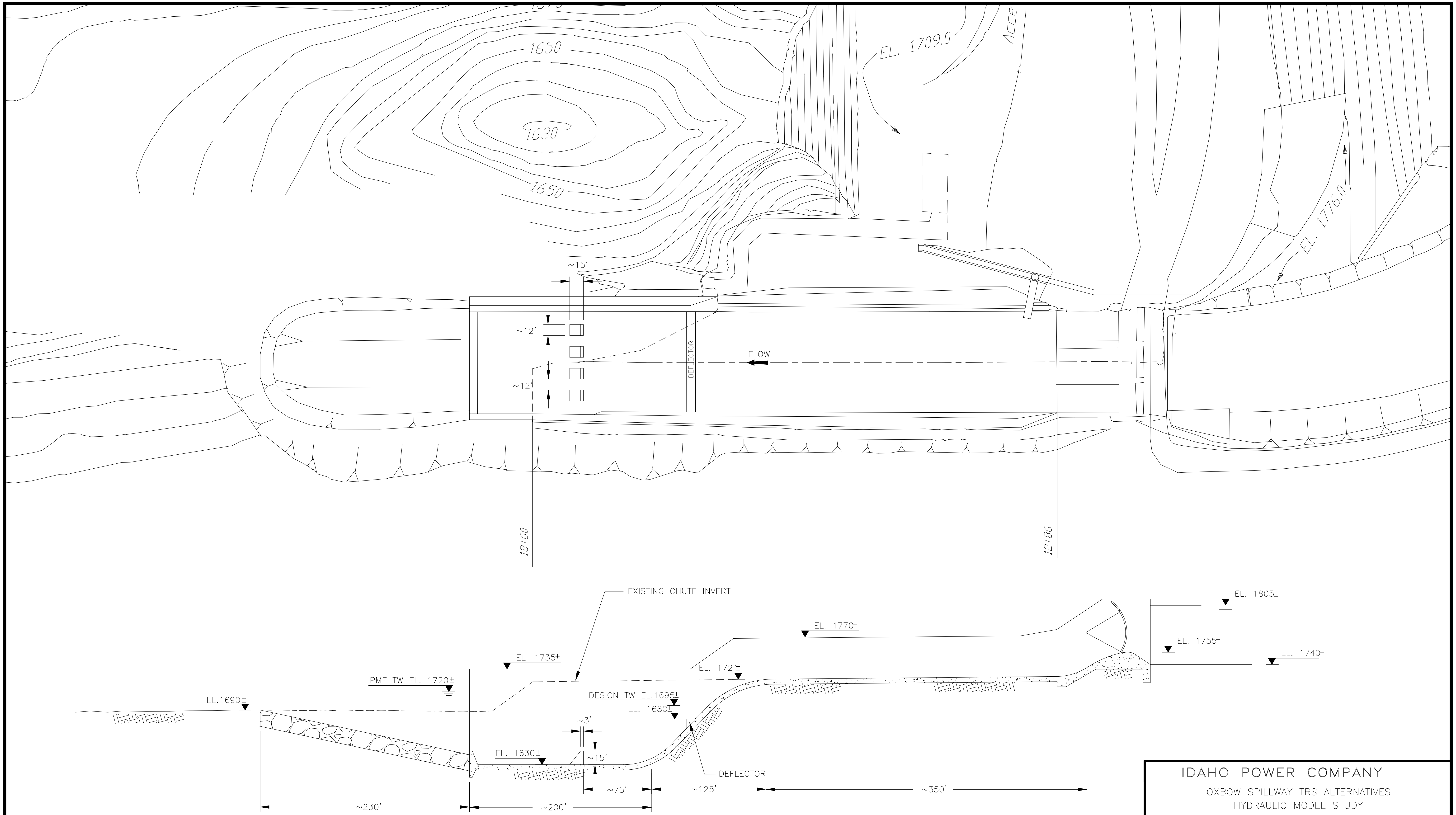
OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Existing Spillway Structure

21513–009	REV. NO.: 0	DRN. BY: RKJ	MAR–08–07

northwest hydraulic consultants

FIGURE 1



0 50' 100' 150' 200'

DISTANCE IN FEET
SCALE 1in : 100ft

NOTES:

1. DIMENSIONS ARE GIVEN IN PROTOTYPE FEET.
2. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

TRS Alternative 1

Standard Stilling Basin

21513-001	REV. NO.: 0	DRN. BY: RKJ	MAR-07-07

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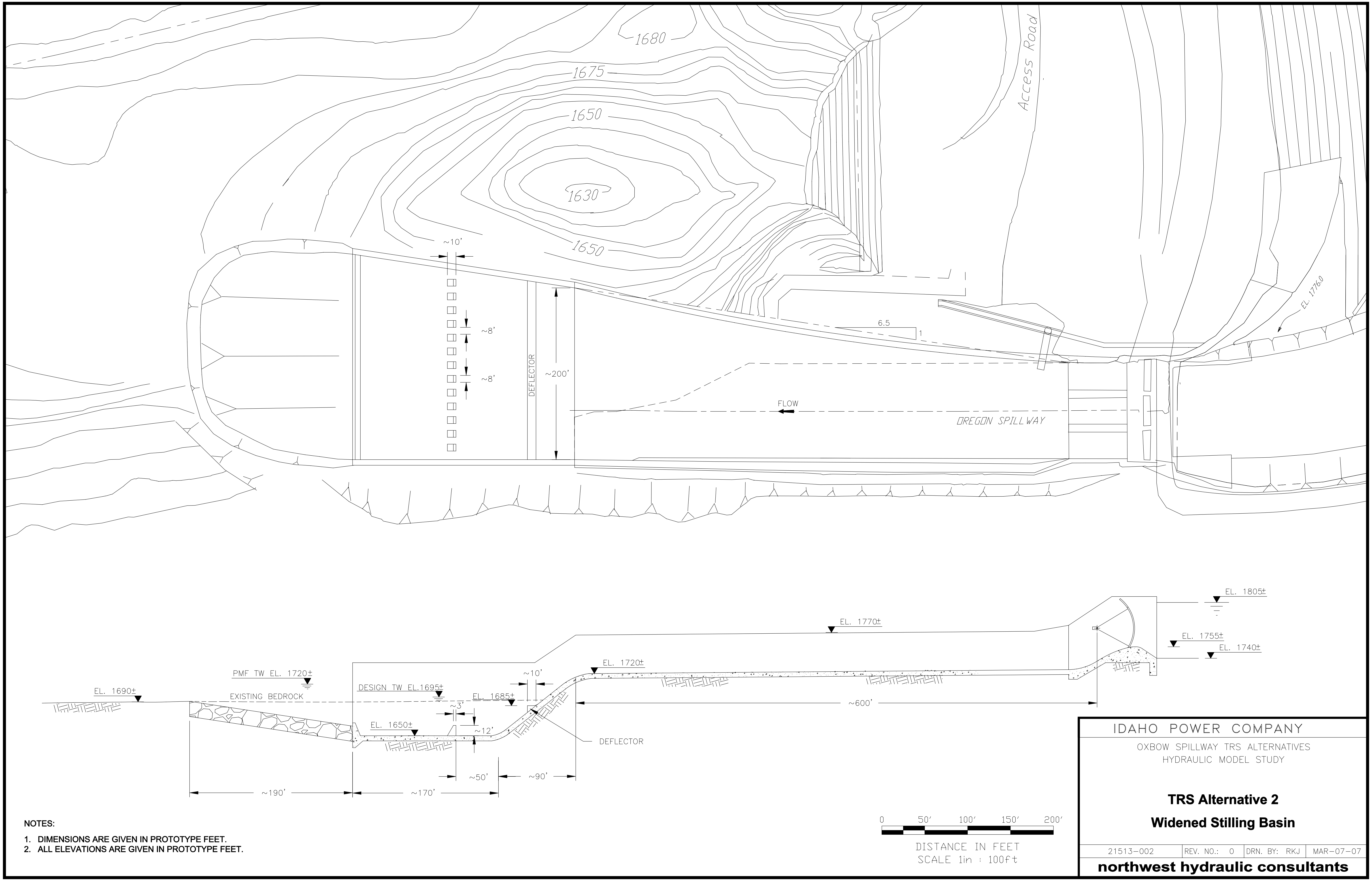
FIGURE 1-1



NOTES:

1. DIMENSIONS ARE GIVEN IN PROTOTYPE FEET.
2. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

TRS Alternative 2

Widened Stilling Basin

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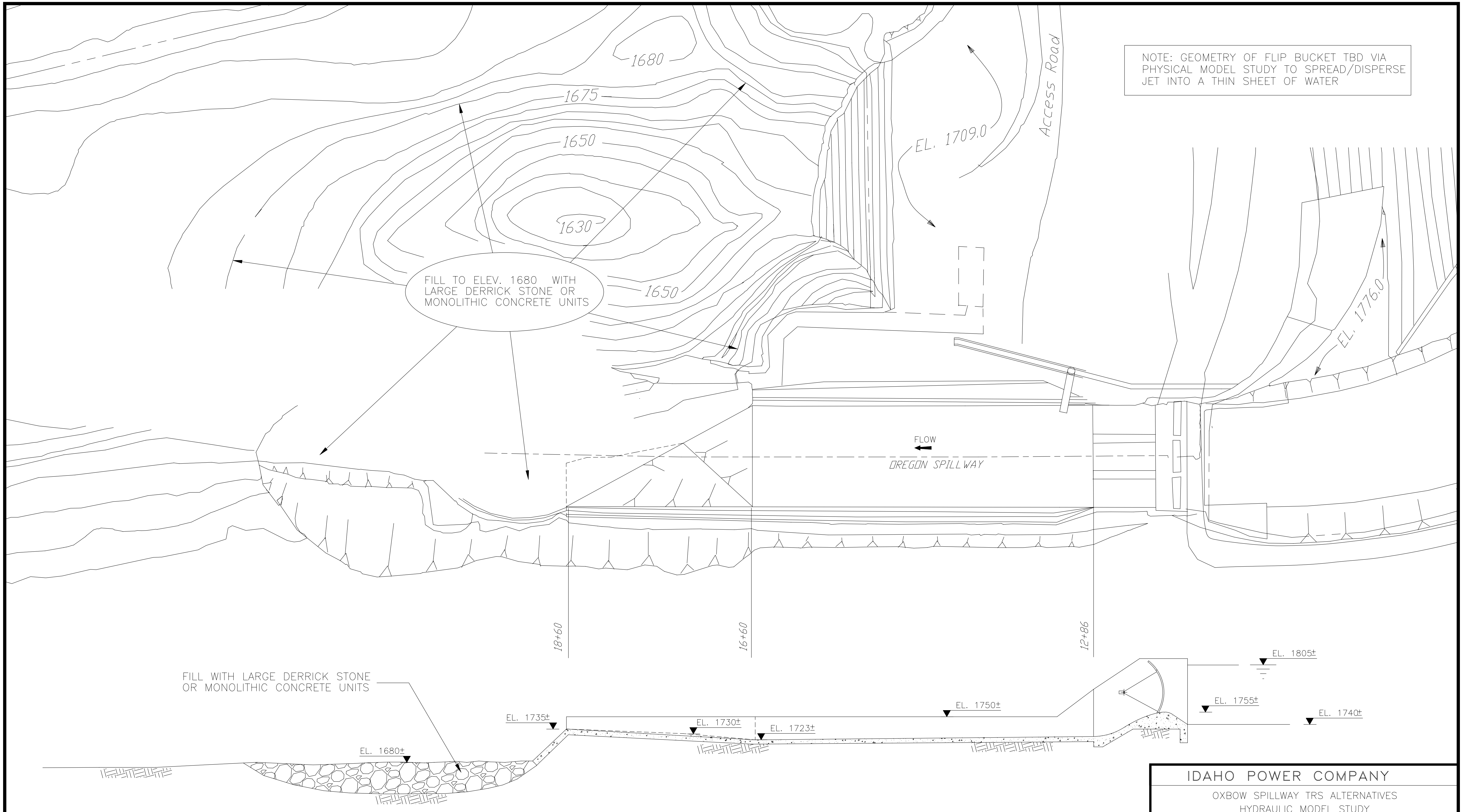
FIGURE 1-2



NOTE: GEOMETRY OF FLIP BUCKET TBD VIA PHYSICAL MODEL STUDY TO SPREAD/DISPERSE JET INTO A THIN SHEET OF WATER

0 50' 100' 150' 200'

DISTANCE IN FEET
SCALE 1in : 100ft

NOTES:

1. DIMENSIONS ARE GIVEN IN PROTOTYPE FEET.
2. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

TRS Alternative 3
Directional Flip Bucket

21513-003	REV. NO.: 0	DRN. BY: RKJ	MAR-07-07

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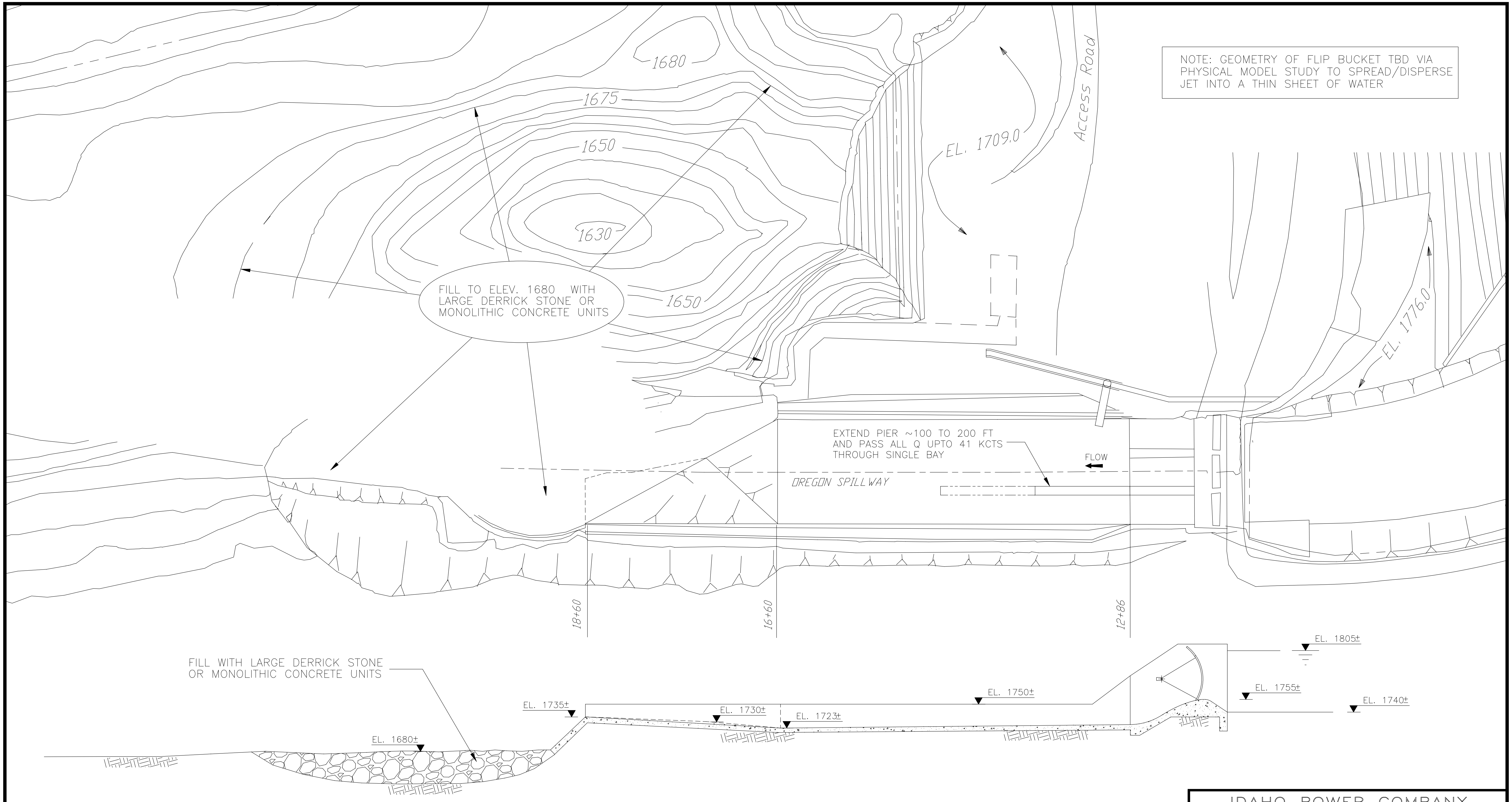
FIGURE 1-3



NOTE: GEOMETRY OF FLIP BUCKET TBD VIA PHYSICAL MODEL STUDY TO SPREAD/DISPERSE JET INTO A THIN SHEET OF WATER

NOTES:

1. DIMENSIONS ARE GIVEN IN PROTOTYPE FEET.
2. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.

0 50′ 100′ 150′ 200′

DISTANCE IN FEET
SCALE 1in : 100ft

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

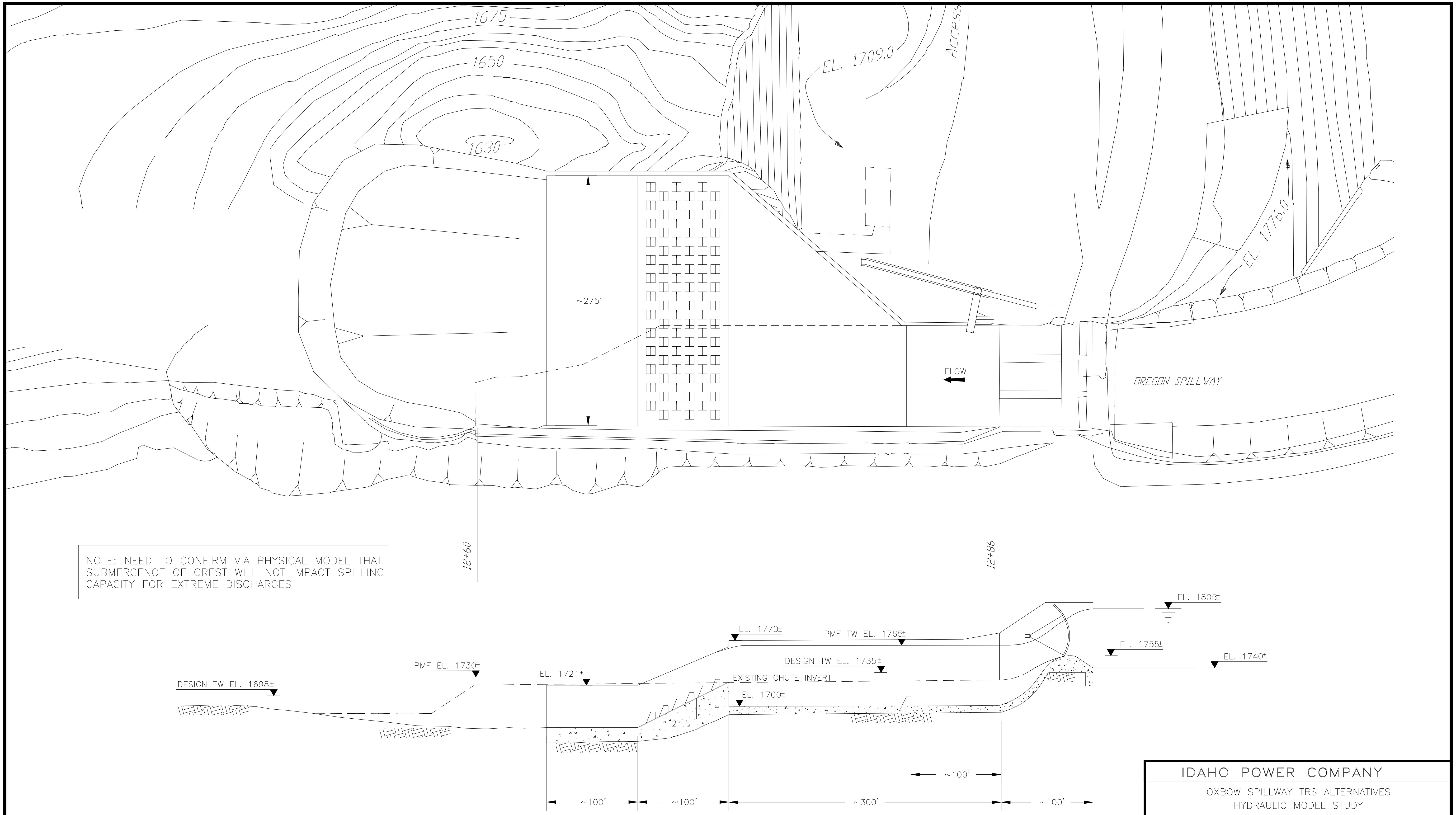
TRS Alternative 4

Directional Flip Bucket with Extended Pier

21513–004 | REV. NO.: 0 | DRN. BY: RKJ | MAR–07–07

northwest hydraulic consultants

FIGURE 1-4



NOTES:

1. DIMENSIONS ARE GIVEN IN PROTOTYPE FEET.
2. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.

0 50' 100' 150' 200'

DISTANCE IN FEET
SCALE 1in : 100ft

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

TRS Alternative 5

Two - Step Stilling Basin

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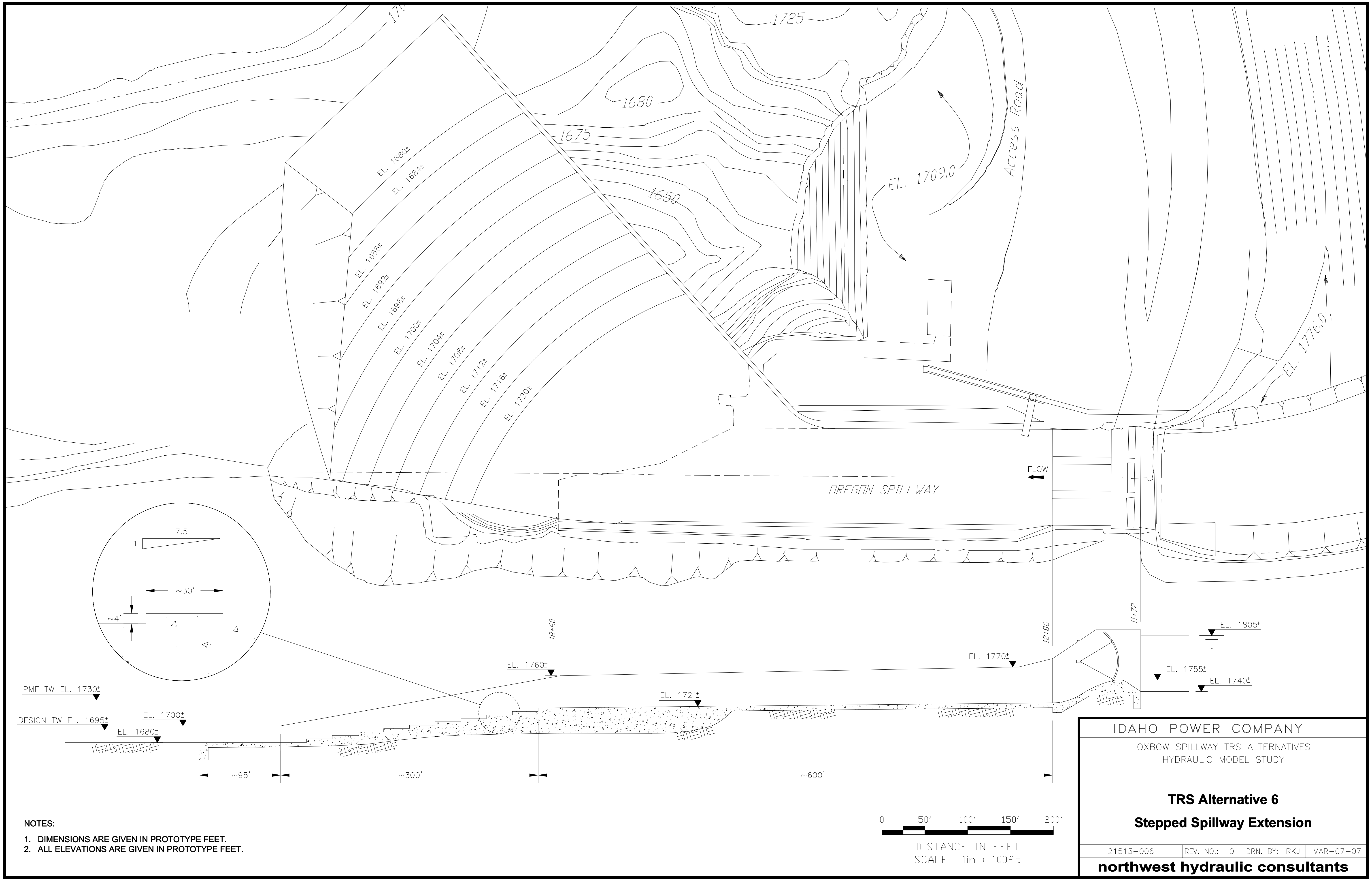
FIGURE 1-5



NOTES:

1. DIMENSIONS ARE GIVEN IN PROTOTYPE FEET.
2. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

TRS Alternative 6

Stepped Spillway Extension

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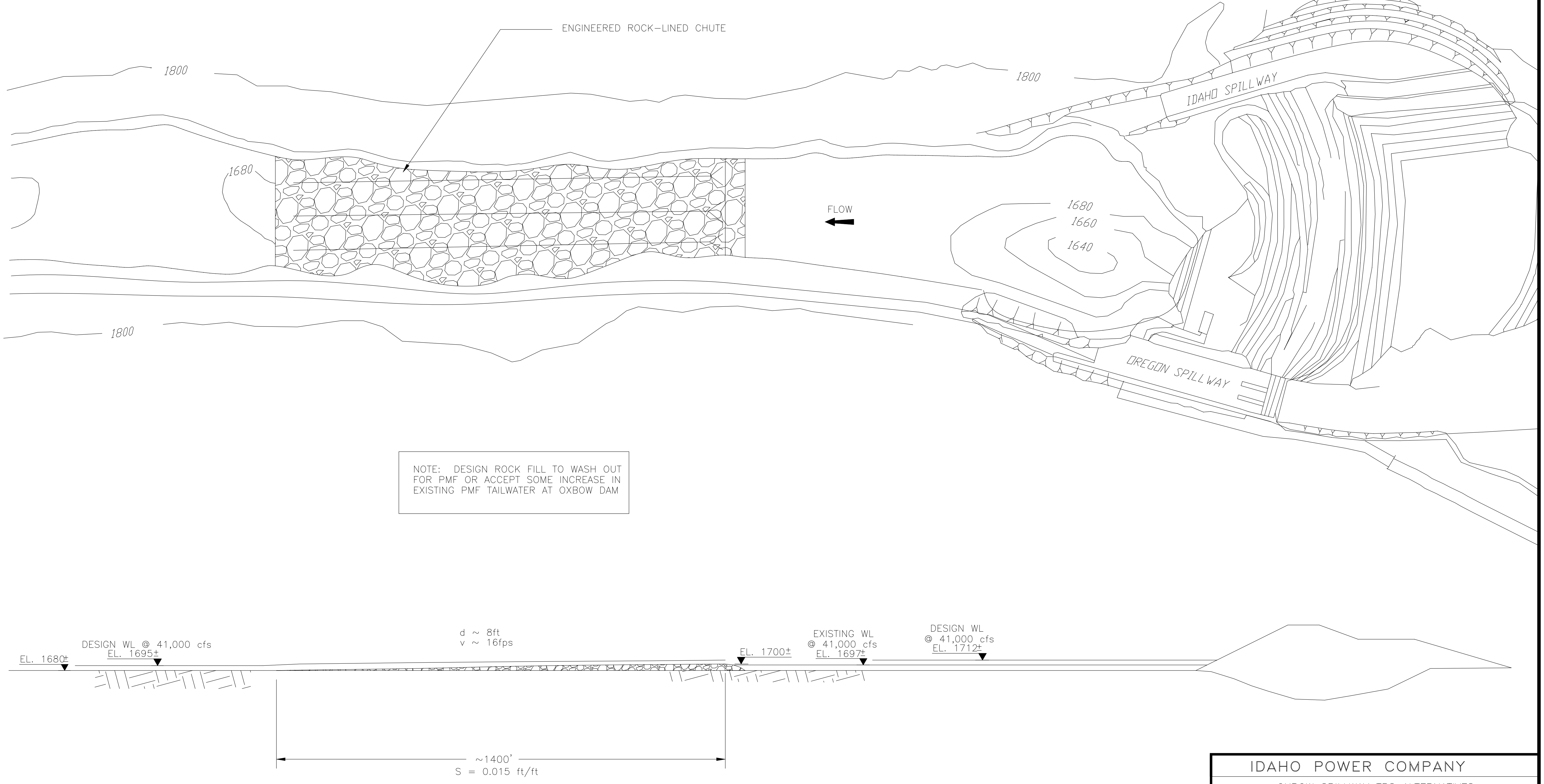
FIGURE 1-6



NOTE: DESIGN ROCK FILL TO WASH OUT FOR PMF OR ACCEPT SOME INCREASE IN EXISTING PMF TAILWATER AT OXBOW DAM

NOTES:

1. DIMENSIONS ARE GIVEN IN PROTOTYPE FEET.
2. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.

0 150' 300' 450' 600'

DISTANCE IN FEET
SCALE 1in : 300ft

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

TRS Alternative 7

Rock Weir in Downstream Channel

21513-007	REV. NO.: 0	DRN. BY: RKJ	MAR-07-07

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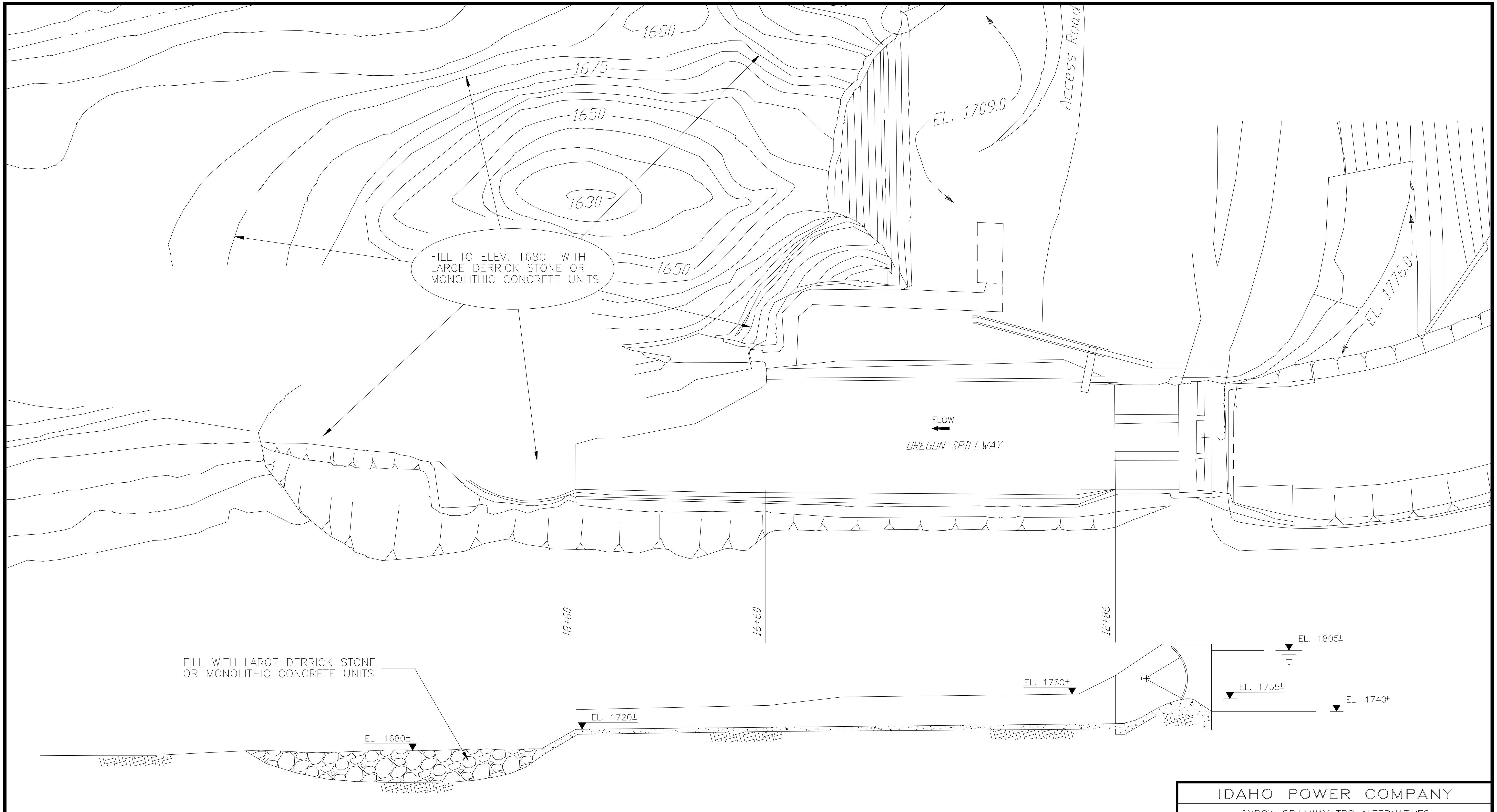
FIGURE 1-7



NOTES:

1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET.
2. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.

0 50′ 100′ 150′ 200′

DISTANCE IN FEET
SCALE 1in : 100ft

IDAHO POWER COMPANY

OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

TRS Alternative 8

Fill - In Plunge Pool

21513-008	REV. NO.: 0	DRN. BY: RKJ	MAR-08-07

northwest hydraulic consultants

FIGURE 1-8

Oxbow Dam TDG Abatement Investigation
Steepened Bouldered Channel Alternative Analysis

Summary by Steve Wilhelms

1. Among the alternatives considered for evaluation to reduce total dissolved gas (TDG) concentration released from the Oxbow Dam during spillway operation is the construction of a steepened bouldered channel in the spillway tailrace. The length initially proposed for the canyon-width channel is 1400 ft with a head loss of approximately 20 ft. As part of the initial assessment of this alternative, the following calculations are offered as bracket estimates for the gas loss that might occur during flow passage through the channel.

2. The gas transfer efficiency of any stream reach can be expressed mathematically as

$$E = 1 - e^{-K\,t} \tag{1}$$

where *E* is the transfer efficiency (ranging from 0 to 100 percent), *K* is the exchange coefficient (dictated by the turbulent mixing and air entrainment of the stream reach), and *t* is the time of flow in the stream reach.

2. Tsivoglou and Wallace (1972) conducted an extensive analysis of gas transfer in rivers and streams in the Southeast and developed a relationship to compute oxygen transfer efficiency based on the rate of energy dissipation in any stream reach. They proposed

$$E = 1 - e^{-C\left(\frac{\Delta h}{t}\right)t} = 1 - e^{-C\Delta h} \tag{2}$$

where Δh is the head difference from upstream to downstream, and *C* is the "escape coefficient." Through regression analysis, they found that *C* was 0.054 per ft for rivers with flows from 25 cfs up to about 3000 cfs. For lesser discharges, the coefficient was found to be 0.110 per ft. They recommend that for higher discharges (although none are cited) that the escape coefficient be adjusted downward to a limiting value of about 0.025 per ft. Using these values and Equation 2, judgments can be made regarding the potential oxygen transfer characteristics of the proposed channel.

3. For TDG, the transfer of nitrogen must also be included by adjusting the escape coefficient. Gulliver, et al. (1990) found the exchange coefficient for nitrogen to be about 94 percent of the coefficient for oxygen. Using this relationship, the gas transfer efficiency for nitrogen can be estimated and combined with the oxygen transfer efficient on proportions based on atmospheric makeup (although this may not be strictly true at the entrance to the channel, but an acceptable approximation).

4. Table 1 shows the gas transfer efficiencies for oxygen, nitrogen, and TDG for a range of escape coefficients. Using the recommendations from Tsivoglou and Wallace for adjusting the escape coefficient downward for larger discharges, these results suggest that about 38 percent of the TDG in excess of saturation could be lost to the atmosphere during passage through the channel reach. The escape coefficients, lower than 0.025 per ft, are given to show the sensitivity of the calculation.

Table 1. Gas transfer efficiency

	Escape coefficient for oxygen, per ft			
	0.054	0.025	0.020	0.012
Oxygen	0.66	0.39	0.33	0.21
Nitrogen	0.64	0.37	0.31	0.20
TDG	0.64	0.38	0.32	0.20

Table 2 shows examples of release TDG for a range of entering TDG levels based upon the TDG transfer efficiencies given in Table 1. As an example, the TDG exiting the channel would be approximately 126 percent (given an entering level of 140 percent) for the 38 percent transfer efficiency. Of the 40 percentage points of supersaturation, 62 percent (26 percent points) would remain in water of the TDG, while 14 percentage points would be lost to the atmosphere.

Table 2. Estimated TDG exiting channel

TDG Transfer Efficiency	0.64	0.38	0.32	0.20
Upstream TDG, percent	Exiting TDG, percent			
140	115	126	128	132
130	111	119	121	124
120	108	113	114	116

5. Presently the TDG levels exiting the Oxbow stilling basin area are on the order of about 125 percent. These estimates would indicate that should that level enter the channel area, the ultimate release TDG would be about 116 percent.

6. These estimates are based on escape coefficients developed from smaller stream and rivers and without significant aeration (air entrainment on the channel due to bouldering), they should likely be considered optimistic. If bouldering the channel can induce more mixing and some level of air entrainment, then these estimates could be considered more realistic. In any event, these calculations show that a significant reduction in TDG should be possible with a channel.

References

Gulliver, J. S, Thene, J. R., and Rindels, A. J. 1990. “Indexing Gas Transfer in Self-Aerated Flows,” Journal of Environmental Engineering, ASCE.

Tsivoglou, E. C. and Wallace, J. R. 1972. “Characterization of Stream Reaeration Capacity,” EPA-R3-72-012, Ecological Research Series, Office of Research and Monitoring, USEPA, Washington, DC

APPENDIX C

Meeting Minutes:
Oxbow Spillway TRS Alternative Evaluation
Kick-off and Brainstorming Meeting
February 15, 2007

Attendees:
Scott Zimmerman, IPC
Scott Lorrondo, IPC
Ralph Myers, IPC
Duncan Hay, Oakwood Consulting
Brian Hughes, nhc
Lisa Larson, nhc
Jim Lencioni, nhc
Steve Wilhelms, nhc
Steve Wittmann-Todd, Jacobs

A brainstorming meeting was held on February 15, 2007 to discuss the Oxbow spillway and potential total dissolved gas reduction structures (TRS).

7:30 am – The group met at **nhc**’s Seattle lab (SeaTac). The Oxbow spillway physical model will be constructed at this facility.

8:30 am – The group reconvened at **nhc**’s main office (Tukwila) for a kick-off/brainstorming meeting.

1. Ralph provided an overview of the project and of the history of the water quality aspects of the project. IPC has submitted a 401 application for the Oxbow project that refers to “modeling” to evaluate TRS alternatives. The goal is to maintain total dissolved gas levels below 110% downstream of the project. The location at which this must be achieved was defined as the “the edge of the aeration zone”. The final TRS option would be implemented at Oxbow after TRS alternatives are implemented at Brownlee and Hells Canyon.

   There is always a possibility that fish passage could be required at this site in the future; however, it is very unlikely that downstream fish passage would be a concern due to the poor habitat conditions upstream. Therefore, downstream fish passage is not an issue for the TRS design.

2. There was some discussion regarding general operating and other conditions at the site.
   - The reservoir fluctuation is generally less than 5 ft.
   - The scour hole downstream of the spillway apron is approximately 35 to 50 ft deep.

3. A list of information needs was developed during the meeting. The items discussed included:
    - Sediment gradation downstream of spillway. Scott Z. will visit the site and provide information on sediment gradation.
    - TDG monitoring location information. The TDG information provided in the RFP package included one year of data and the gage was located approximately 500 ft downstream.
    - TDG data were also collected in the past (in addition to the graph provided with the proposal information), and IPC will provide any information that may be beneficial to this study.
    - The maximum permissible tailwater elevation will be confirmed by IPC.
    - An update was provided on the status of the bathymetry. Scott Z noted that IPC is currently preparing consolidated shoreline topography and riverbed bathymetry and should have this information ready by March 2nd.

4. The group spent time brainstorming a wide range of possible TRS alternatives. The original list was simply a brainstorming list and included alternatives that were later removed from the list as they were not considered feasible.

    IPC representatives stated that this study should focus only on the Oregon spillway chute and tailrace modifications that would degas the flow at the downstream end of the spillway or within the tailrace channel downstream of the project. The group noted that flow deflectors are a common TDG abatement solution that prevents plunging flow, reducing TDG levels, and would be considered the most "traditional alternative".

    The initial list of brainstorming options included:
    - Chute Modifications: baffled chutes, stepped spillways, stilling basin with degas structure, parabolic drop and flow deflector, baffles on apron, flip bucket, spread spillway flow, divider wall separating spillbays
    - Tailrace Modifications: fill-in downstream (rock, concrete, geobags), construct downstream weir with a rock chute
    - Tunnel: utilize old diversion tunnel, new tunnel
    - New Bypass: reconfigure fuse plug spillway, add new spillway
    - Operational: turbine upgrade, gate operations, manipulate tailrace water levels

Note that IPC representatives requested that the tunnel, new bypass, and operational options taken off the table for consideration under this contract and were therefore excluded from future discussions.

5. A list of evaluation criteria was also developed. Each item was then given a low, medium, or high level of importance. The evaluation criteria included:
    - D/S Fish passage (low)
    - Downstream general river bank erosion (low)
    - Constructability (medium)

  - Cost (medium)
  - Maintenance (low)
  - TDG Reduction Effectiveness (high)
  - Retention of Existing Spillway capacity (high)
  - Operational Complexity (low)
  - Construction duration (low)
  - Impacts on dam safety (high)
  - Impacts on habitat (medium)
  - Proven technology/best practices (medium)
  - Impacts on recreation (low)
  - Personnel/Public safety (high)

   The group decided that a formal matrix evaluation was not the best approach in selecting the most promising alternatives for this site. Past experience and TDG knowledge were considered to be the best way to select the alternatives. It was left to the **nhc** Team to determine whether an internal matrix evaluation would assist them in selecting the preferred TRS alternatives, however IPC requested that a numerical matrix evaluation not be part of the study deliverables.

6. After discussing all possibilities, the list of alternatives was reduced to alternatives that were considered most practical for the Oxbow site. This list included the following:
   - Construct a stilling basin with flow deflector at the downstream end of the existing spillway chute. This is the most traditional alternative and deflectors have been implemented at several sites.
   - Construct a stilling basin with flow deflector at the downstream end of the spillway chute, but expand the width of the chute to reduce the unit discharge.
   - Construct a directional and spreading flip bucket (3-bay) at the downstream end of the spillway chute and in-fill plunge pool area to prevent flow from plunging to depth.
   - Construct a directional and spreading flip bucket at the downstream end of the chute, but install a partial-length training wall to isolate a single bay to promote spreading of flow downstream of the wall.
   - Construct an energy dissipater within the existing spillway chute to reduce the energy of the flow to be followed by a stepped or baffled spillway degassing structure into the tailrace.
   - Construct a stepped and spreading extension at the downstream end of the existing spillway chute to serve as a degassing and energy dissipation structure.
   - Construct a reach of raised, steep rock lined channel downstream of the existing plunge pool to reduce flow depth and promote degassing of the flow.
   - Fill-in plunge pool with large rock or concrete to eliminate the plunge just downstream of the apron; however, there would still be a significant amount of energy to dissipate downstream of the filled-in plunge pool.

7. The attendees agreed that **nhc** would provide a summary memo describing these 8 alternatives in a bit more detail, including a generalized schematic layout for each alternative and a recommendation on which three alternatives appear to be the most promising overall based on past experience. After the memo is reviewed by the team, the most promising three alternatives would then proceed to the conceptual design stage and would be physically modeled.
8. The group completed the brainstorming of TRS alternatives at around 3:30 pm and then discussed the physical modeling aspects of the project.
    - Preliminary model drawings were reviewed.
    - The possibility of changing the model scale from 1:40 to 1:48 and extending the model basin was discussed. This would allow more of the downstream river channel to be included in the model to accommodate the steep rock chute alternative and provide a better indication of downstream impacts for the remaining alternatives.
    - Duncan and Steve W. noted that changing the scale would not adversely impact the TDG evaluation of the alternatives in the general model.
    - **nhc** was tasked with evaluating the possibility of changing the model scale and/or extending the model basin, and would provide this information to IPC.
    - The schedule was discussed and the model commissioning is scheduled to occur near the end of April/first of May.
9. The meeting was adjourned at approximately 4:45 pm.

Meeting Minutes:
Oxbow Spillway TRS Alternative Evaluation
Conference Call
April 4, 2007
10:00 a.m. Pacific Time

Attendees:
Scott Zimmerman, IPC
Scott Lorrondo, IPC
Ralph Myers, IPC
Brian Hoelscher, IPC
Duncan Hay, Oakwood Consulting
Brian Hughes, NHC
Lisa Larson, NHC
Steve Wilhelms, NHC

A conference call was held on April 4, 2007 to discuss the following items:

- TRS Alternatives Memo, comments, relative costs
- Identify three alternatives for conceptual design/physical modeling
- Discuss status of bathymetry and confirm direction
- Updated on physical model
- Discuss schedule and action items

TRS Alternative Memo Discussions

1. A brief overview of the 8 alternatives was provided.
    - Alternative 1 - Standard Stilling Basin Downstream of Spillway Chute with Flow Deflector
    - Alternative 2 - Standard Stilling Basin Downstream of Widened Chute with Flow Deflector
    - Alternative 3 - Flip Bucket, Three Bay Version
    - Alternative 4 - Flip Bucket, One Bay Version with Dividing Wall
    - Alternative 5 - Two-Stage Energy Dissipation Structure
    - Alternative 6 - Stepped Spillway Downstream of Chute
    - Alternative 7 - Downstream Rock Weir and Ramp
    - Alternative 8 - Fill in Existing Plunge Pool

2. Scott Z noted that baffle blocks on the spillway chute were identified in the memo as an option that could reduce the energy before the end of the chute and asked if baffles should be considered for several of the alternatives. NHC conducted some preliminary calculations of small baffles on the chute. The energy would be reduced; however, additional calculations would be required to quantify this in more detail. Duncan noted that cavitation on the baffles would be a concern at the

upstream end of the chute before the hydraulic jump where the velocities would be high. Steve W. also added that the discharge may end up leaving the chute as it impacts the baffles.

3. The 200 cfs/ft design discharge used for the widened chute options was discussed. This unit discharge could be decreased; however, the cost would increase significantly, and there are hydraulic limitations on the expansion rate.

4. Duncan noted that a combination of the existing width chute w/ a deflector in combination with a filled in plunge pool downstream should be considered. Even with the widened chute, it is unlikely that the 110% could be met. Steve agreed that the shallowest depth possible downstream would be very beneficial to degassing the flow after it plunges.

5. The alternatives recommended in the memo for further investigation included: Alternative 2 (flow deflector/stilling basin, expanded width, Alternative 3 (flip-bucket, existing chute width), and Alternative 7 (rock weir/ramp).

   Duncan noted that deflectors are the most common and proven TDG abatement alternative so there is merit to investigating deflectors for Oxbow. We may want to start with Alternative 1 (flow deflector/stilling basin, existing width) in combination with a filled plunge pool before considering the expanded width option - Alternative 2, which would be more costly.

   Filling in the plunge pool was presented as Alternative 8. NHC's internal review noted that Alternative 8 should be investigated and this was also recommended by Duncan. Testing a filled in plunge pool in the model would provide an indicator as to the size of material that would be required.

6. Scott Zimmerman summarized the alternatives that will be carried forward to conceptual design/modeling.
   - Alternative 8 - Fill in plunge pool (most likely not a stand alone alternative).
   - Alternative 1 – Stilling basin/deflector, existing width
   - Alternative 3- Flip bucket, three bay version
   - Alternative 7 – Downstream Rock weir/ramp

   Brian pointed out that we may want to re-order the sequence for testing in the physical model.

7. The bathymetry status was discussed. IPC will finish the interpolation and NHC will then cut cross-sections. Brian will coordinate with Scott Z.

8. The rock distribution data was also discussed. NHC has the information required to recommend a mix for the model and will discuss with Duncan.

9. A brief update on the physical model was provided. NHC will try to rearrange some of the model construction tasks to accommodate the delay in the bathymetry.

10. The schedule for the physical model witness tests was discussed. NHC recommended moving the late June visit to earlier in June. This would allow the group to view the existing conditions and the filled-in plunge pool option at the onset of the study.

11. Action Items:
    - Scott Zimmerman will coordinate finishing the bathymetry.
    - NHC will recommend a rock distribution size.
    - NHC will continue developing Alternatives 1, 3, and 7. Alternative 8 will be included in the physical model test program (minimal conceptual design work required for that alternative.

Meeting Minutes:
Oxbow Spillway TRS Alternative Evaluation
Witness Test – NHC's Seattle Lab
June 7th and 8th, 2007

Attendees:

Scott Zimmerman, IPC	Brian Hughes, NHC
Scott Lorrondo, IPC	Lisa Larson, NHC
Ralph Myers, IPC	Jim Lencioni, NHC
Brian Hoelscher, IPC	Steve Wilhelms, NHC
Duncan Hay, Oakwood Consulting	Andre Ball, NHC
	Noah Carlson, NHC

On June 7th and June 8th, 2007, a witness test was held to review the Oxbow physical model at NHC's Seattle lab.

June 7th

8:30 am. The group convened in NHC's conference room to discuss the project. The following were discussed in the presentation:

- TRS alternatives identified by the group at February 2007 meeting.
- HEC-RAS model developed to provide tailwater elevations for the physical model. Sensitivity analyses and boundary conditions were presented.
- Model overview, operation, and status of model.
- Deflector concept and fill-in plunge pool alternatives.

9:30 am. The group viewed the model operating at 20 kcfs, 40 kcfs, 60 kcfs, and 100 kcfs for the existing spillway configuration (see Photos 1, 2, and 3). The predominant portion of spillway flow is directed in a downstream direction with a smaller portion off the right side of the chute. The flow in the chute exhibits numerous standing waves emanating from the spillway piers and the chute sidewall transition at the toe of the ogee crest. These standing waves were further enhanced by the converging left wall of the chute near the downstream end. These conditions create a very non-uniform flow distribution at the end of the chute with a significantly larger unit discharge at the left side of the chute.

"Plunging flow" off of the angled portion of the spillway chute was observed in the model for all four flow conditions and causes a very strong vertical circulation cell that spirals parallel to the spillway, entraining the flow from the horizontal circulation cell. The flow off the end of the spillway impacts on the bench at elevation 1687 ft, which somewhat deflects flow across the surface in what could be classified as a "ramped jet". Due to the combination of the large portion of the flow on the left side of the spillway and the spiraling circulation cell, velocities along the left bank are high. In addition, water impacting the small wedge-shaped deflector along the left wall at the end of the chute "bench" creates a jet that falls into the plunge area and appears to likely contribute to the plunging flow condition downstream of the chute. During the detailed documentation, the flow classifications will be re-visited and fully documented. For all flows, the most obvious plunging flow occurred along the downstream most portion of the spillway chute.

In the mobile bed section of the model, the model bed was formed prior to the witness test. The mobile bed was raked to survey pins that coincide with the top of the bed from the bathymetry data provided by IPC prior to the first calibration test. QA/QC on the mobile bed elevations had not been conducted prior to the witness test. A review of the bed elevations indicated that the rebar pins on the right bank and along one transect may need to be revised. All of the mobile bed pins will be checked during QA/QC before the documentation tests commence.

1:30 pm. The plunge pool was filled in to approximate elevation 1685 ft with 2 - 4 inch (model) rock and the model was operated at flows of 10 kcfs, 20 kcfs, 40 kcfs, 60 kcfs, and 100 kcfs. Photos 4, 5, and 6 show the riprap before any tests were conducted, and flow conditions at 40 kcfs and 100 kcfs operations. The most significant observation from the filled-in plunge pool tests was a significant increase in velocities along the left bank downstream of the chute. The reason for the observed increase in velocity is likely due to the shallower depth and decreased energy dissipation created by raising the bed in the plunge area. The flow regime exiting from the chute was similar to that existing with the baseline tests. As a result of the raised plunge pool bed elevation, the flow did not appear to plunge as deep compared to the existing condition, which is considered beneficial for reducing TDG; however, the flow classification leaving the chute was still considered to be in the plunging category. For flows up to 40 kcfs, there was minimal movement in the rip rap material. There was more observed movement in the rip rap material at 60 kcfs and significant movement at 100 kcfs.

4:00 pm. The model tests were completed at about 4 pm. Noah Carlson proceeded with installing a deflector for additional testing the next day. In addition, the bed was raked back to the existing prototype bed elevations. The bed along the right bank was modified slightly from the survey pin elevations to account for the differences between the observed bathymetry (from photos) and the survey pin elevations as noted previously.

June 8th

8:30 am. The group reconvened to view the deflector option suggested by Duncan Hay as shown in Photo 7. The riprap material previously placed remained in the plunge pool for the deflector tests. After some difficulties with the tilting tailgate at the downstream end of the model, flows of 20 kcfs, 40 kcfs, 60 kcfs and 100 kcfs were observed. Photos 8 and 9 show flows of 40 kcfs and 100 kcfs.

The deflector option provided “skimming flow” along the angled portion of the spillway and the flow spread much more toward the center of the channel, avoiding the formation of the strong spiraling counter clockwise circulation cell. The skimming action created an entrainment demand, but it appeared to be much weaker than the existing conditions.

The flow conditions on the downstream portion of the spillway did not change significantly; however, the spreading action along the angled portion of the spillway pulled toward the center of the channel. Plunging flow was still observed at the downstream end of the chute for discharges of 40 kcfs and higher; however, at 20 kcfs the flow in this area was classified as more of a "ramping flow". In general, these observations were considered to be a significant improvement compared to the baseline tests. Lowering the downstream most portion of the deflector was considered to be a potential modification to achieve a more desirable skimming flow condition. This would require a two step deflector since skimming flow occurs along the side deflector, and the 1690 ft elevation was considered satisfactory for that portion of the deflector.

The movement of the plunge pool riprap was similar to that observed for the existing spillway geometry. However, significant changes in the velocities downstream were observed. With the deflector in place, the velocities along the left bank were reduced and the higher velocities were re-directed toward the center of the channel and toward the right bank farther downstream from the chute where there would likely be erosion potential. These observations were verified by the mid-river scour hole and channel that developed within mobile bed material leading toward the right bank.

Noon:

The group discussed the outcome of the tests and a test plan. The deflector option was considered to be a promising alternative and is a proven technology used at other facilities. Therefore, the group consensus was to refine the deflector design to optimize its performance and conduct a more detailed test program. The attached test plan will be followed in the next few weeks. Duncan Hay will likely visit NHC's lab during the second week of July. NHC anticipates that testing will commence on or before June 20th to allow time for QA/QC, revise the tilting tailgate, and add a sand trap in the model. Tentative dates for the testing program are also noted below.

Photo 1 - Baseline 20kcfs

Photo 2 - Baseline 40kcfs

Photo 3 - Baseline 100kcfs

Photo 4 – Plunge Pool Riprap Test

Photo 5 – Plunge Pool Riprap Test 40 kcfs

Photo 6 – Plunge Pool Riprap Test 100 kcfs

Photo 7 – Deflector with Riprap

Photo 8 – Deflector Test 40 kcfs


Photo 10 – Deflector Test 100 kcfs

nhc

Oxbow TRS Project
Physical Model Test Plan:

Baseline: (approx June 21st to June 29th)

1. Rake mobile bed to existing condition.
2. Add thin layer of concrete to surface (sand and Portland cement).
3. Document flow conditions associated w/ 20k, 40k, 60k (i.e. plunging flow, skimming flow, combinations, water surface profiles, transect velocities, still photos, video, overhead time-exposure photos).
4. Spillway gates at equal settings for the baseline tests.

Baseline Erosion Test: (July 2nd and 3rd – gap in schedule to accommodate vacations)

1. Rake mobile bed flat (set to El. 1695ish), removing thin layer of concrete placed for previous tests.
2. Document change in bed at 70k
    - let run for 1 hr, collect WSEL & velocity data, drain & limited documentation;
    - let run for 2 more hours, drain & limited documentation;
    - let run for 4 more hours, drain & final document (with yarn)

Deflector Test: (approx July 9thth to July 20th)

Fabricate and install revised deflector – El.1690 along sloping section parallel to river, El. 1687 on existing downstream shelf (extended perpendicular to spillway centerline). Vertical step or slight ramp from El. 1690 to 1687. Leave the width the same. Remove existing curved fillet along downstream shelf near bank. Use "best" gate operations (providing most uniform unit discharge):

1. Repeat "Baseline" testing as described above (with thin concrete on existing channel bathymetry)
2. Repeat "Baseline Erosion Test" as described above (with flat bed at El. 1695)

Data Collection:

1. Classify flow exiting chute for 20k, 40k, 60k – still photos, video footage (with narrative) & overhead photos
2. Collect velocities – near-bank velocities at Transects 14 – 24 (near-surface & mid-depth measurements at three lateral locations: 2", 6" and 12" from bank)
3. Document gate settings, model discharge, upstream pool, chute & downstream channel water surface profiles
4. Mobile bed (Erosion) tests –
    - Limited documentation
        - Drain model (with sump pumps), measure deepest scour (elevation & location), take still photos, overhead photos & video
    - Final Documentation

- Place white yarn (knitting wool) at El. 1700, 1695, 1690, 1685, etc… including contour labels (using either water levels or survey pins to determine alignment of contours)
- Take still & overhead photos and video

Oxbow Dam – TRS Alternatives Physical Modeling

June 7, 2007

Oxbow TRS Project

MODEL DEMONSTRATION AGENDA

June 7th, 2007

8:30 - 9:30	Presentation/discussion
9:30 – 12:00	Model demonstration – existing condition
noon – 1:00	Working lunch – lab conference room
1:00 – 4:00	Model demonstration – plunge pool
4:00 – 5:00	Discussions

June 8th, 2007

8:00 – noon	Model demonstration – deflector option
noon – 1:30	Working lunch – lab conference room

Oxbow TRS Project

Scope of Work

- TRS alternatives – conceptual designs
- HEC-RAS modeling – tailwater curve
- Physical modeling – existing condition & alternatives
  - ✓ Construction
  - ✓ Calibration Testing
  - ✓ TRS Alternative Testing

Alternatives

8 alternatives considered including:

1) Standard stilling basin constructed at downstream of existing spillway chute with flow deflector
2) Standard stilling basin constructed at downstream end of widened chute with flow deflector
3) Flip bucket constructed at downstream end of existing spillway chute (full width)
4) Flip bucket constructed at downstream end of existing spillway chute with dividing wall installed
5) Two-stage energy dissipation structure replaces existing spillway chute
6) Stepped spillway constructed at downstream end of existing spillway chute
7) Rock weir and ramp constructed in downstream channel
8) Plunge pool filled in (common to all alternatives)

- **Alternatives 1,3, and 7 selected for modeling.**

Alternatives

Status of designs

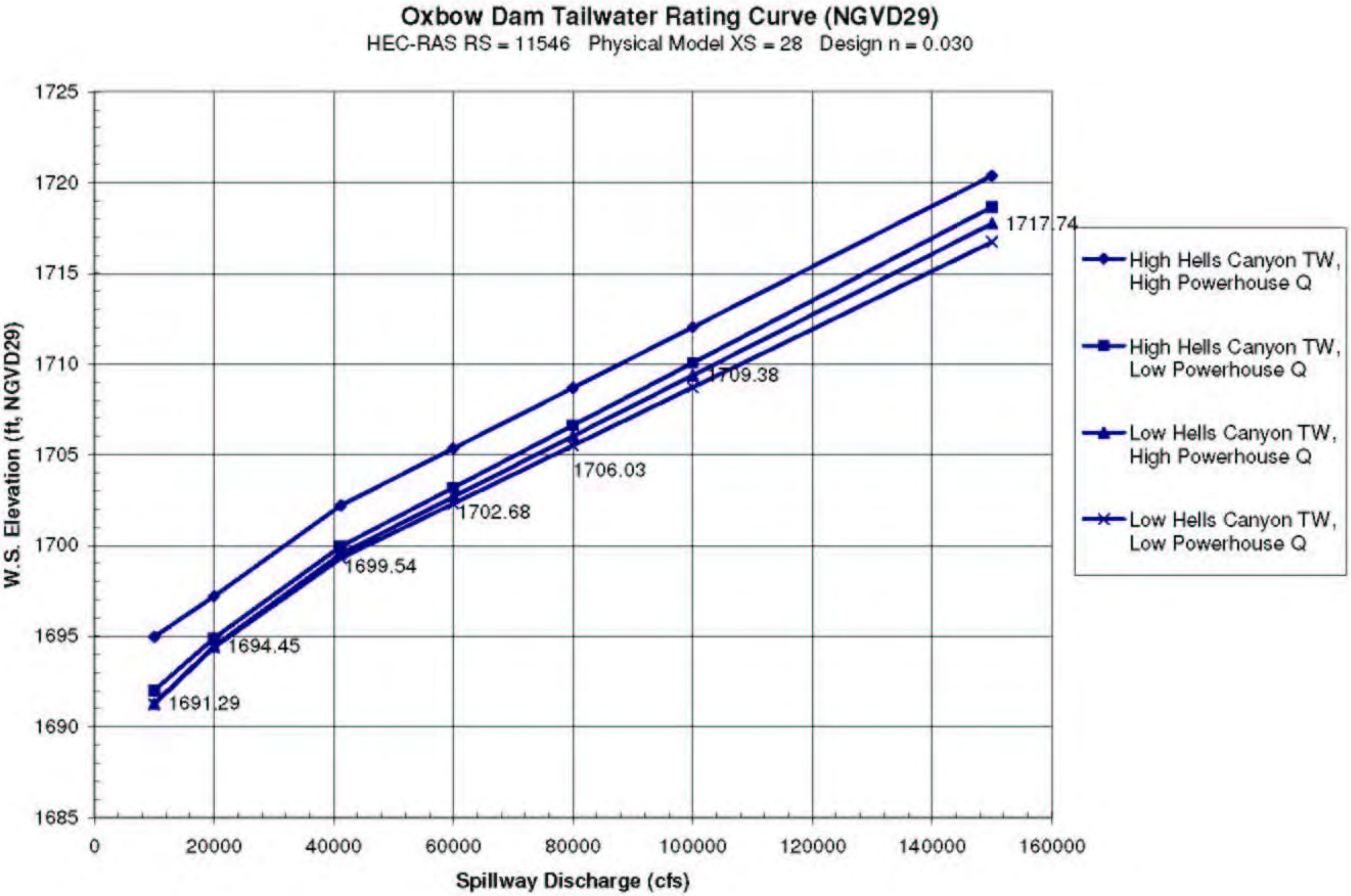
- **Alt 1 and Alt 3 – Viewing model results before additional design efforts. Re-visit during model demonstrations.**
- **Alt 8 – Testing today**
- **Alt 7 - Rock Weir and Ramp**
  - ✓ **Estimates of de-gassing potential indicate ~38% reduction of TDG in excess of saturation (eg. 125% reduces to 116%)**
- **Other options discussed since alternative analysis:**
  - ✓ **Deflector**

HEC-RAS Modeling

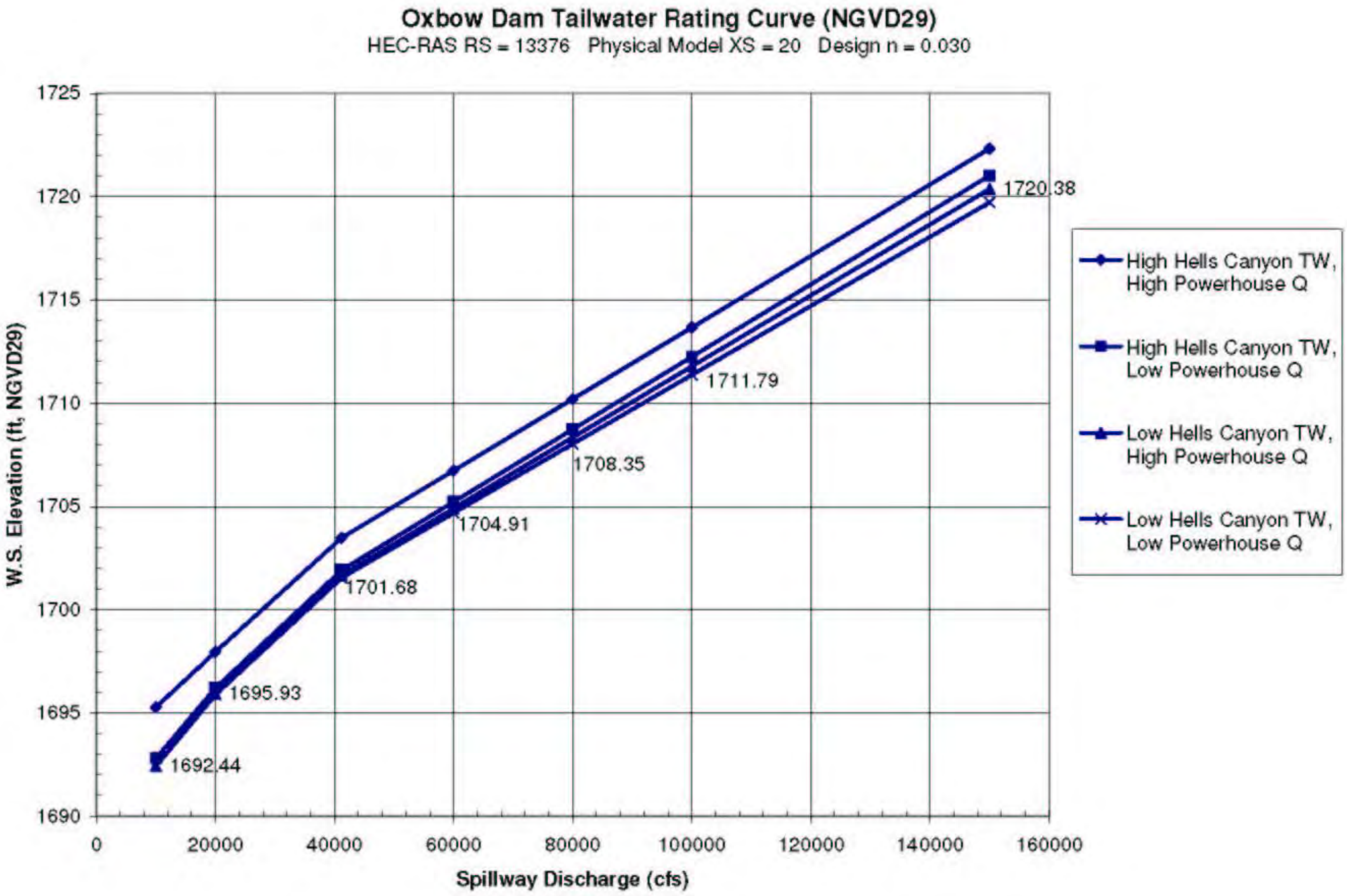
Tailwater Curve Development

- **Bathymetry provided by IPC extending from spillway tailrace to Oxbow powerhouse**
- **Used in HEC RAS model to provide predictions of water levels in the spillway tailrace**
- **Test Plan included a variety of Hells Canyon FB and ‘n’ values**

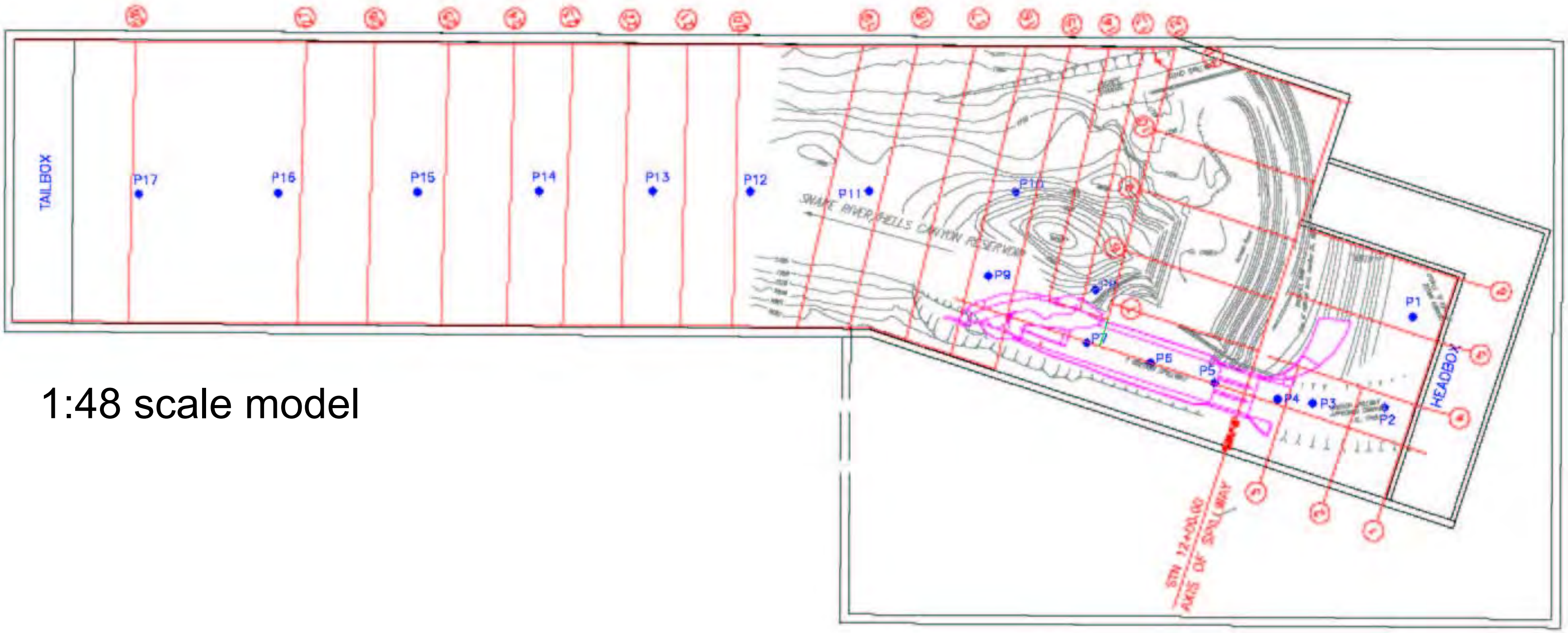
HEC-RAS Modeling



HEC-RAS Modeling


Oxbow Dam Tailwater Rating Curve (NGVD29)
HEC-RAS RS = 13376   Physical Model XS = 20   Design n = 0.030

Physical Modeling



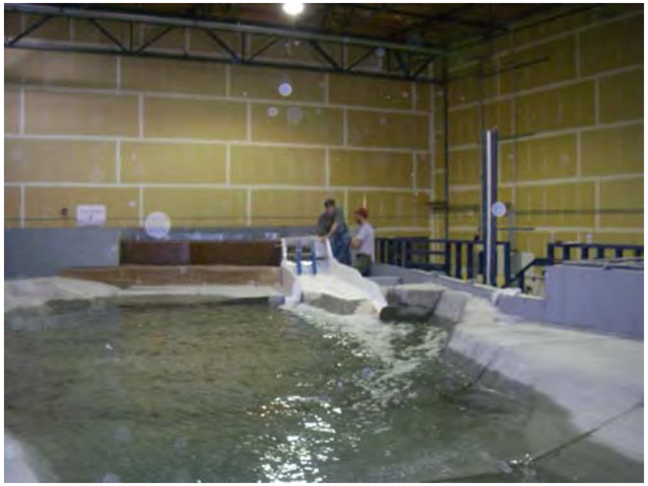
1:48 scale model

Model Layout

Physical Modeling

Model Features:

- 450 ft of reservoir and 3,300 ft of downstream river channel
  - ✓ Bathymetry from IPC data
- Oregon spillway and chute
  - ✓ Model structures based on drawings provided by IPC
- Mobile bed – 80% sand, 20% pea gravel, 20% 7/8'' washed



Physical Modeling

Model Measurements & Control:

- **Flow: Orifice-plate flow meters**
- **Water Surface Elevations: pressure taps, stilling wells**
- **Flow Patterns: Dye**
- **Velocities: 1-d miniature propeller meters**
- **Upstream headbox – baffling, manifolds, perforated plate**
- **Downstream Control: WSEL from RAS, controlled by tilting weir**

Physical Modeling

Preliminary Testing:

- Shake-down test
- Added mobile bed
- Calibration of Point Gages
- Establish tailrace gate setting for flows from 20kcfs to 100kcfs
- Model spillway gate rating curve under development

Physical Modeling

Preliminary Results:

- At design flow (40 kcfs) majority of flow exits on far downstream end of chute vs. along side slope of chute
- Significant movement in mobile bed at flows around100 kcfs (formation left in model)
  - ✓ Deepening scour along toe of spillway
  - ✓ Increased deposition on mid-river bar
  - ✓ Bed load transported downstream


approx. 60kcfs


approx. 100 kcfs

Physical Modeling

Test Program – June 7th:

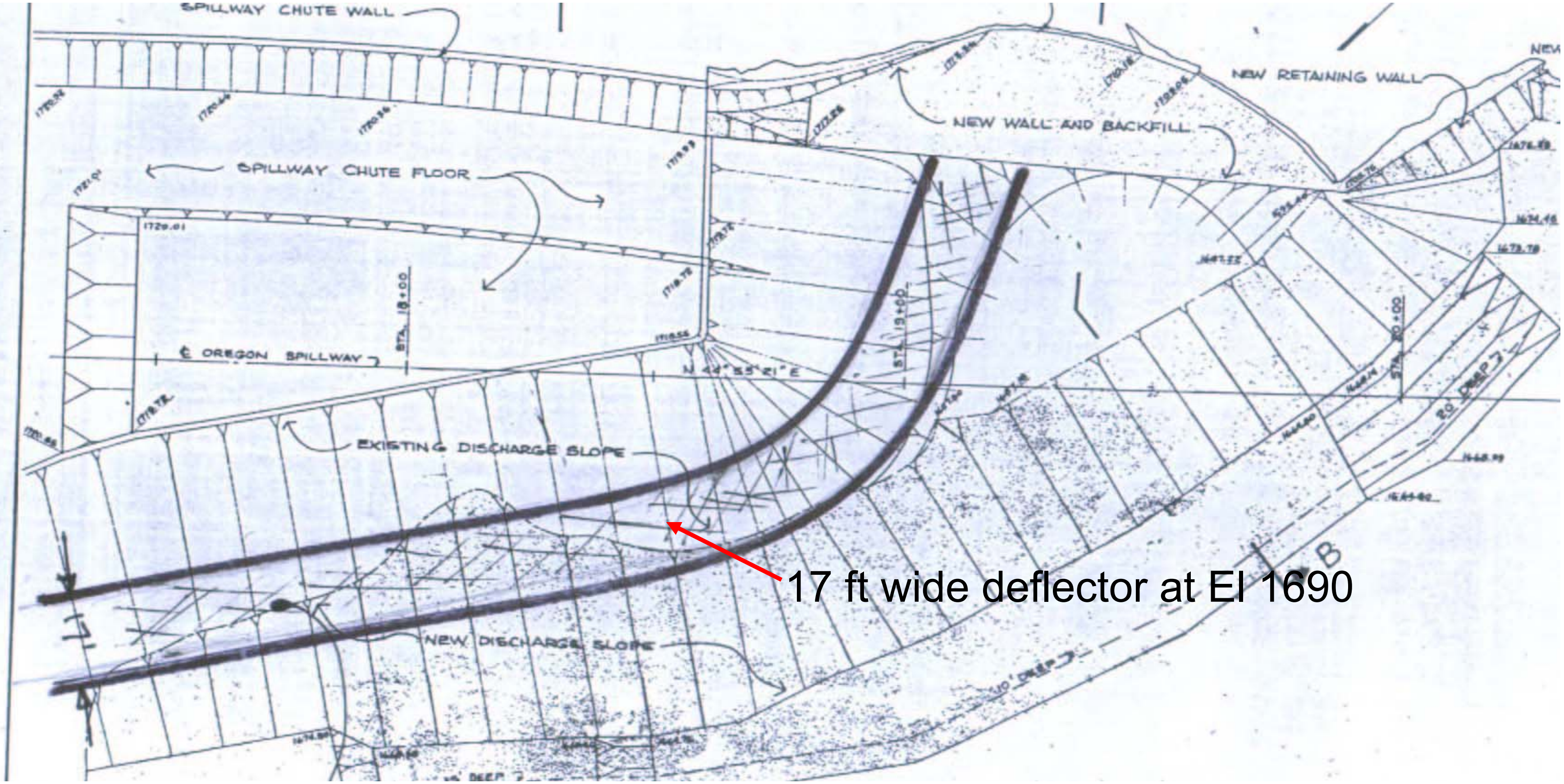
- Baseline Conditions – 20kcfs, 40kcfs, 60kcfs, 100kcfs
- Filled in Plunge Pool Test – same flows

- Test Program - June 8th:
  - Apron slope deflector – same flows

Fill-In Plunge Pool

Deflector Test

Apron Slope Deflector:



17 ft wide deflector at El 1690

Oxbow TRS Project

Summary/Discussion

Oxbow Dam – TRS Alternatives Physical Modeling

June 7, 2007

nhc

Meeting Minutes:
Oxbow Spillway TRS Alternative Evaluation
Witness Test – nhc's Seattle Lab
August 16th and 17th, 2007

Attendees:

Scott Zimmerman, IPC
Scott Larrondo, IPC
Ralph Myers, IPC
Duncan Hay, Oakwood Consulting
Brian Hughes, **nhc**
Lisa Larson, **nhc**
Jim Lencioni, **nhc**
Steve Wilhelms, **nhc**
Andre Ball, **nhc**
Noah Carlson, **nhc**
Rob Lohr, **nhc**

On August 16th and 17th, 2007, a witness test was held to review the deflector options for the Oxbow physical model at **nhc**'s Seattle lab.

Day 1 Thursday, August 16th, 2007

8:30 a.m. The group convened in **nhc**'s conference room to discuss the project. **nhc** gave a brief presentation summarizing the deflector design results that had been produced since the last witness test. The surface jet flow regime was a primary performance metric used in the evaluation of the deflector designs (Figure 1).

9:20 a.m. Model demonstrations began.

Deflector 6

Deflector six was the first concept tested during the witness test. The attached table provides a summary of the deflectors tested at the time of the witness test. Deflector 6 was a two step deflector at elevation 1689.5 ft and 1692.5 ft. A still photo of Deflector 6 in the dry condition was unavailable. Figure 2 shows Deflector 8, which was essentially a modified version of Deflector 6 (Figure 2 identifies a raised section that distinguishes Deflectors 6 and 8).

The following 20k cfs tests were conducted:

20k cfs, 2-bay, Low Oxbow TW, Deflector 6 (Right bay closed, standard 2-bay operation)
20k cfs, 3-bay, Low Oxbow TW, Deflector 6
20k cfs, 2-bay, Low Oxbow TW, Deflector 6 (Center bay closed)
20k cfs, 3-bay, Low Oxbow TW, Deflector 6 (repeated)
Multiple 40kcfs iterations with Deflector 6

Deflect 6 resulted in skimming to undular flow for flows between 20k and 40k cfs and for the operating range of tailwaters. Flow off the NE corner was not uniform (choppy); however, the performance was considered to be on the lower end of the acceptable range.

After observing various 2 and 3-bay operations, the group also observed a 1-bay operation. This type of operation is unlikely to occur; however, the full range of possible operating conditions was viewed. For a 40k cfs, 1-bay, Low Oxbow TW, Deflector 6 (center bay only open) test, the flow conditions were considered to be acceptable with a uniform flow distribution off of the NE corner and side deflector. There was a much higher unit discharge off the corner of the deflector. For 2-bay and 3-bay operations, the corner typically resulted in the lowest unit discharge.

Deflector 8

After observing the Deflector 6 operations, a short length of the side deflector was raised 2 feet to elevation 1694.5 just upstream of the deflector corner. This new configuration was identified as Deflector 8 (see Figure 2). The following tests were conducted.
Deflector 8: Deflector 6 with an added step (1989.5’/1694.5’/1692.5’)

11:15 a.m. 40k cfs, 2-bay, Low Oxbow TW, Deflector 6
11:20 a.m. 40k cfs, 2-bay, Low Oxbow TW, Deflector 8
11:27 a.m. 40k cfs, 3-bay, Low Oxbow TW, Deflector 8
11:30 a.m. 40k cfs, 3-bay, Low Oxbow TW, Deflector 6
11:35 a.m. 20k cfs, 2-bay, Low Oxbow TW, Deflector 6
11:40 a.m. 20k cfs, 2-bay, Low Oxbow TW, Deflector 8

Deflector 8 improved the flow in the NE corner relative to deflector 6; however, it did not alter the overall flow regime or show substantial improvements. The additional construction cost was not considered to be warranted for the minimal improvement that was observed.

Deflector 6 with Parabolic Drop

To improve the hydraulic conditions on the downstream end of the chute, a parabolic shaped drop was added as shown in Figure 3.

At approximately 11:45 a.m., a 20k cfs, 2-bay, Low Oxbow TW, Deflector 6 + Parabolic Drop test was conducted. For this condition, the side deflector flow condition was more ramped compared to the deflector 6 performance curve. The reason for this may be due to the starting bed condition for this test. There was a significant movement in the bed that occurred with the prior test, 1-bay operation at 40k cfs, and the bed was not raked back to existing conditions before the Deflector 6 w/ Parabolic Drop test was conducted. After viewing the parabolic drop, the group concluded that it would be a costly addition and that although the jet does adhere more closely to the parabolic drop than the existing slope and reduces the rooster tails resulting from the jet impact on the end deflector, the additional construction costs would not necessarily warrant this type of substantial addition. Later in the witness test, smaller parabolic type alternatives were tested.

General Discussions:

The width of the deflector was not optimized prior to the witness test, and it was concluded from the tests that the deflector width could be reduced significantly. At 11:50 a.m., the group estimated and marked the portion of the deflector that was considered to be wider than necessary. Identified as Deflector 9, the reduced width deflector was about one-half of the width on the end and side deflector (approximately 40’ wide at downstream end and 10’ along the side) of deflector 6. The deflector was not actually cut at this time but was marked for observation and consideration (i.e. is this the optimum amount to cut the deflector).

12:00-1:00 Lunch

The bed was re-raked to the survey pins and additional tests were conducted with the parabolic shaped drop.

1:10 p.m. 20k cfs, 2-bay, Low Oxbow TW, Deflector 6 + Parabolic Drop
1:18 20k cfs, 3-bay, Low Oxbow TW, Deflector 6 + Parabolic Drop
1:30 40k cfs, 3-bay, Low Oxbow TW, Deflector 6 + Parabolic Drop
1:35 40k cfs, 2-bay, Low Oxbow TW, Deflector 6 + Parabolic Drop

Side Fillet

After viewing the parabolic drop tests, a fillet was installed along the side of the discharge slope as shown in Figure 4. This fillet was an attempt to improve the flow regime at the corner of the deflector and extended from the crest of the discharge slope down to the deflector.

The following tests were conducted:

2:00 40k cfs, 2-bay, Low Oxbow TW, Deflector 6 + Parabolic Drop + Fillet
2:05 40k cfs, 3-bay, Low Oxbow TW, Deflector 6 + Parabolic Drop + Fillet
2:08 20k cfs, 3-bay, Low Oxbow TW, Deflector 6 + Parabolic Drop + Fillet

The addition of both the parabolic shaped drop and the fillet made marginal improvements to flow conditions but did not result in significant overall improvements to the Deflector 6 design configuration

General Discussions:

There was general consensus that Deflector 6 performed well. Subsequent testing was then conducted to investigate ways to economize the design and further reduce construction costs. While waiting for modifications to the model, the group also reviewed video footage of baseline 20k, 40k, 60k cfs flows to compare the existing condition with the deflector improvements. The videos confirmed a significant improvement with Deflector 6.

Deflector 9

The parabolic drop and fillet were removed, and the deflector width was cut in half along entire perimeter where it had been marked prior to lunch. This resulted in a deflector width of ~40' on the d/s end and approximately 10' along the side.

The following tests were conducted with Deflector 9:

3:06 20k cfs, 3-bay, Low Oxbow TW, Deflector 9
3:11 20k cfs, 2-bay, Low Oxbow TW, Deflector 9
3:15 40k cfs, 2-bay, Low Oxbow TW, Deflector 9
3:27 40k cfs, 3-bay, Low Oxbow TW, Deflector 9

During 3-bay operation, a large depression in WSEL with plunging flow appeared for the first time off the NE corner of the deflector. After a few moments, the depressions seemed to disappear. Except for the depression, the performance was acceptable with a skimming/undular jet regime existing.

4:00 Testing concluded for the day. The lab started constructing additional modifications for the following day.

Day 2 Friday, August 17th, 2007

The lab installed a revised deflector configuration on Friday morning.

Deflector 10:

Deflector 10 was a modification to Deflector 9 that included filling in the sloped transition so that a vertical step existed from elevation 1689.5 ft to 1692.5 ft and was parallel to the centerline of the spillway chute. The side deflector width was a consistent 10’ wide as it wrapped around the corner to meet the end deflector.

A small shaped drop, “brow”, addition was added at the downstream end of the spillway chute. This brow was mounted to the end of the spillway chute where the prior parabolic drop structure was mounted but did not extend all the way down to the end deflector (see Figure 5). The brow appeared to cause negative pressure that caused the jet to draw down as it exited the chute and cause it to impact more on the upstream end of the deflector.

The following tests were conducted;

8:22 a.m. 20k cfs, 3-bay, Low Oxbow TW, Deflector 10 + Brow
8:30 a.m. 20k cfs, 3-bay, High Oxbow TW, Deflector 10 + Brow
8:35 a.m. 20k cfs, 2-bay, High Oxbow TW, Deflector 10 + Brow
8:45 a.m. 40k cfs, 2-bay, Low Oxbow TW, Deflector 10 + Brow
8:57 a.m. 40k cfs, 2-bay, High Oxbow TW, Deflector 10 + Brow
Note: Side Deflector flow looked cleaner/more uniform on 2-bay operation
9:02 a.m. 40k cfs, 3-bay, High Oxbow TW, Deflector 10 + Brow

The corner area seemed to be improved with an undulating surface jet (USJ). The U/S portion of the side deflector was slightly more ramped but still appeared to have more unit discharge on the upstream side deflector than on the downstream end/corner.

A 5-6” deep depression with plunging flow formed again off the NE corner with 3-bay operation. Flow distribution shifted in this operation, more flow came off the end and much less comes off the corner. This depression was repeatable and appeared to be stable. During previous testing on Thursday, the depression associated with a 3-bay operation with Deflector 8 was not stable and disappeared at times. Duncan noted that, the corner and D/S end of the side may need to be lowered to prevent the depression at certain gate openings.

Deflector 11

At approximately 9:13 a.m. the model was shutdown and additional modifications were made to the deflector. The following modifications were made:

- Reduce width of end deflector by 3" (12') (resulting in 32' width on the left side and 44' width on the right)
- Add 1" (4') in width to the right side of end deflector to prevent the jet from impacting on the tailwater at that area.
- Raise the end deflector 1/8" (0.5', resulting in 1690' elevation)
- Decrease the width of the brow by ¼" (1') along the right side in efforts to lower the high jet/rooster tail forming off this side.

The following tests were conducted:
9:55 a.m. 40k cfs, 2-bay, High Oxbow TW, Deflector 11 + Brow R1
Plunging did not occur at the corner; however, the brow was thought to be too narrow with this modification. On the right side, the negative pressure appears to be significantly reduced and the flow off the end is no longer pulled down on the edge of the brow. As a result, some of the jet is still not adhering to the brow.

The group concluded that a training wall downstream of the existing bench off the downstream end of the chute would keep flow from returning over jet off the D/S end of the deflector during the 2-bay operation described above. The training wall was discussed but not installed at this time.

10:08 a.m. 40k cfs, 3-bay, High Oxbow TW, Deflector 11 + Brow R1

- Plunging flow and the depression off NE corner reappears with 3-bay operation

10:15 a.m. 40k cfs, 3-bay, High Oxbow TW, Deflector 11 (Brow removed)
10:18 a.m. 40k cfs, 2-bay, Low Oxbow TW, Deflector 11
10:22 a.m. 40k cfs, 3-bay, Low Oxbow TW, Deflector 11
10:25 a.m. 20k cfs, 2-bay, Low Oxbow TW, Deflector 11

- Ramping occurs off NE corner but the deflector still needs to be modified for 3-bay 40k cfs flow to prevent plunging.
- Training wall not needed in this condition to prevent return from flow overtopping flow of end deflector.

10:32 a.m. 20k cfs, 3-bay, Low Oxbow TW, Deflector 11

- USJ off corner, no depression
- Ramped surface Jet (RSJ) along side deflector
- Submerged Jet on U/S edge of side deflector

Deflector 12:

The Deflector 12 configuration lowered the end of the deflector back to elevation 1689.5' and removed the 4' end deflector width previously added to Deflector 11.

10:38 a.m. 10k cfs, 2-bay, Low Oxbow TW (1691.5'), Deflector 12

- Steep RSJ around NE corner and up side deflector
- Submerged jet on U/S edge of side deflector

10:45 a.m. 10k cfs, 3-bay, Low Oxbow TW (1691.5'), Deflector 12

- RSJ at NE Corner (12-o'clock to 1-o'clock)
- Roller comes back on top of itself near NE Corner(1-o'clock to 3-o'clock)
- Steep RSJ along side of deflector
- Steep RSJ (extends further U/S than in previous test above)
- Submerged jet on U/S edge of side deflector

10:53 a.m. 60k cfs, 3-bay, Low Oxbow TW, Deflector 12

- Large depression off NE corner, hydraulic jump downstream

10:58 a.m. 60k cfs, 2-bay, Low Oxbow TW, Deflector 12

- Slight depression, plunging flow off the NE Corner

11:10 a.m. The model was shutdown and the mobile bed section was drained. A significant scour hole was present off the D/S end of the side deflector.

Conclusion and Next Steps Discussion

The following text is an abbreviated set of comments and ideas discussed at the conclusion of the witness test.

Duncan Hay (DH): Optimize the length and elevation of training wall. Spend the available construction funds for the wall rather than a brow. Keep the brow idea on the shelf. The corner of the side deflector should be lowered to prevent plunging flow from forming.

Brian Hughes (BH): Look at widening the side and corner of the deflector to prevent the plunging flow regime from forming..

Steve Wilhelms (SW): In moving from Deflector 6 to Deflector 12, we have gone from two more or less separate jets (side deflector and downstream deflector) to spreading the flow. This may be detrimental regarding gas issues.

DH: Design objective should be no flow regime change between 2 and 3-bay operation, preserve spillway flexibility. Use the model to determine whether this is controlled by deflector width or elevation. With respect to field conditions, the concrete fillet dimensions at the downstream end of the prototype spillway are still unkown.

- Upper fillet (material has been added in model)
- Lower fillet (material has been removed in the model)
-

Idaho Power Company (IPC) / Scott Zimmerman (SZ): We will look at our photogrametric data. We need to find out what is there as best we can.

Jim Lencioni (JL): End deflector elevation of 1689.5’ and length of ~45’ seems ok

DH: Agreed, length and elevation of the end deflector looks fine.

SW: Originally a degassing channel was discussed. If this is a future option then it should be looked at now due to its effect on tailwater

IPC: Not likely that a permit would be obtained to be able to build a degassing channel.

BH: There was also discussion of filling in the existing scour hole off the tailrace.

SW: Compare scour tests, decide on protection sizes, and determine at what flow the riprap will be allowed to fail (while the model is still available to determine this). Filling in the plunge pool will provide a TDG benefit.

DH: It is easier to protect and maintain the bed at a lower elevation due to decreased energy at the bed.

IPC: With respect to heavy equipment IPC would want to consolidate the in-channel work to minimize the in-channel work time.

SW: Based on observations during the testing, Steve noted that a large vortex may form in the forebay with 2-bay operation

DH: Define velocities along left bank and define benefit of training wall. Erosion has occurred near the left bank eddy. We need to determine the differential hydrostatic pressure on the wall using model measurements.

nhc was tasked with looking at two different options to prevent plunging regime at the NE corner with Deflector 12 following the witness test:

1. Lower the deflector
2. Widen the deflector and maintain 1692.5 elevation.

nhc will coordinate with Duncan. 12:00 The meeting concluded at approximately noon.

Table 1 Oxbow Spillway Deflector Designs Developed Prior to August 16th-17th Witness Test

Fully Documented Iterative Deflector Configurations

Name	Testing Date	Deflector Type	D/S Edge Length	D/S Edge Elevation	Step Transition	Side Edge Width	Side Edge Elevation
Deflector Configuration 1	7/16/2007	Two Step	~80'	1689'	1v:3h Parallel to Spillway CL	~20'	1692'
Deflector Configuration 2	7/17/2007	Constant Elevation	~80'	1689'	N/A	~20'	1689'
Deflector Configuration 3	7/18/2007	Two Step	~80'	1689'	1v:3h Curve Expansion from	~20'	1692'
Deflector Configuration 4	7/22-23/2007	Two Step	~80'	1691'	1v:3h Curve Expansion from	~20'	1694'
Deflector Configuration 5	7/25/2007	Two Step	~80'	1690'	1v:3h Curve Expansion from	~20'	1693'
Deflector Configuration 6	8/1-2/2007	Two Step	~80'	1689.5'	1v:3h Curve Expansion from	~20'	1692.5'

Refined Proposed Deflector Configuration

Name	Testing Date	Deflector Type	D/S Edge Length	D/S Edge Elevation	Step Transition	D/S Side Edge Width	D/S Side Edge Elevation	Step Transition	U/S Side Edge Width	U/S Side Edge Elevation
Deflector Configuration 7	8/2/2007	Three Step	~80'	1689.5'	~1v:3h Curve Expansion from	~20'	1695.5'	~1v:2h slope, 45° off	~20'	1692.5'
Deflector Configuration 8	8/2/2007	Three Step	~80'	1689.5'	~1v:3h Curve Expansion from	~20'	1694.5'	~1v:2h slope, 45° off	~20'	1692.5'

Table 2 Oxbow Spillway Deflector Designs and Additions Investigated During August 16th-17th Witness Test

Deflector Configurations - August 16th and 17th Witness Test

Name	Testing Date	Deflector Type	D/S Edge Length	D/S Edge Elevation	Step Transition	Side Edge Width	Side Edge Elevation	Notes
Deflector Configuration 9	8/16/2007	Two Step	~40'	1689.5'	1v:3h Curve Expansion from NE corner	~10'	1692.5'	Deflector 6 modified by reducing width by roughy half.
Deflector Configuration 10	8/17/2007	Two Step	~40'	1689.5'	Parallel to Spillway CL at NE corner, no slope,	~10'	1692.5'	Deflector 9 modified by replacing sloped transition with a step. Deflector width along NE corner is reduced to ~10', continuation of side.
Deflector Configuration 11	8/17/2007	Two Step	32' LS 44' RS	1690'	Parallel to Spillway CL at NE corner, no slope,	~10'	1692.5'	Deflector 10 modified by: 1) 12' removed from D/S end length 2) 4' added to RS of D/S end def 3) 0.5' added to D/S end elev (1690')
Deflector Configuration 12-13	8/17/2007	Two Step	32' LS 44' RS	1689.5'	Parallel to Spillway CL at NE corner, no slope,	~10'	1692.5'	Deflector 11 modified by: 1) D/S end elev lowered 0.5' (1689.5') 2) 4' removed from RS of D/S end def

Deflector Addition Options - August 16th and 17th Witness Test

Name	Description
Parabolic Drop	The Pabablic drop addition fits on the to the downstream end of the spillway chute. The parabolic curve was designed per Corps specifications. The performance of this addition was evulatued after it was fitted to the Deflector Configuration 6.
Fillet	This Fillet forms a smoothed transition from the right side of the Parabolic drop to slope of the rightside of the spillway chute. The performance of the fillet was evalutued after it was fitted to the Deflector Configuration 6 with the Parabolic Drop.
Brow	The brow addition fits to the downstream end of the spillway chute.The brow has a more aggressive downward curve than the Parabolic drop and is shorter. It does not support the flow all the way to the D/S end deflector. The brow was evalutued in conjunction with Deflector Configuration 10

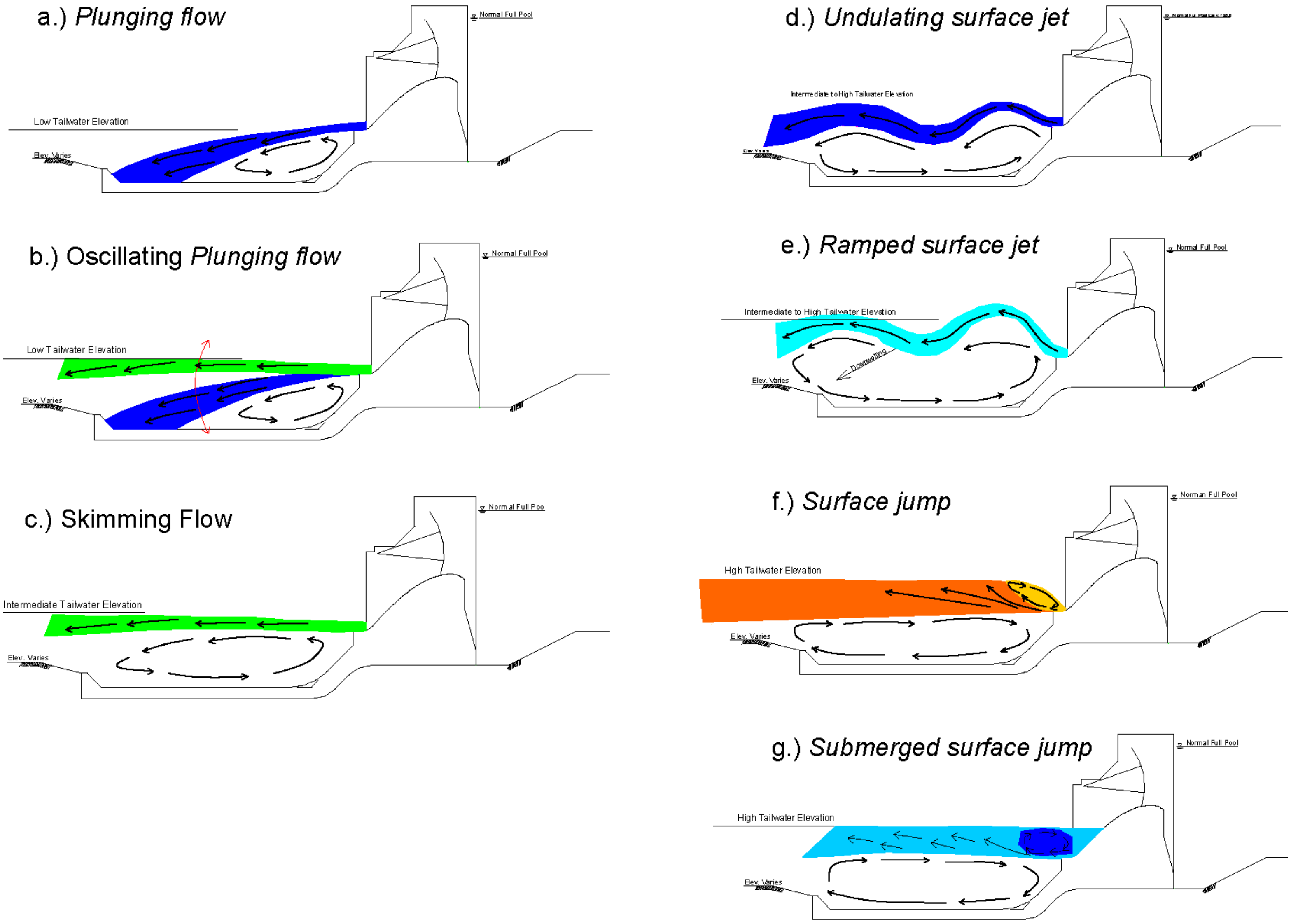


Figure 1 Surface Jet Flow Regime Classification

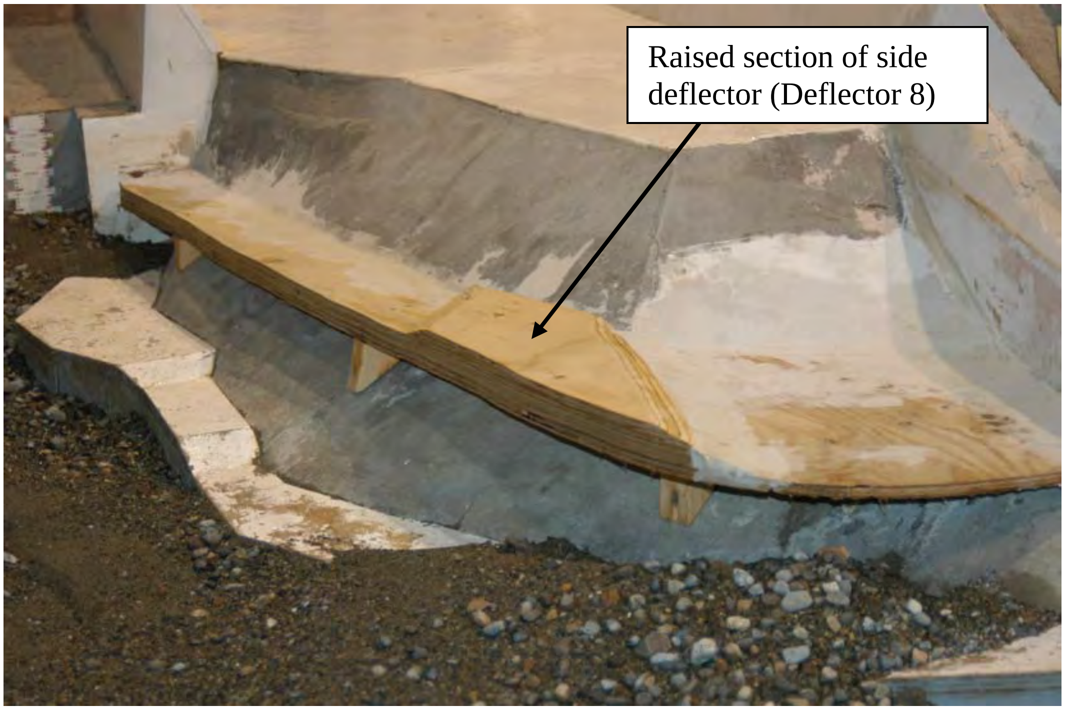


Figure 2 Deflector 8, a modified version of Deflector 6

Figure 3 Parabolic Shaped Drop

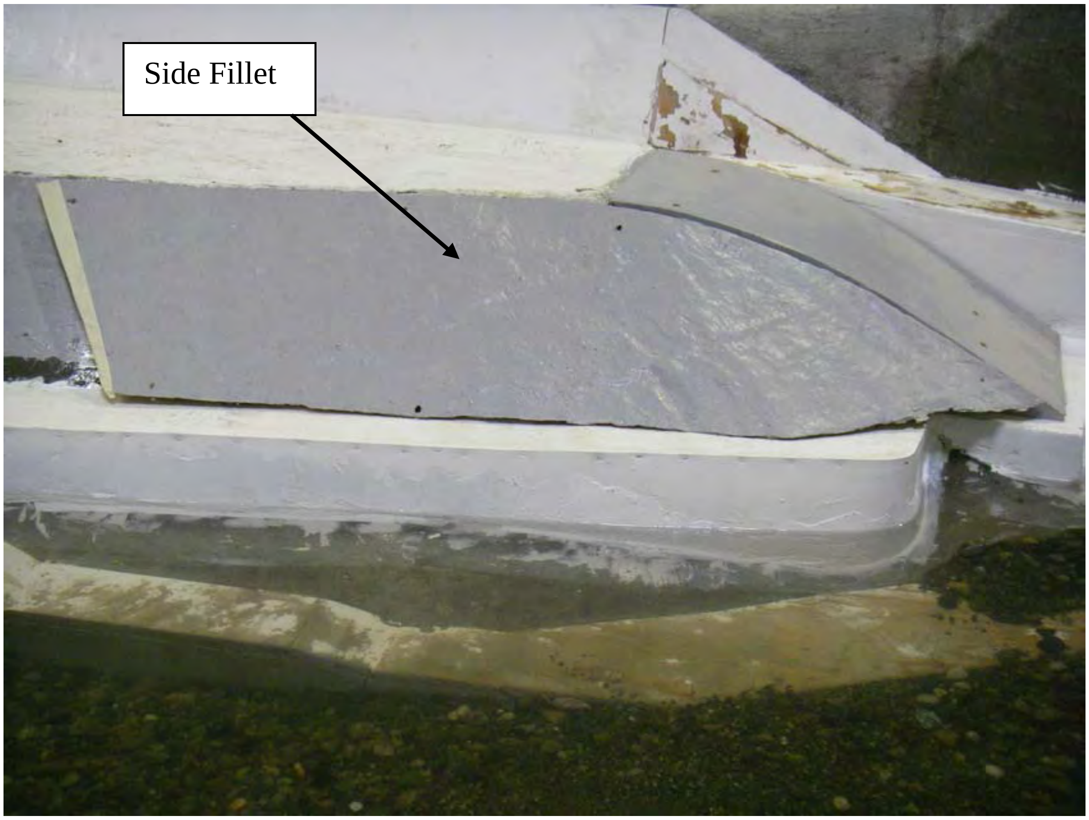


Figure 4 Side Fillet with Parabolic Shaped Drop

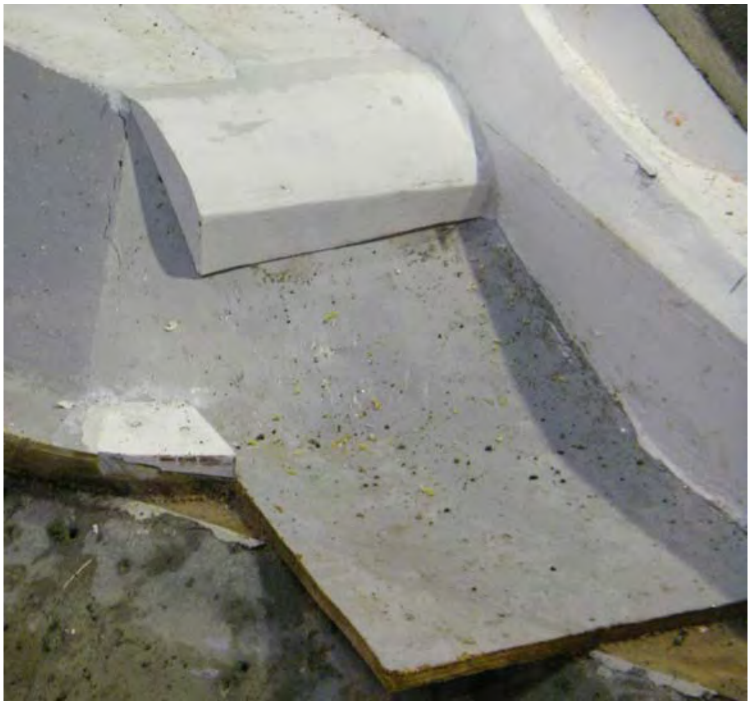


Figure 5 "Brow" Addition

Oxbow Dam – TRS Alternatives Physical Modeling

August 16th and 17th, 2007

Oxbow TRS Project

MODEL DEMONSTRATION AGENDA

June 7th, 2007

8:30 - 9:30	Presentation/discussion
9:30 – 12:00	Model demonstration – deflector performance test curve
12:00 – 1:00	Working lunch – lab conference room
1:00 – 4:00	Model demonstration – finish deflector performance test curve, install and test “third step” deflector
4:00 – 5:00	Discussions

June 8th, 2007

8:00 – 12:00	Model demonstration – refinements parabolic drop, training wall, slope fillet
12:00 to 1:30 pm	Lunch, wrap-up

Oxbow TRS Project

Testing Progress

- ➢ Completed baseline tests and documentation
  - ✓20kcfs, 40kcfs, 60kcfs, and 100kcfs
  - ✓Baseline erosion
- ➢ Constructed, tested, and documented eight deflector configurations (post June 7th/8th meeting)

Baseline

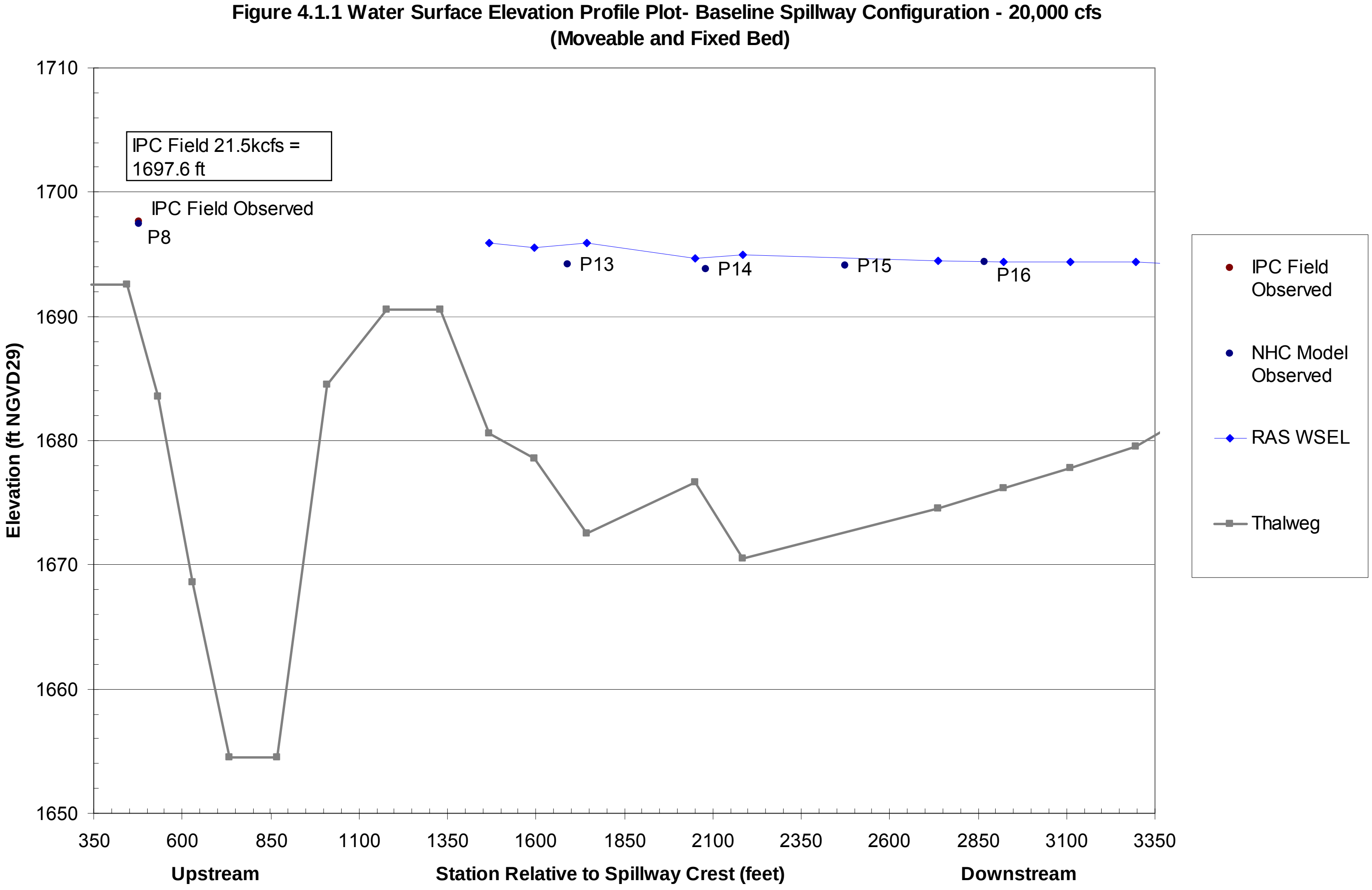


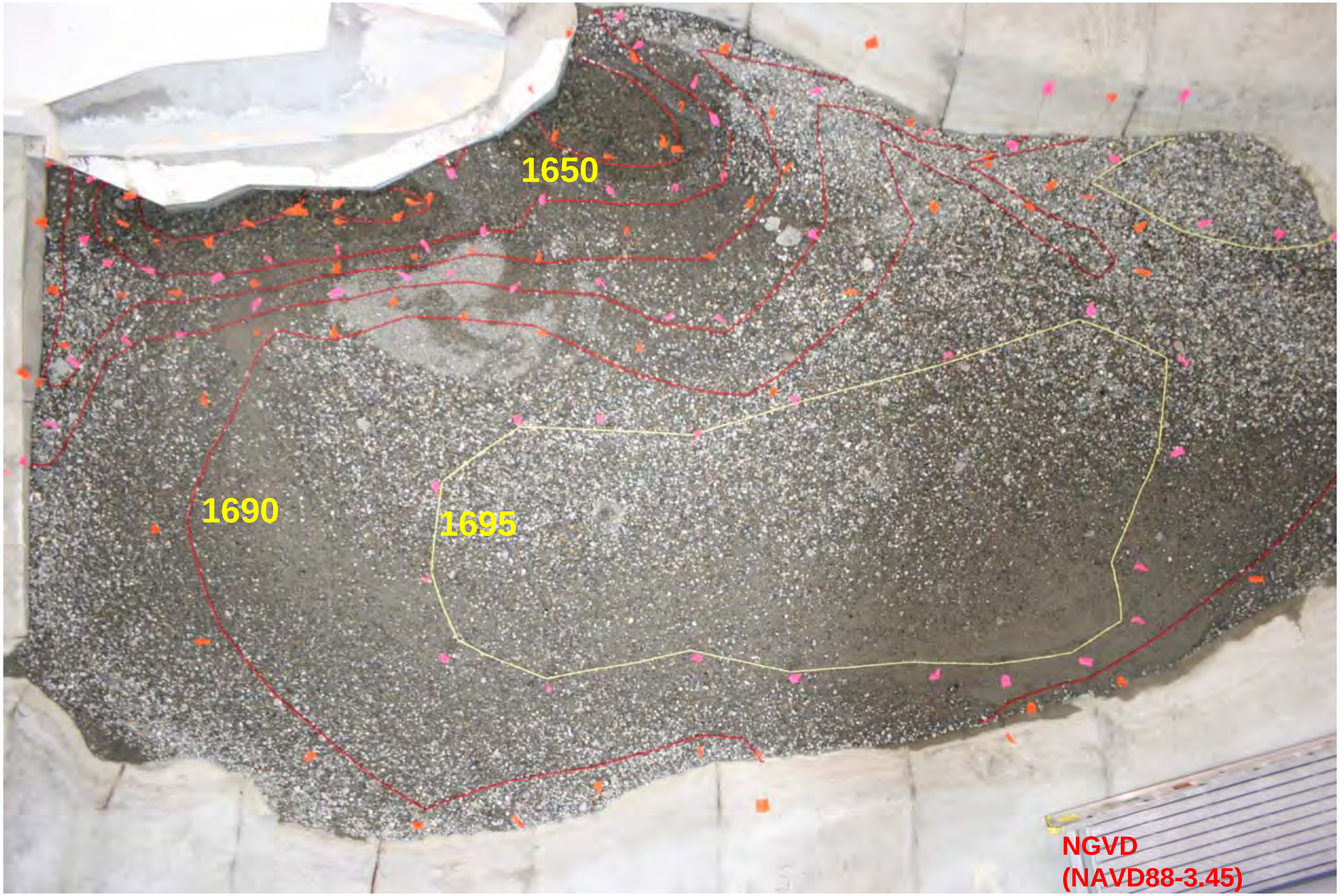
Figure 4.1.1 Water Surface Elevation Profile Plot- Baseline Spillway Configuration - 20,000 cfs
(Moveable and Fixed Bed)
IPC Field 21.5kcfs =
1697.6 ft
IPC Field Observed
P8
P13
P14
P15
P16
1710
1700
1690
1680
1670
1660
1650
Elevation (ft NGVD29)
350
600
850
1100
1350
1600
1850
2100
2350
2600
2850
3100
3350
Upstream
Station Relative to Spillway Crest (feet)
Downstream
IPC Field Observed
NHC Model Observed
RAS WSEL
Thalweg

Baseline

Figure 4.1.2 Water Surface Elevation Profile Plot- Baseline Spillway Configuration - 40,000 cfs (Moveable and Fixed Bed)

IPC Field 39kcfs = 1699.3 ft
NHC Observed = 1698.9 ft

Baseline

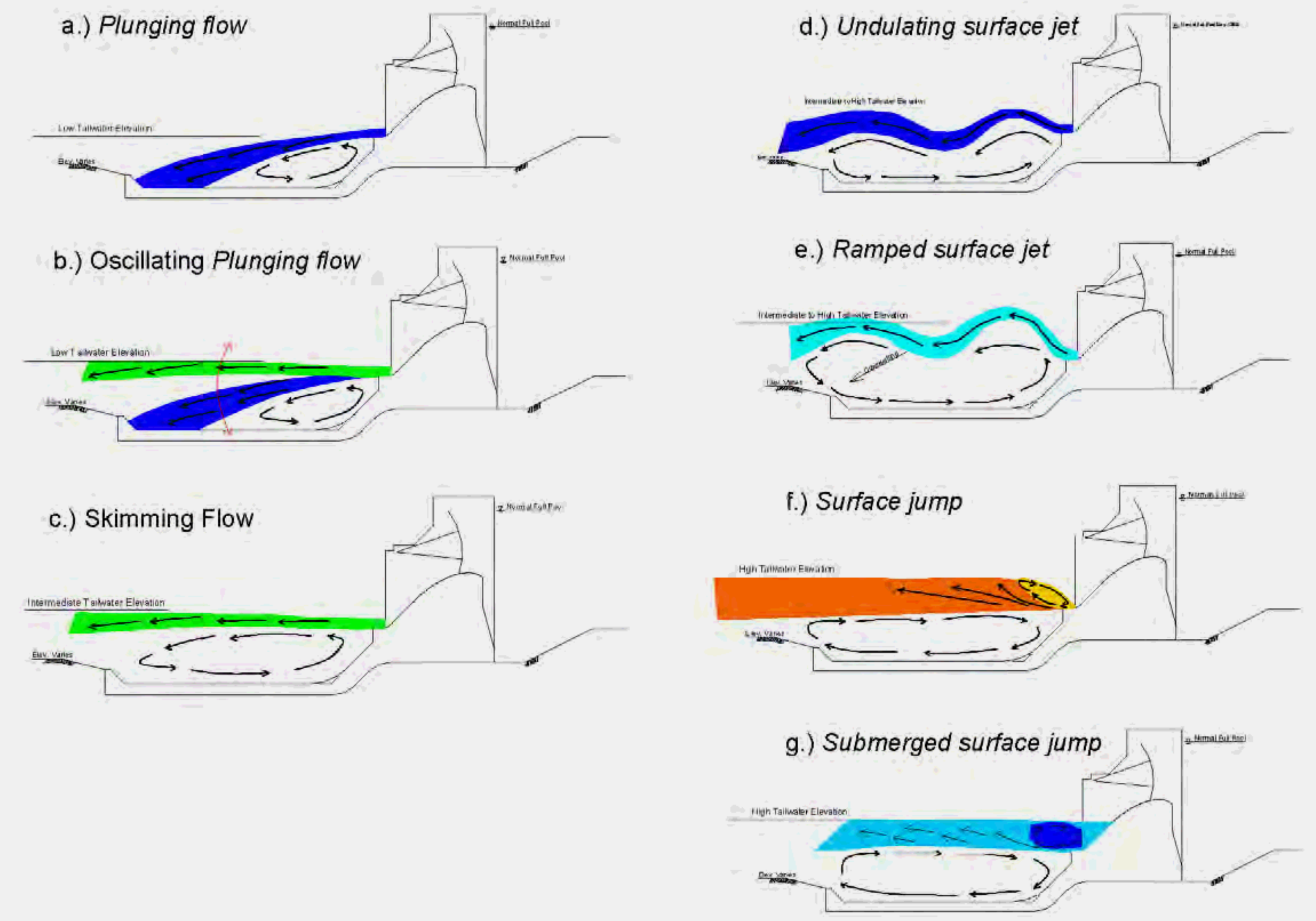


Deflector Tests

Deflector Tests

- June 8th Witness Test - Deflector at 1690’
- July 13th Meeting w/ Duncan – Two Step Deflector (1687’/1690’); moved transition
- Since July 13th – Tested 8 variations

Deflector Tests



Deflector Tests

Partially Documented Initial Deflector Concepts

Name	Testing Date	Deflector Type	D/S Edge Length	D/S Edge Elevation	Step Transition	Side Edge Width	Side Edge Elevation
Witness Test 6/8/2007 (Day 2, Friday)	6/8/2007	Constant Elevation	~40'	1690'	N/A	~20'	1690'
Concept 1 (7/13/2007 Duncan Visit)	7/13/2007	Two Step	~80'	1689'	1v:3h 50' U/S of NE Corner	~20'	1692'
Concept 2 (7/13/2007 Duncan Visit)	7/13/2007	Two Step	~80'	1689'	1v:3h ~20° NE from NE corner	~20'	1692'

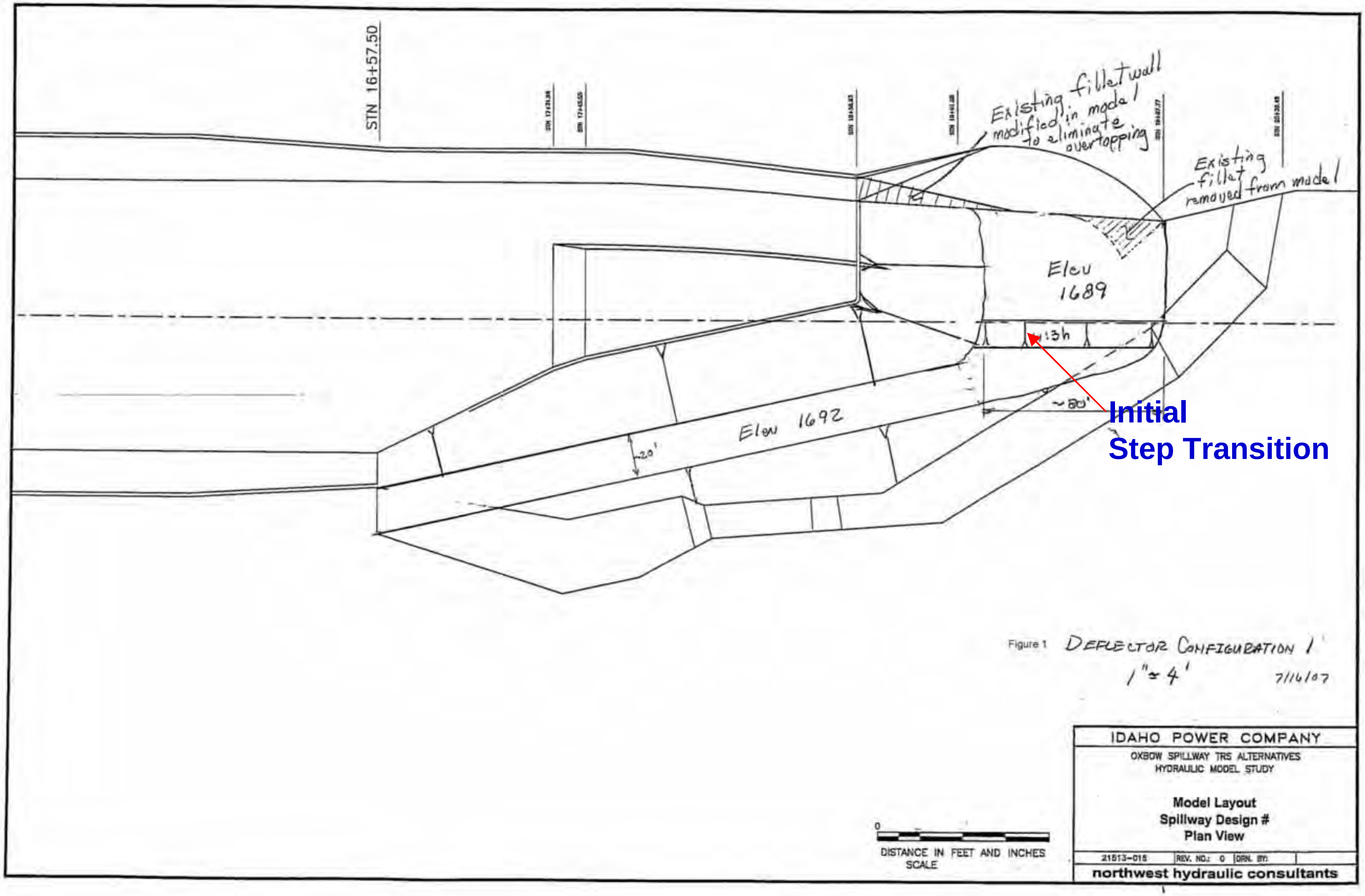
Fully Documented Iterative Deflector Configurations

Name	Testing Date	Deflector Type	D/S Edge Length	D/S Edge Elevation	Step Transition	Side Edge Width	Side Edge Elevation
Deflector Configuration 1	7/16/2007	Two Step	~80'	1689'	1v:3h Parallel to Spillway CL	~20'	1692'
Deflector Configuration 2	7/17/2007	Constant Elevation	~80'	1689'	N/A	~20'	1689'
Deflector Configuration 3	7/18/2007	Two Step	~80'	1689'	1v:3h Curve Expansion from	~20'	1692'
Deflector Configuration 4	7/22-23/2007	Two Step	~80'	1691'	1v:3h Curve Expansion from	~20'	1694'
Deflector Configuration 5	7/25/2007	Two Step	~80'	1690'	1v:3h Curve Expansion from	~20'	1693'
Deflector Configuration 6	8/1-2/2007	Two Step	~80'	1689.5'	1v:3h Curve Expansion from	~20'	1692.5'

Refined Proposed Deflector Configuration

Name	Testing Date	Deflector Type	D/S Edge Length	D/S Edge Elevation	Step Transition	D/S Side Edge Width	D/S Side Edge Elevation	Step Transition	U/S Side Edge Width	U/S Side Edge Elevation
Deflector Configuration 7	8/2/2007	Three Step	~80'	1689.5'	~1v:3h Curve Expansion from	~20'	1695.5'	~1v:2h slope, 45° off	~20'	1692.5'
Deflector Configuration 8	8/2/2007	Three Step	~80'	1689.5'	~1v:3h Curve Expansion from	~20'	1694.5'	~1v:2h slope, 45° off	~20'	1692.5'

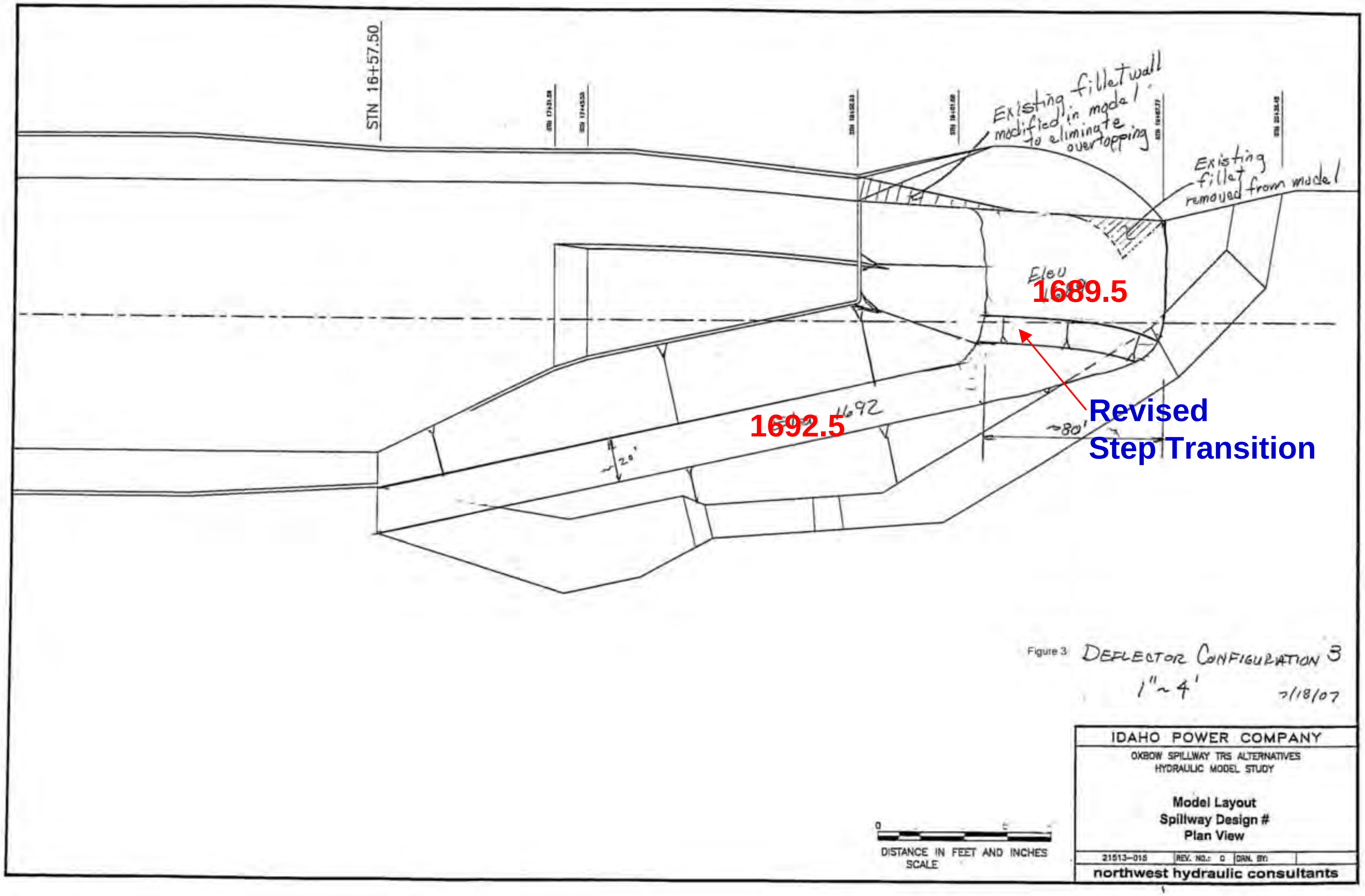
Deflector Tests



Initial
Step Transition

Figure 1 DEFLECTOR CONFIGURATION 1
1" ≈ 4'
7/16/07

Deflector Tests



1689.5

1692.5

Revised Step Transition

Figure 3 DEFLECTOR CONFIGURATION 3

1" ~ 4'

7/18/07

IDAHO POWER COMPANY
OXBOW SPILLWAY TRS ALTERNATIVES
HYDRAULIC MODEL STUDY

Model Layout
Spillway Design #
Plan View

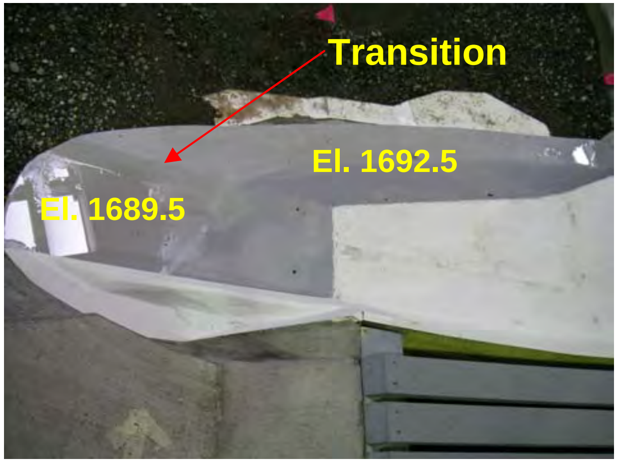
21513-015 | REV. NO.: 0 | DRN. BY:

northwest hydraulic consultants

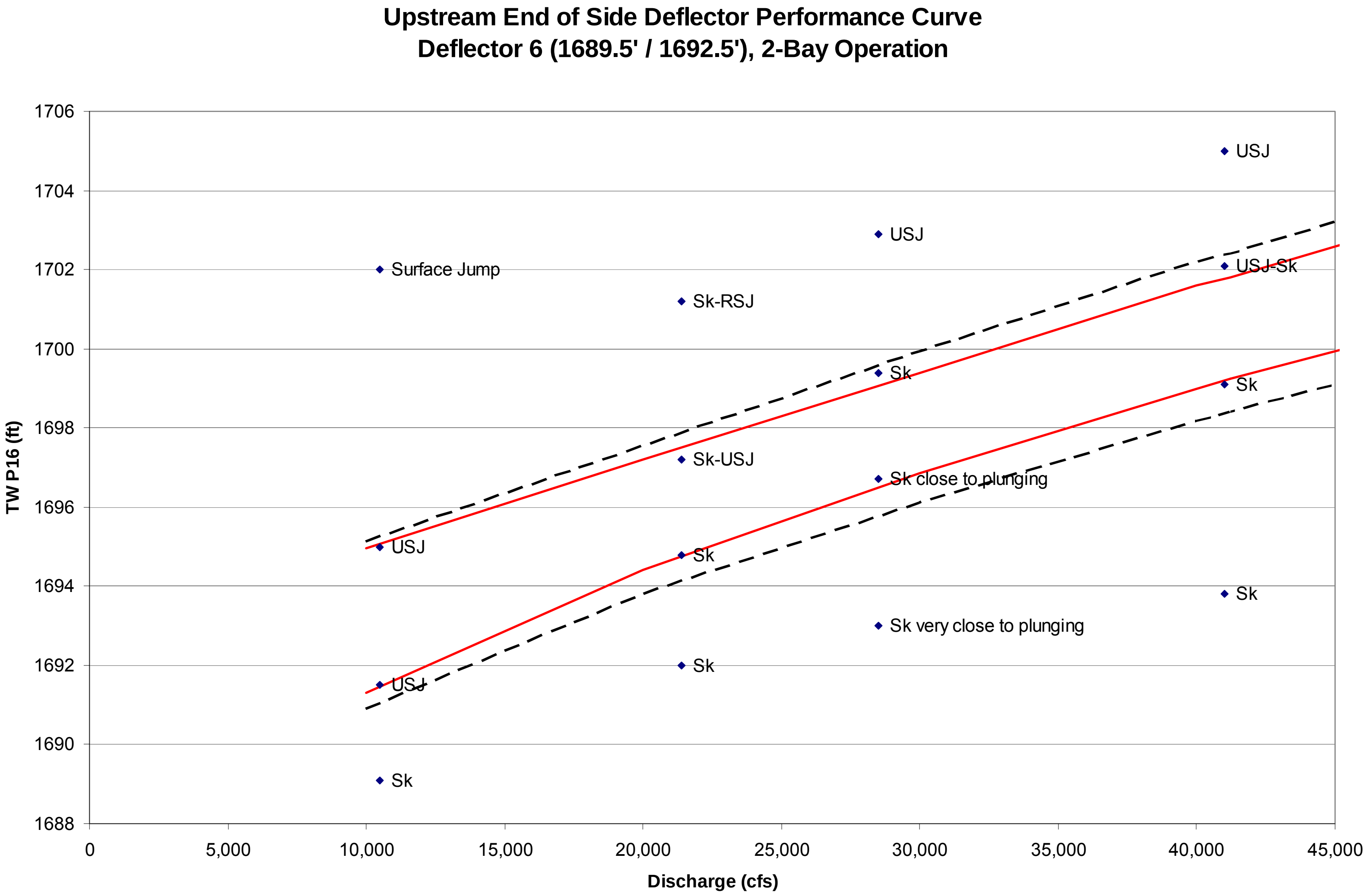
Deflector Tests

Results

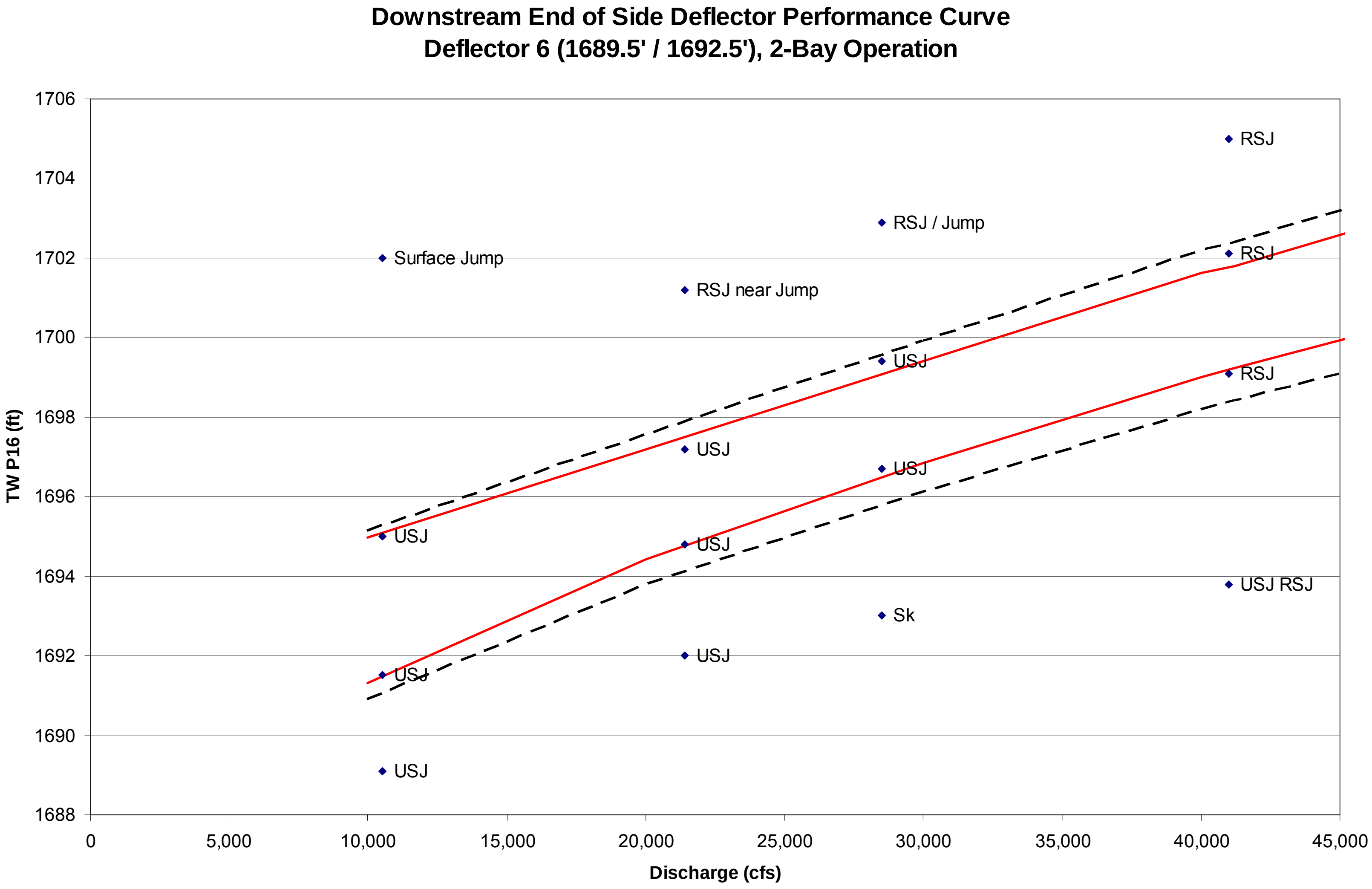
- ➢ **Deflector 6 – optimum design elevations tested**
  - ✓ **D/S edge – Elev. 1689.5, width 80 ft**
  - ✓ **Side edge – Elev. 1692.5, width 20 ft**
  - ✓ **Future design modification - Reduction in width**



Performance Curve

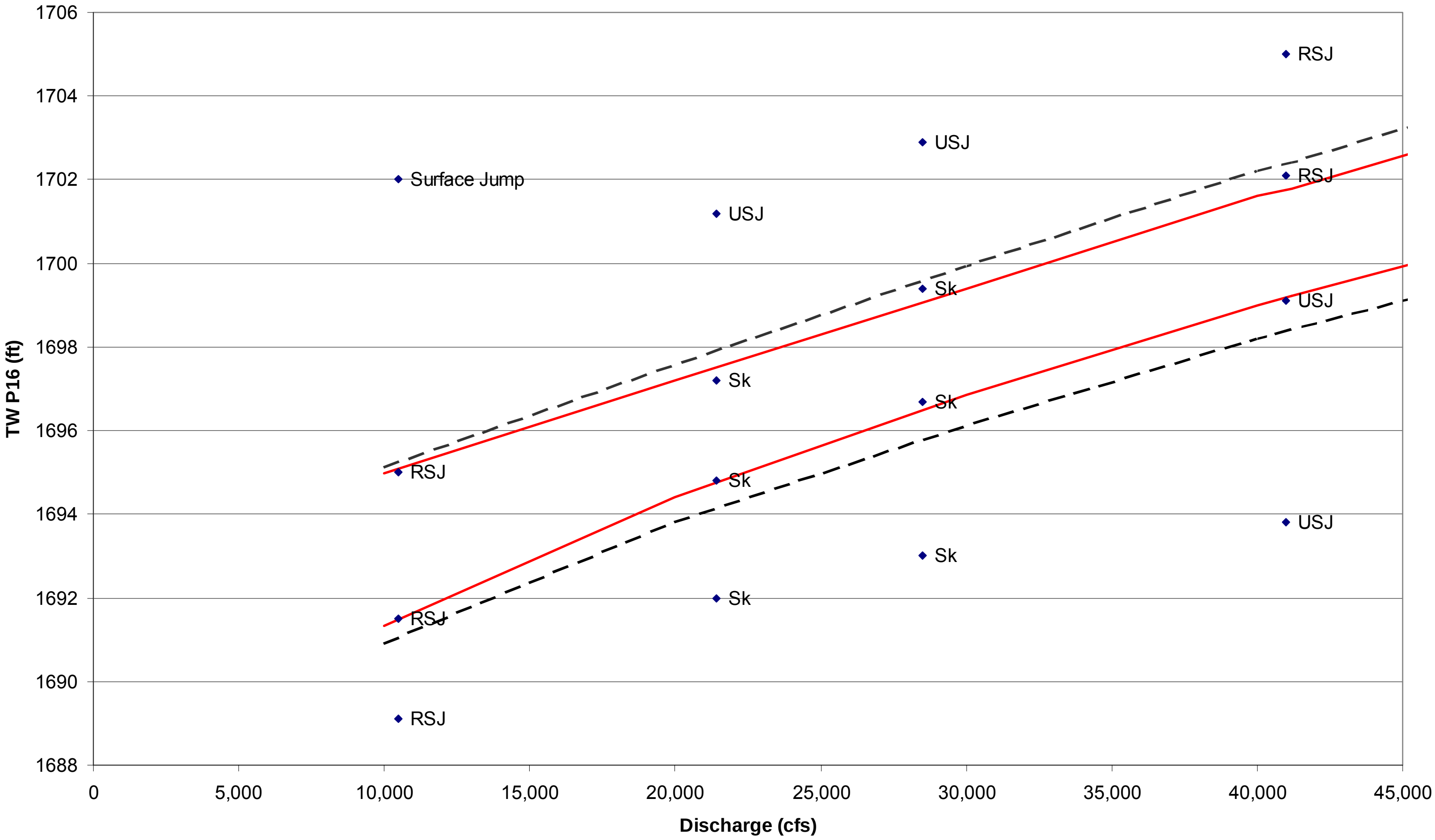


Performance Curve

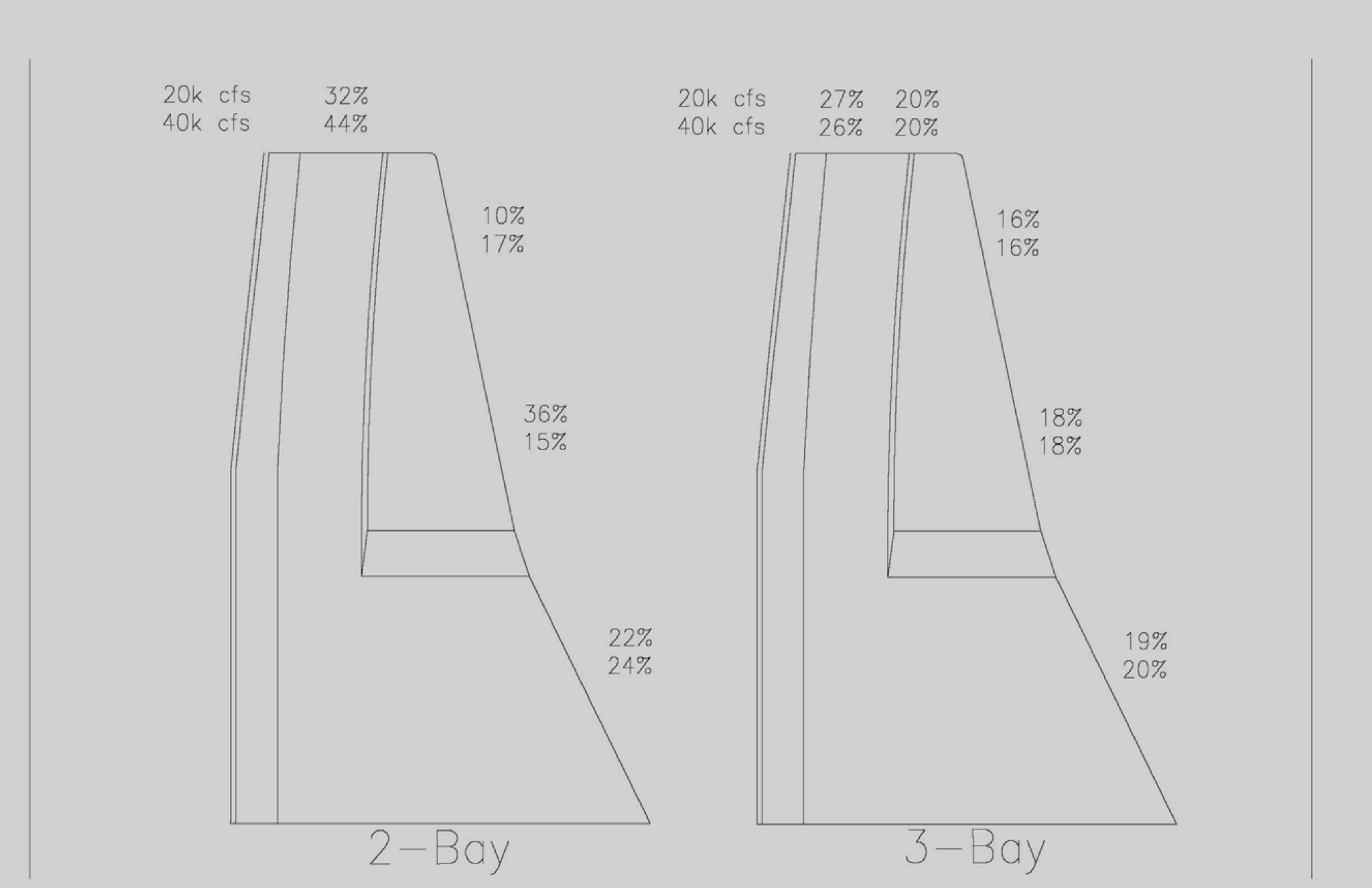


Performance Curve

Downstream End of Deflector Performance Curve
Deflector 6 (1689.5' / 1692.5'), 2-Bay Operation



Performance Curve



Deflector Refinements

Refinements

- Parabolic drop
- Training Wall
- Side Slope Fillet

Future Refinements

- Reduce deflector width
- Fill-in tailrace?
- Others?

Oxbow Dam – TRS Alternatives Physical Modeling

August 16th and 17th, 2007

nhc

APPENDIX D

OAKWOOD CONSULTING INC.

237 Turtlehead Road, Belcarra, B.C. V3H 4P3 (604) 936-5161
fax: (604) 936-5157
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MEMORANDUM

TO: **File** **File: OAK 148**

FROM: **Duncan Hay**

CC: **Scott Zimmerman, Brian Hughes, Lisa Larson**

DATE: **May 11, 2007**

SUBJECT: **Visit to NHC Seattle Lab**

I visited with Brian Hughes, Lisa Larson, Jim Lencioni and other NHC staff on May 10, 2007 to view and discuss the 1:48 scale model of the Oxbow Dam spillway tailrace area that is under construction. We also discussed other topics related to the designs of the TDG abatement concepts and the model test program and schedule.

Model construction is well underway. The basic model platform, sump, headbox and tailbox have been completed and most piping, except in the headbox, has been installed. A sand underlay for the tailrace area has been placed together with the templates that define the bathymetry. A concrete surface has been placed over the sand to define the bathymetry over most of the model and will be completed in a day or two. A concrete sub-base has been placed in the area immediately downstream of the spillway that will be overlain with a mobile-bed material to observe scour in the model. Manometers for measuring water surface elevations are under construction.

The following items were discussed:

1. Field survey data and datum elevations

We reviewed the survey data received from Idaho Power and went over the differences in datums and co-ordinate systems. NHC have reconciled the differences and produced drawings that pull together the structure layout and elevations (based upon the old datum) with the more recent topography and bathymetry that is based on a different datum and co-ordinate systems. They will likely reference all elevations to the new datum in their report.

The model was laid out principally on the basis of a centerline through the spillway and a baseline aligned with the crest of the spillway for which coordinates for a point on the baseline are given together with the azimuth. Elevations are set in reference to the given crest elevation of the spillway. There did not appear to be any glitches in combining the field data to a single layout for the model.

They have limited the height of the river banks so as not to put too much weight on the model support. It is likely that the banks will need to be raised for the tests with the rock-lined channel. Lightweight foam would be used for this.

2. Model bench mark

A bench mark for the model has been established on the laboratory floor.

3. Tailwater elevations

We reviewed the output of some preliminary runs of HEC-RAS for flows of 10 and 41 Kcfs and Manning ‘n’ values of 0.025 and 0.040. While the outputs need to be reviewed before some final conclusions and values can be used for the model, it appears there is a control section in the river in the area of the tributary that comes in on the right bank downstream of the spillway. This control section tends to make water levels in the spillway area somewhat independent of Hell’s Canyon forebay fluctuations. The backwater effect may only occur at the highest forebay elevations at Hell’s Canyon dam.

The plan is to complete and review the RAS runs and produce a rating curve at a point that represents the downstream end of the model probably using an ‘n’ value more like 0.03 with some indication of what fluctuation in level could be expected as a result of fluctuations in the forebay at Hell’s Canyon.

4. Tailwater control

We chatted about establishing the elevation of the tailgate as a means of being able to quickly set tailwater elevations on the model and not be concerned about changes in velocity head as a result of modifications to the spillway. The changes in velocity head is of less concern with the longer model but it still may be advantageous to rate the elevation of the tailgate with respect to being able set water levels quickly.

5. Mobile-bed materials

The lab will use a gap-graded mix of coarse sand and gravel. Washed sand is available that is about 1-2 mm. While this sand on scale would represent 1.5- 2.0 inch material in the model it was decided to use this material since the scour depth will be controlled largely by the small gravel added to the mix and there is a distinct value in using washed sand in model work with respect to water clarity (even though washed sand is not always that clean). There would be about 20% of small 0.25 to 1.0 inch gravel in the mix.

6. Model flow measurement

Orifice meters will be used for flow measurement. They have been installed in accordance with ASTM specifications and have a flow-straightening bundle upstream. Arrows are marked on the orifice plates to show the direction of flow for the purpose of correct installation.

7. Forebay stilling

Additional head is provided in the forebay to permit a headloss across screens to spread and quiet the flow coming into the forebay. I suggested they replace hog’s hair matting with a perforated plate. Additional perforated plate may be required after flow conditions are observed on the model.

8. Model structures

The spillway crest, piers and chute have been constructed and incorporated in the model. Some additional work is required in the area of the terminus of the spillway. Some details evident on photographs are not included on drawings so the technicians will reproduce some of the features seen on the photos.

Work was underway on modeling the approach channel to the spillway crest.

9. Model spillway gate rating

The model spillway gates will be rated for the purpose of the model work only. It is not intended to try and reproduce existing rating curves for the spillway but only to be able to set flows correctly on the model.

10. Status of conceptual designs

Some calculations had just been received from Steve Wilhelms regarding degassing of flow in a rock-lined channel based upon a range of coefficients. The results of the calculations will be reviewed by NHC and passed along at some time. Some of the results ‘look promising’.

There has been no additional work done on the conceptual designs since any work on the stilling basin requires input on the tailwater elevations and the flip bucket design would benefit from some observation of flow in the model.

11. Proposed order of testing

The order of testing proposed is as follows:

- Scour test
- Scour-hole stabilization test
- Deflector test
- Rock lined channel test
- Flip bucket
- Stilling basin/deflector

12. Schedule

It is expected that the model will be watered up on May 21. The meeting for June 7 and 8 is on schedule and it is expected that the scour test, scour-hole stabilization test, and deflector test will be undertaken (at least for an initial look) during June 7-8 with spillway flows up to about 41 Kcfs.

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MEMORANDUM

TO: **File** **File: OAK 148**

FROM: **Duncan Hay**

CC: **Scott Zimmerman, Brian Hughes, Lisa Larson**

DATE: **July 19, 2007**

SUBJECT: **Visit to NHC Seattle Lab**

I visited with Lisa Larson, Jim Lencioni and other NHC staff on July 12, 2007 to view and discuss test results from 1:48 scale model of the Oxbow Dam spillway tailrace area and view the performance of a deflector. I forgot to take my camera with me but NHC staff recorded the test conditions we observed.

The following items were discussed and/or viewed:

1. QA/QC

The survey pins in the area of the mobile bed were checked and it was found that corrections were required of in the order of 0 to 3 inches, model. Pin elevations were generally low on template 17 as thought during the meeting of June 7-8, 2007. Corrections were made to the pin elevations as required in the area of the mobile bed. Corrections were not required in the area of the fixed bed.

2. Baseline Tests

The mobile bed (upstream of cross-section 19) was fixed with a skim of concrete to document hydraulic conditions using the most recent riverbed survey data. Baseline data was collected for spillway flows of 20, 40, 60 and 100 Kcfs using the ‘low curve’ of the tailwater rating with an ‘n’ value of 0.30, where the low curve represents low forebay levels at Hells Canyon Dam.

Velocity and water level elevation data was collected for each flow. The data will be tabulated and plotted for distribution and review. The water surface elevation at P8, at the toe of the dam, was within 0.4 ft of IPC observations at this point during a spill of 40 Kcfs and within 2.2 ft of observations at a spill of 20 Kcfs. If there is robust and reliable field data for a comparison to model values then an agreement of +/- 0.5 between the field and model data is a criterion I have often used for model calibration. For this model and this data point there are two factors that affect the comparison and, in my opinion, would not warrant taking any measures to change the model. First it is necessary to know what the powerhouse flow and Hells Canyon forebay elevation were at the time of the field measurement and secondly the pressure tap for P8 is in an area affected by the mobile bed of the model. Without a rigorous set of water surface measurements taken in the field for which the spill flow, powerhouse flow and Hells Canyon forebay elevation, and river bed bathymetry are all known at the time of measurement it is best to rely on the backwater curve to set the tailwater elevation at the downstream end of the model, let the model establish the backwater from this point, and test the sensitivity of any remedial measure to changes in tailwater elevations. This is the present course of action.

Some of the skim of concrete was plucked off during the baseline tests, particularly when flows were above 40 Kcfs. It is not known what effect, if any, this had on the baseline data.

3. Scour Test

The mobile bed material, consisting of sand and gravel, was raked flat to an elevation of 1690 ft except where it was sloped near the spillway in the area of existing scour to meet apron at an elevation of approximately 1670 ft.

A flow of 70 Kcfs was released through the spillway for about 7 hours until there was no noticeable increase in the depth and extent of scour. The bed elevations were recorded by placing cord on the contours at 10 ft increments and taking an overhead photograph. The deepest scour was to elevation 1640 ft, the lab floor, and the bar elevation reached 1698 ft. In general the locations of scour and deposition appeared to compare favorably with field conditions although the depth of scour was greater than recorded in the most recent field survey but the elevation of 1640 was recorded in earlier surveys. Armoring on the bed of the larger bed material occurred on the model. NHC will overlay model and field data for a comparison.

The scour test serves as a benchmark for examining the potential for scour associated with any modifications to the spillway.

4. Deflector Tests

We conducted two series of test observations of the performance of a deflector added to the spillway. The first, Figure 2, had a deflector at elevation 1690 ft along the side spill section and at elevation 1687 ft on the end centerline portion of the spillway. The 1690 elevation deflector sloped at 3H:1V to elevation 1687 about 1 ft from end of the spillway chute. The width of the side spill deflector was 5 inches and the width of centerline deflector was 20.375 inches. The second deflector tested, Figure 3, kept the same widths but raised the elevations to 1691 ft and 1688 ft while extending the 1691 elevation to the end of the side spill portion of the spillway.

NHC had removed the filet on the left hand side of the spillway that sat at elevation 1687, (filet 1 of Figure 1) and resulted in a rooster tail of flow seen during earlier tests. The size and location of the filets and their contribution or adverse impact on the spillway flows associated with any spillway modifications will need to be reviewed.

First Series

We observed flow conditions with the tailwater elevation set at what is estimated to be a normal condition for a flow of 20 Kcfs. It was apparent the deflector at elevation 1690 needed to be extended toward the end of the spillway since flow was not sweeping off the apron around the perimeter of the deflector. There was skimming flow over the upstream portion of the deflector at elevation 1690 and off the centerline of the spillway at elevation 1687, Figure 4.

We lowered to the tailgate on the model until flow control developed at section 20 in the model. Flow conditions at the deflector changed very little and there was no plunging flow. It appears that section 20 is close to imposing control on the tailwater elevations at the spillway for a flow of about 20 Kcfs.

We increased the flow to 40 Kcfs and flow was swept off the apron. There was a surface jet from the apron at 1690 ft but a ramped surface jet from the apron at 1687 ft, Figure 5.

There are two conditions that are not particularly attractive: one is there is ‘leakage’ of flow passed the filet on the right hand side of the spillway terminus that sweeps around the elevated concrete lined embayment and re-enters the flow; the other is a strong return current that moves upstream in the embayment in the rock wall that contacts flow from the spillway apron and creates a high level of turbulence and air entrainment. This latter condition could be curtailed by a training wall and also would be less if the width of the apron at elevation 1687 was reduced, Figure 5.

Flow conditions on and off the deflector at elevation 1687 could be improved by supporting the jet leaving the terminus of the spillway chute as suggested by NHC earlier. This could be examined after the best elevation of the deflector is established and looked at in conjunction with establishing the width of the deflector.

We dropped the model tailgate until control was established in the river. The water surface elevation at P8 dropped from el 1695.5 ft to 1694.7 feet. The surface jet swept a little further downstream but plunging flow did not occur.

We increased flow to 60 Kcfs and flow from the deflector was generally a surface jet around the periphery of the deflector. We lowered the tailgate on the model but there was very little change in the flow characteristics at the spillway. Water levels at the toe of the dam (P8) did not change, most likely due to the build of the bar as some material was scoured and deposited on the bar at this flow.

The conclusions from this test series were we could raise the elevation of the deflectors since there was no tendency for plunging flows and should also extend the length of the deflector on the side-spill side of the spillway.

The tests we conducted were all with uniform spill gate openings, recognizing that a different gate operation such as opening only the left spillway gate may lead to a different and more effective deflector design.

Second Series

The deflector along the side-spill section was raised to el 1691 ft and on the centerline the deflector was raised to elevation 1688 ft. The side-spill deflector was extended further downstream. A test with a flow of 20 Kcfs indicated that extending the length of the deflector at el 1691 improved flow exiting the spillway by increasing the area over which skimming surface flow occurred but the length at this, or a higher elevation, could be extended further, Figure 6. This test was also undertaken with a uniform spill gate opening.

5. Discussions

It appears feasible to develop a deflector design for the spillway that will reduce the uptake to dissolved gas in the tailrace when the spillway is operating for flows up to 60 Kcfs. Model tests need to be undertaken to determine the best elevation, length and width of the deflector. The following general criteria were suggested:

- Develop a design that does not require special operations of the spill gates, that is would work with the normal equal gate opening operation of the spillway. This may require the deflector elevation to change around the periphery of the spillway, as we tested, in order to reflect the different cfs/ft around the periphery.
- Set the deflector elevations to achieve skimming flow for up to 40 Kcfs and avoid plunging flows at low tailwater elevations for this range of flows.

6. Tasks Suggested

- Modify the filet on the right hand side to prevent 'leakage' of spilled flow on to the concrete embayment.
- Optimize a deflector length and elevation.
- Plot the type of flow, plunging, skimming, ramped surface jet, as a function of tailwater elevation and discharge similar to the plot for Wanapum Dam or similar plots for some of the Corps projects.
- After establishing an appropriate elevation and length of deflector then assess the required deflector width and other features such as supporting the jet on the centerline or adding a training wall that would reduce turbulence and air entrainment.
- Consider making a presentation of deflector designs at the meeting on August 16 at which time the advantages and disadvantages of supporting the flow and/or training walls could be discussed. Also the advantages and disadvantages on not imposing any special spillway gate operating procedures on the project could be discussed.
- Consider holding off on scour test with the deflector in place until after the August 16 meeting. The need for any scour protection would be discussed following the scour tests.

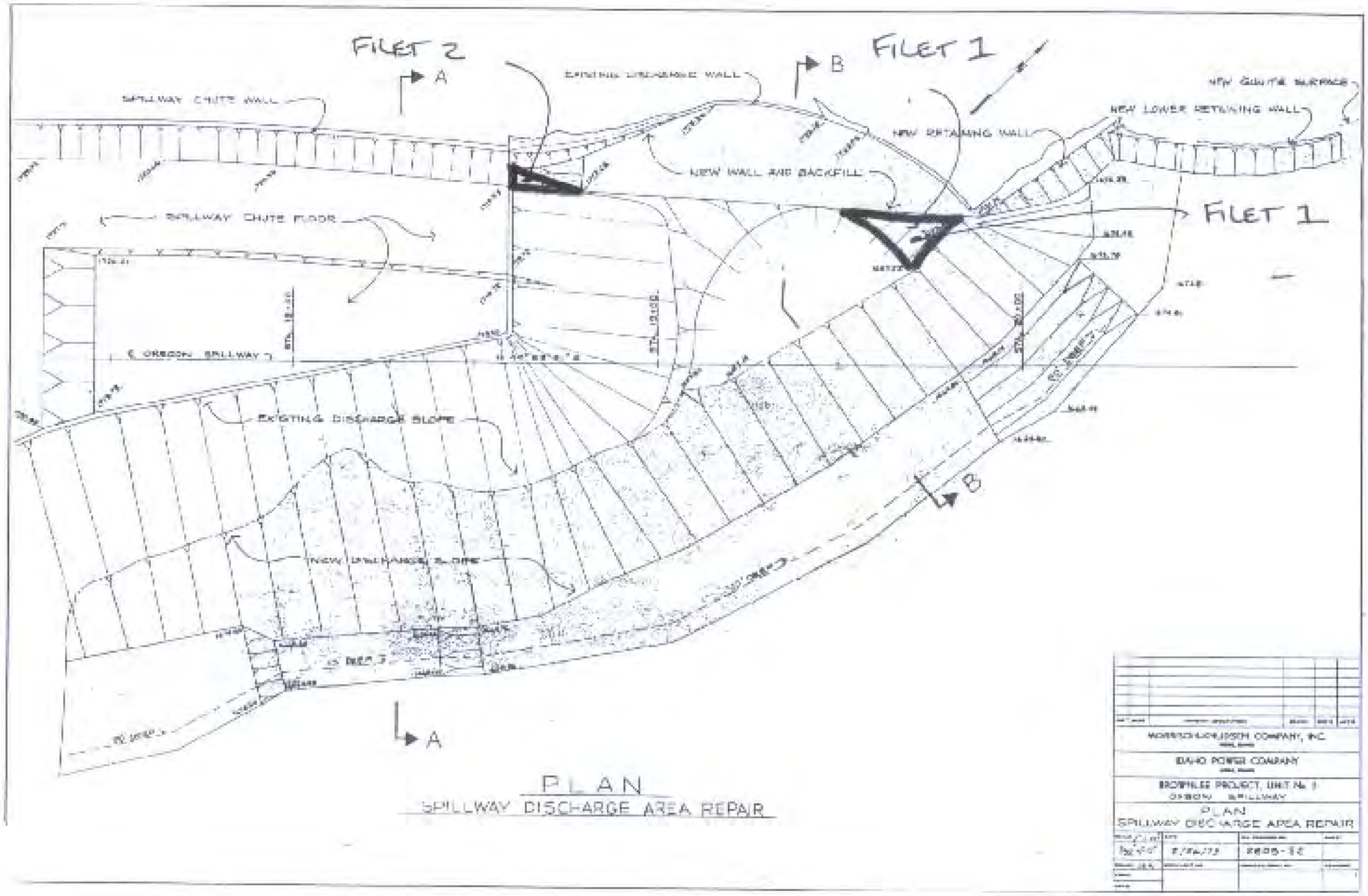
FILET 2
FILET 1
FILET 1
A
A
B
B
SPILLWAY CHUTE WALL
EXISTING DISCHARGE WALL
NEW GUNITE SURFACE
NEW LOWER RETAINING WALL
NEW RETAINING WALL
NEW WALL AND BACKFILL
SPILLWAY CHUTE FLOOR
℄ OXBOW SPILLWAY
EXISTING DISCHARGE SLOPE
NEW DISCHARGE SLOPE
PLAN
SPILLWAY DISCHARGE AREA REPAIR
IDAHO POWER COMPANY
BROWNLEE PROJECT, UNIT No. 1
OXBOW SPILLWAY
PLAN
SPILLWAY DISCHARGE AREA REPAIR

FIGURE 1

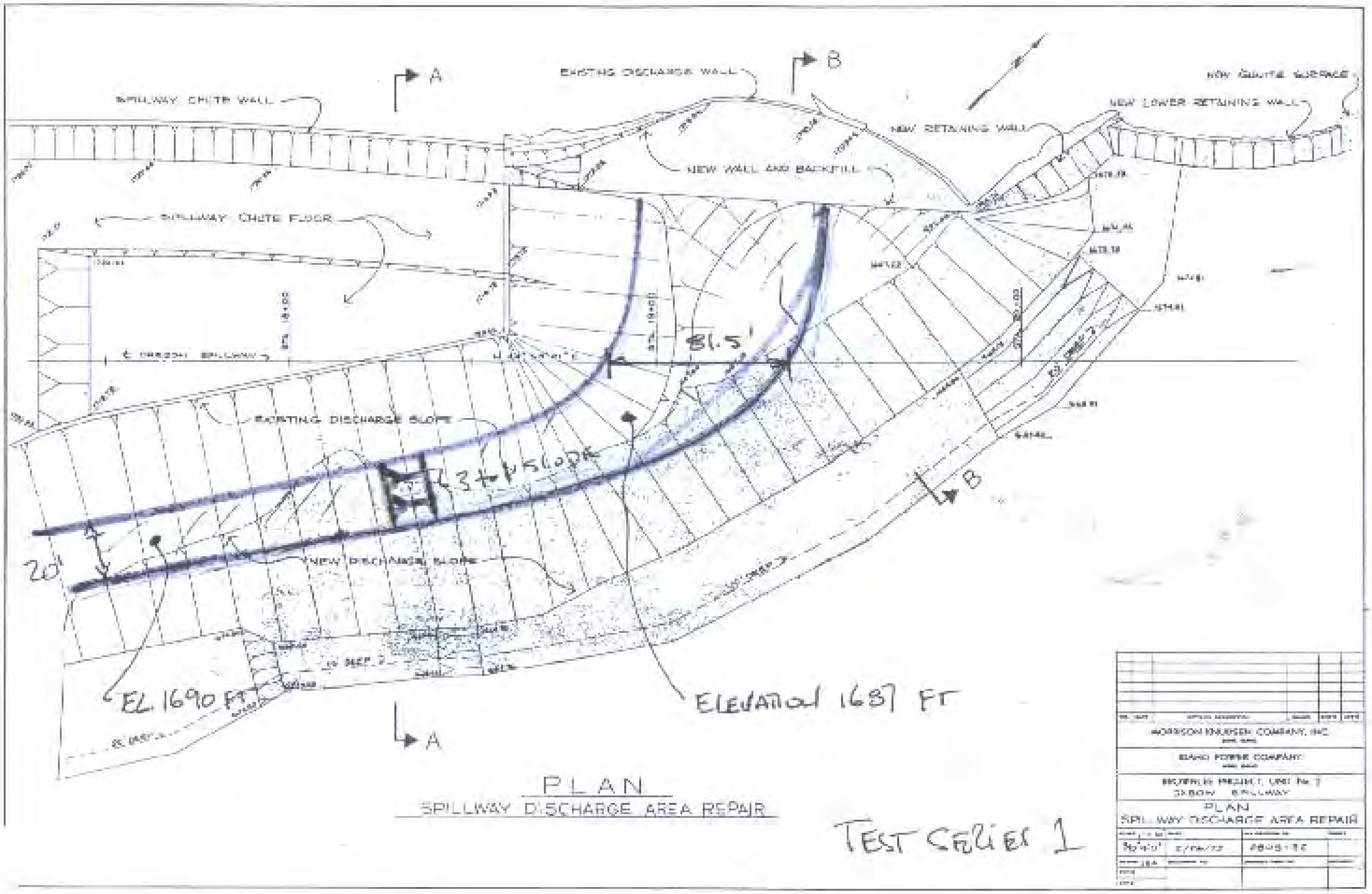
A
B
EXISTING DISCHARGE WALL
SPILLWAY CHUTE WALL
NEW GUNITE SURFACE
NEW LOWER RETAINING WALL
NEW RETAINING WALL
NEW WALL AND BACKFILL
SPILLWAY CHUTE FLOOR
STA. 18+00
STA. 19+00
STA. 20+00
℄ OXBOW SPILLWAY
EXISTING DISCHARGE SLOPE
NEW DISCHARGE SLOPE
81.5'
3 to 1 slope
20'
EL. 1690 FT
ELEVATION 1687 FT
PLAN
SPILLWAY DISCHARGE AREA REPAIR
TEST SERIES 1
MORRISON KNUDSEN COMPANY, INC.
IDAHO POWER COMPANY
BROWNLEE PROJECT, UNIT No. 7
OXBOW SPILLWAY
PLAN
SPILLWAY DISCHARGE AREA REPAIR

FIGURE 2

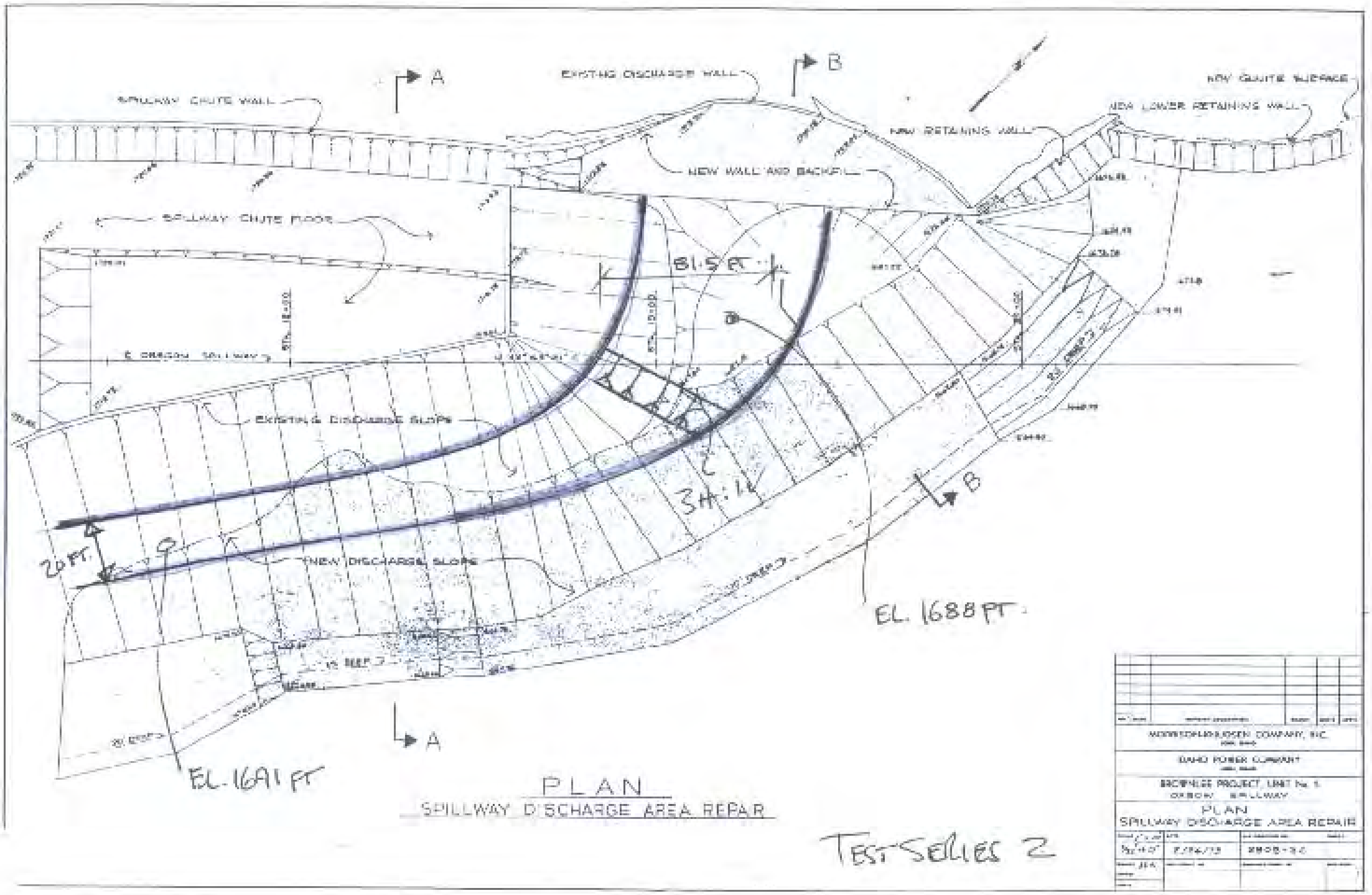
A
EXISTING DISCHARGE WALL
B
SPILLWAY CHUTE WALL
NEW GUNITE SURFACE
NEW LOWER RETAINING WALL
NEW RETAINING WALL
NEW WALL AND BACKFILL
SPILLWAY CHUTE FLOOR
81.5 FT
℄ OXBOW SPILLWAY
EXISTING DISCHARGE SLOPE
3H:1V
B
20 FT.
NEW DISCHARGE SLOPE
EL. 1688 FT.
A
EL. 1691 FT
PLAN
SPILLWAY DISCHARGE AREA REPAIR
MORRISON-KNUDSEN COMPANY, INC.
IDAHO POWER COMPANY
BROWNLEE PROJECT, UNIT No. 1
OXBOW SPILLWAY
PLAN
SPILLWAY DISCHARGE AREA REPAIR
TEST SERIES 2

FIGURE 3

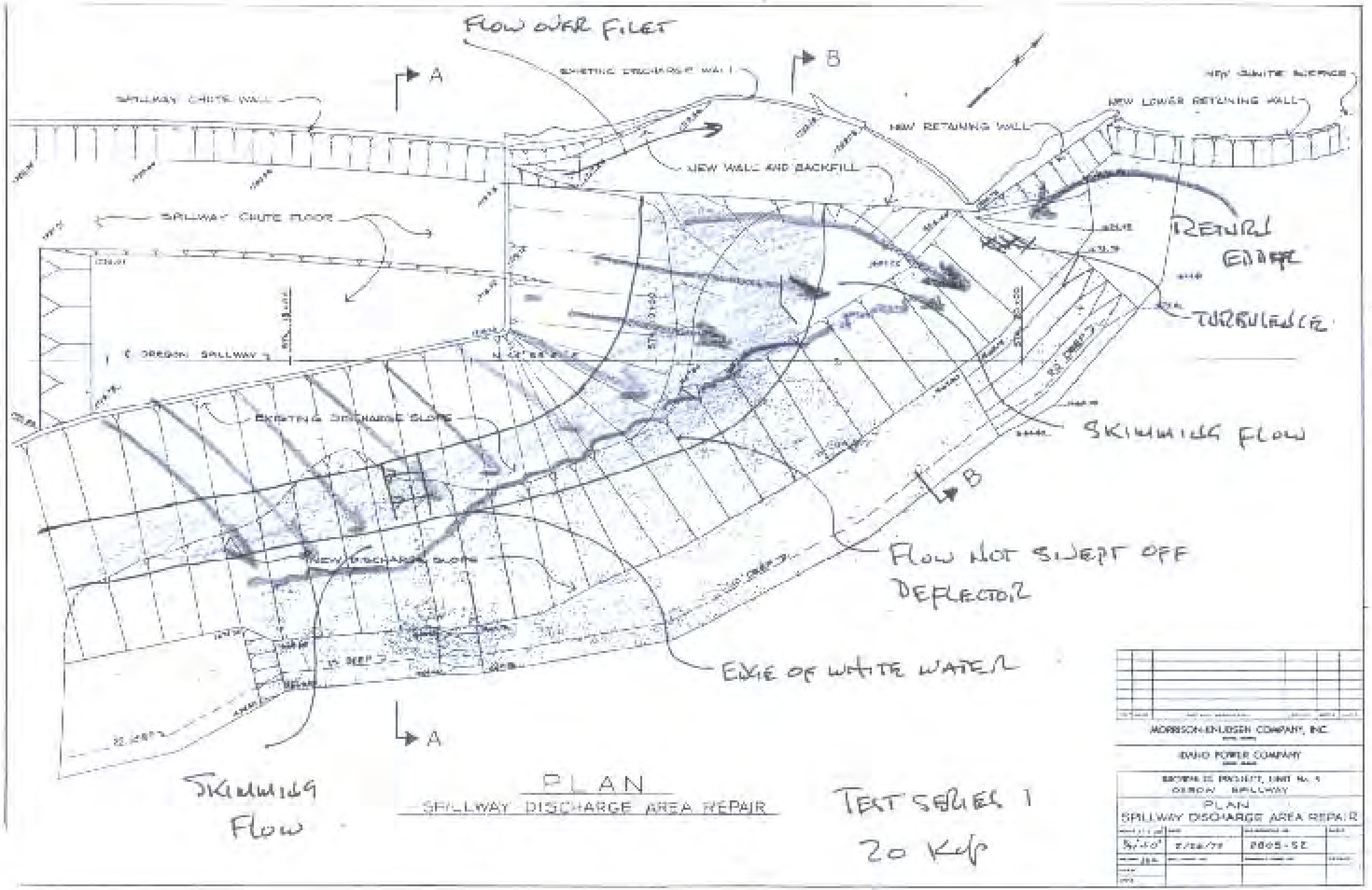
FLOW OVER FILET
A
B
SPILLWAY CHUTE WALL
EXISTING DISCHARGE WALL
NEW RETAINING WALL
NEW LOWER RETAINING WALL
NEW GUNITE SURFACE
NEW WALL AND BACKFILL
SPILLWAY CHUTE FLOOR
RETURN EDDY
TURBULENCE
℄ OREGON SPILLWAY
EXISTING DISCHARGE SLOPE
SKIMMING FLOW
FLOW NOT SWEPT OFF DEFLECTOR
NEW DISCHARGE SLOPE
EDGE OF WHITE WATER
SKIMMING FLOW
PLAN
SPILLWAY DISCHARGE AREA REPAIR
TEST SERIES 1
20 Kcfs
MORRISON-KNUDSEN COMPANY, INC.
IDAHO POWER COMPANY
BROWNLEE PROJECT, UNIT No. 1
OXBOW SPILLWAY
PLAN
SPILLWAY DISCHARGE AREA REPAIR
2805-52

FIGURE 4

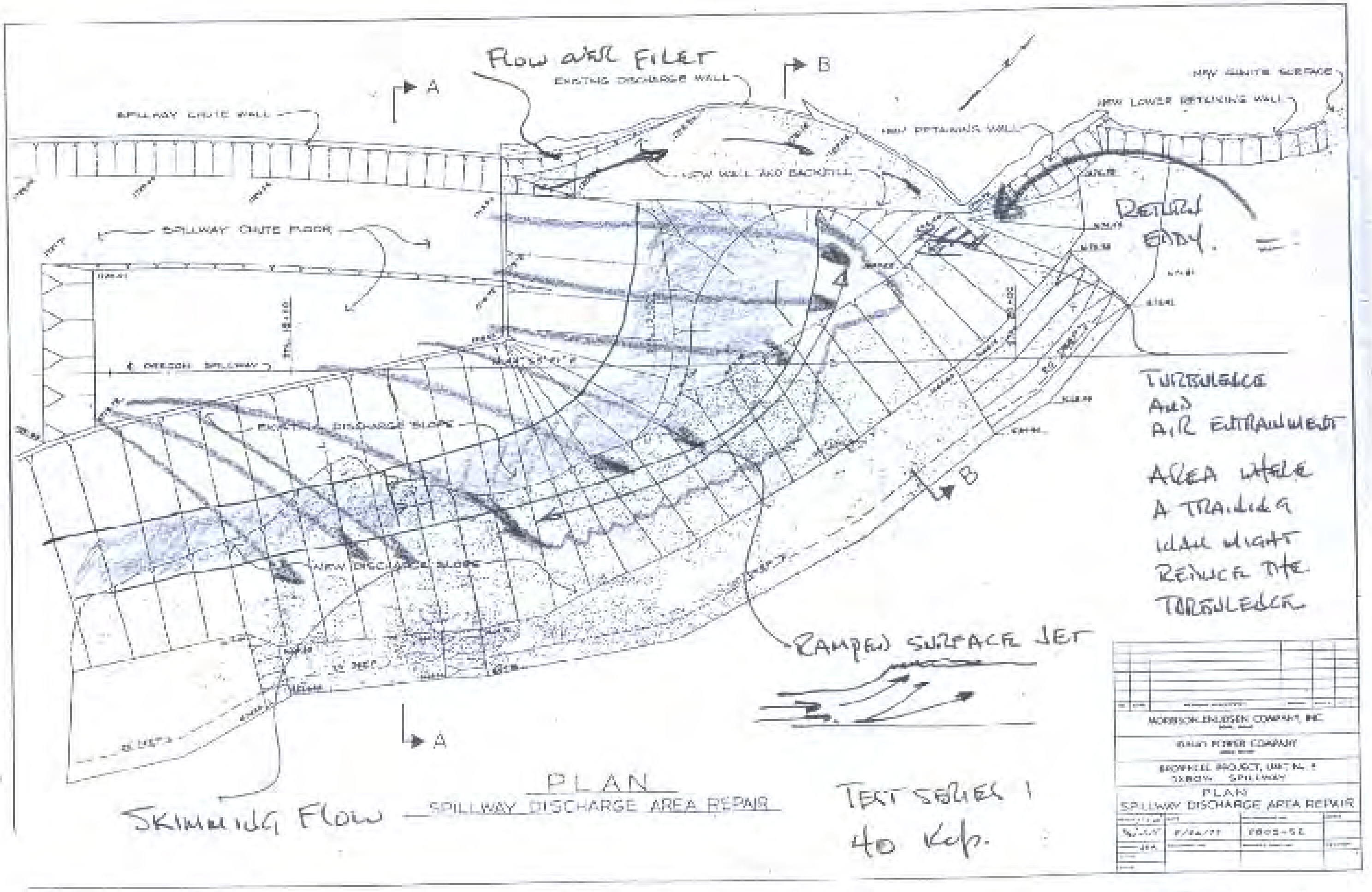
FLOW OVER FILET
EXISTING DISCHARGE WALL
A
B
SPILLWAY CHUTE WALL
NEW GUNITE SURFACE
NEW LOWER RETAINING WALL
NEW RETAINING WALL
NEW WALL AND BACKFILL
SPILLWAY CHUTE FLOOR
RETURN EDDY
℄ OXBOW SPILLWAY
EXISTING DISCHARGE SLOPE
NEW DISCHARGE SLOPE
TURBULENCE AND AIR ENTRAINMENT
AREA WHERE A TRAINING WALL MIGHT REDUCE THE TURBULENCE
RAMPED SURFACE JET
SKIMMING FLOW
PLAN
SPILLWAY DISCHARGE AREA REPAIR
TEST SERIES 1
40 Kcfs.
MORRISON-KNUDSEN COMPANY, INC.
IDAHO POWER COMPANY
BROWNLEE PROJECT, UNIT NO. 5
OXBOW SPILLWAY
PLAN
SPILLWAY DISCHARGE AREA REPAIR
8/24/77
8803-52

FIGURE 5

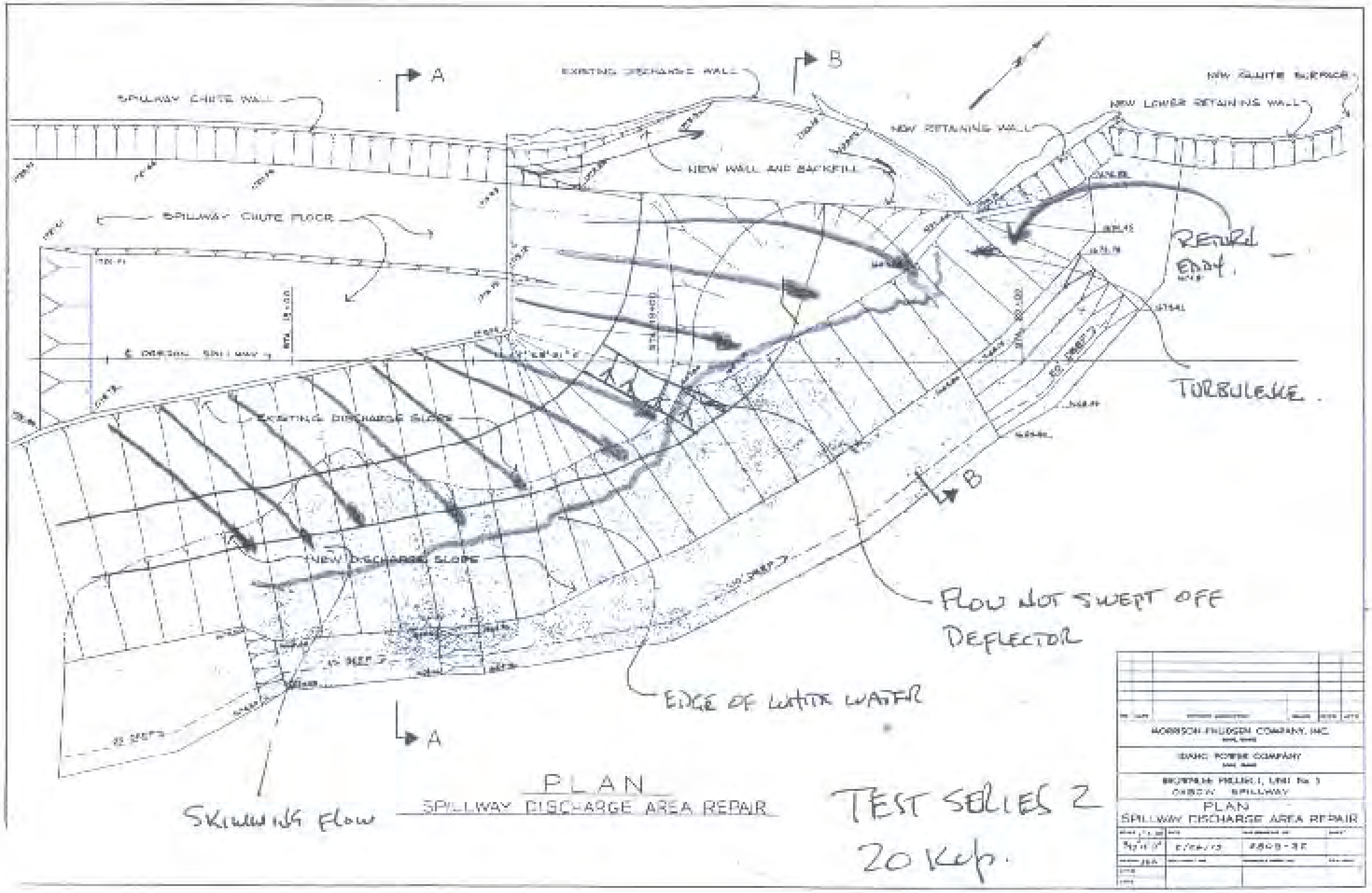
A
B
EXISTING DISCHARGE WALL
SPILLWAY CHUTE WALL
NEW GRANITE SURFACE
NEW LOWER RETAINING WALL
NEW RETAINING WALL
NEW WALL AND BACKFILL
SPILLWAY CHUTE FLOOR
RETURN EDDY.
TURBULENCE.
EXISTING DISCHARGE SLOPE
NEW DISCHARGE SLOPE
FLOW NOT SWEPT OFF DEFLECTOR
EDGE OF WHITE WATER
SKIMMING FLOW
PLAN
SPILLWAY DISCHARGE AREA REPAIR
TEST SERIES 2
20 Kcfs.
MORRISON-KNUDSEN COMPANY, INC.
IDAHO POWER COMPANY
OXBOW SPILLWAY
PLAN
SPILLWAY DISCHARGE AREA REPAIR

FIGURE 6

OAKWOOD CONSULTING INC.

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MEMORANDUM

TO: **File** **File: OAK 148**

FROM: **Duncan Hay**

CC: **Scott Zimmerman, Brian Hughes, Lisa Larson**

DATE: **September 4, 2007**

SUBJECT: **Visit to NHC Seattle Lab**

I visited with Lisa Larson, Brian Hughes and other NHC staff on August 28, 2007 and then with Lisa Larson on August 31, 2007 to view and discuss test results from the 1:48 scale model of the Oxbow Dam spillway tailrace area, viewing the performance of deflector designs.

August 28. 2007

We observed flow conditions for deflector arrangements 18 and 19 that the lab staff had tested earlier.

Test arrangement number 19

Test arrangement number 19 was on the model and we tested it with flows of 20 Kcfs and 40 Kcfs using 2-gate and 3-gate operations with the 2 gate operation using the left and center gates.

For the 20 Kcfs flow the flow and low normal tailwater the flow was skimming off the upstream end of side spill deflector where the elevation was 1692.5 and ramped over the downstream section of the side spill where the elevation was 1689.5. Flow was skimming/ramped off the left main flow side of the spillway. There was a tendency for two jets to form in the tailrace with a dead space and return flow between them.

For the 40 Kcfs flow there was a tendency for the flow to plunge downstream of the deflector at elevation 1689.5 both for the 2 and 3-gate spillway operations. This plunging, or depression in the surface of the flow downstream of the deflector, tends to be characterized by air being present under the flow at the lip of the deflector, Photo 1. It appeared the portion of the side deflector at elevation 1689.5 needed to be raised so later we raised this section of the deflector to elevation 1690.5 ft but there was no noticeable improvement in the flow in the tailrace. The tendency for the flow to plunge downstream of the central portion of the side spill remained.

Test arrangement 18

We ran the model with test arrangement 18 where the downstream deflector remained at elevation 1689.5 and the side deflector was at a constant elevation of 1692.5 ft. We also added a 40-ft long training wall along the left side of the spillway to curtail the return flow into the jet on the left side.

We ran the model with 2 and 3 gates and a flow of 20 Kcfs. For both gate operations the flow was skimming to ramped all the way around the deflector with a tendency for more ramped characteristics on the left side where there is more flow. There was a tendency for two jets to be formed for both gate operations leading to the deposition of a long sand bar between the two jets.

For the 40 kcfs flow there was plunging flow downstream of the central portion of the side spill for both 2 and 3 gate operations. There was perhaps less of a tendency for the plunging to occur for the 2 gate operation but more of a tendency for two distinct jets to form in the tailrace. We removed the training wall to see if it had any influence in causing a portion of the jet to plunge but there was no effect for either the 2 or 3-gate operation. It was noticed that the side deflector had a slight upward slope on it but pulling the outer edge down to give a flat deflector did not make any change to the flow characteristics.

August 31, 2007

Test arrangement 20

I made the suggestion earlier in the week that the side deflector be tested at elevation 1691.5 over its entire length and some minor changes be made on the width. The end deflector remained at elevation 1689.5 ft and the 40-ft training wall was left in place. This arrangement was tested at flows of 10, 20, 40 and 60 Kcfs.

Skimming flow developed downstream of the side deflector for 2 and 3-gate operations with a low tailwater for 20 Kcfs. Conditions were unchanged for a high tailwater elevation and a 2-gate operation. We did not test a high tailwater for a 3 gate operation but I would not expect any difference. The flow appeared to be skimming/ramped downstream of the left side of the spillway where the deflector was at elevation 1689.5. There were less shock waves and concentrations of flow with the 2-gate operation than with the 3-gate operation downstream of the left side of the spillway in the area of higher unit discharges, although the flow tends to be more ramped and ragged at the upstream end of the side spill under the 2-gate operation. In general flow conditions looked good for all gate operations with 20 Kcfs flow.

Flow conditions also looked good for 2 and 3 gate operations with 40 Kcfs for both low and high tailwater elevations established on the model. Flow was in the skimming/ramped regimes for the side and end spills. As for the 20 Kcfs there are less shock waves off the end of the spillway when flow is passed through the center and left spillbays. There was no indication of plunging flow and no indication of two distinct jets in the tailrace area. Flow conditions for a 3-gate operation are shown in Photo 2.

At a 2-bay release of 10 Kcfs, a ramped surface jet forms downstream of the central portion of the end of the spillway and on the central portion of the side deflector. In other areas there is a submerged jet that forms on the deflector. There was nothing in the flow condition that appeared problematic with respect to gas uptake or dam safety at this flow.

At a 3-bay release of 60 Kcfs and a low tailwater elevation a combination of skimming and plunging flow developed with the plunging flow developing off the central portion of the side spill and end of the spillway. The jet was broad and well spread in the tailrace even though plunging in the some areas, Photo 3.

Other observations

Tailwater elevations at P8, at the toe of the dam, are generally 2 feet lower than observed during the baseline tests. This is consistent with the local depression of the water surface that is expected with the deflector forcing higher horizontal components of velocity than occur without the deflector in place.

The elevation 1691.5 ft of the side deflector appears to give good flow conditions for minimizing the uptake of gas in the tailrace. The depth of submergence on this deflector of 4 to 5 feet, based on the P8 values, seems consistent with other projects for the unit discharge that passes over the side deflector.

The elevation 1689.5 ft for the deflector at the end of the spillway is high when compared to the submergence required at other projects (Hells Canyon and Wanapum Dam) for the unit discharge that passes over this portion of the spillway. One would expect the elevation needed here to be in the order of 1676 ft to avoid plunging flow. However in observing the model I have not seen classic plunging flow occurring at the end of the spillway. Flow appears to be skimming or ramped although I expect the jet expands downstream and contacts the bottom at some distance. The introduction of dye in this area indicated upstream movement of flow under the jet which is usually indicative of skimming or ramped flow. The 3-dimensional nature of flow in this area, as compared to the 2-dimensional nature of the flow at Hells Canyon and Wanapum, may explain the difference. However it would be good to document the flow conditions in this area, particularly flow on the bottom, when looking closer at arrangement 20.

The affect of placing a vertical wall at the face of the deflectors, if any, should also be examined on the model since it is most likely there would be solid face constructed in the field.

Photo 1 – Arrangement 19 – 40 Kcfs – 3 gates

Photo 2 – Arrangement 20 – 40 Kcfs – 3 gates

Photo 3 – 60 Kcfs – 3 gates

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MEMORANDUM

TO: **File** **File: OAK 148**

FROM: **Duncan Hay**

CC: **Scott Zimmerman, Brian Hughes, Lisa Larson**

DATE: **September 18, 2007**

SUBJECT: **Visit to NHC Seattle Lab**

I visited with Lisa Larson, Jim Lencioni and staff on September 17, 2007 to view the results of a scour test which was run with a spillway flow of 70 Kcfs and the deflector design concept number 20 in place. The test was conducted in the same manner and for the same duration as an earlier baseline test with the existing spillway configuration in place. As for the previous baseline test the model was run for a total of 8 hours. The lab staff did a good job in marking and flagging the bed contours after the test, Photos 1 and 2. Contours were plotted on an overhead photo of the model for comparisons with the existing bathymetry and the earlier baseline scour test.

The earlier baseline test showed a reasonable comparison with the existing bathymentry even though the complete flow history that developed the existing bed is not known. Given the reasonable comparison the best assessment of changes that will likely occur if concept 20 is constructed could be made by comparing the baseline scour and the post-concept 20 scour. The lab will see if they can produce a plot of bed elevation differences between these two tests for ease of comparison.

Based on examining the contour plots, the differences observed between scour with the existing spillway and scour with deflector concept 20 in place include:

1. scour along the side of the spillway is generally reduced with the deflector in place.

2. the deepest scour along the side of the spillway occurs where the return current moving across the toe of the dam impinges on the spillway. Further downstream there is deposition of material on the toe apron alongside the spillway that was not there following the baseline scour test.
3. the deepest depth of scour, downstream on the spillway centerline, is essentially unchanged by concept 20 but the channel is wider and there is deposition on the left bank immediately downstream of the training wall. No change in deepest scour on the spillway centerline is consistent with there being essentially no change in the configuration of the spillway on the centerline. The widened channel is indicative that velocities from the spill off the side of the deflector have increased with the deflector in place. Without the deflector there was energy being dissipated in the scoured trench along the side of the spillway.
4. the elevation of the bar off the right bank opposite the spillway increased in elevation with the deflector in place. This is associated with a narrower return channel between the bar and the right bank. Velocities will be measured in this area as part of subsequent documentation.

We briefly discussed what could be done to reduce the depth of scour. From earlier work it does not seem practical to think we can place rock of a sufficient size to reduce the depth of scour immediately downstream of the spillway centerline. However it may be feasible to reduce the depth of scour that occurs alongside the spillway by placing rock in this area and keeping any aerated return flow from being taken to depth there. This is to be discussed with IPC.

It was suggested the elevation of the top of the training wall be 1705 ft which is the same as the top of the bench immediately upstream. This would not be overtopped at a flow of 40 Kcfs but there would be some overtopping at a flow of 70 Kcfs.

The lab plans to:

1. put in the ‘filet’ according to the dimensions and photos received from IPC.
2. cut the top of the training wall to elevation 1705 ft.
3. put a skin coat on the existing model bed and then measure velocities and water levels for 60, 40 and 20 Kcfs observing and recording the characteristics of the spill flow for each case.
4. develop a performance curve for concept 20 for 40 and 60 Kcfs spillway flows.
5. complete a draft report several weeks before the model is scheduled to be removed.
6. take direction from IPC with respect to tests to assess whether the depth of scour at the toe alongside the spillway can be reduced by rock placement.
7. obtain a construction cost estimate of concept 20 from Jacobs.

October 4 was suggested as a possible date for a final demonstration and meeting with IPC at the lab.

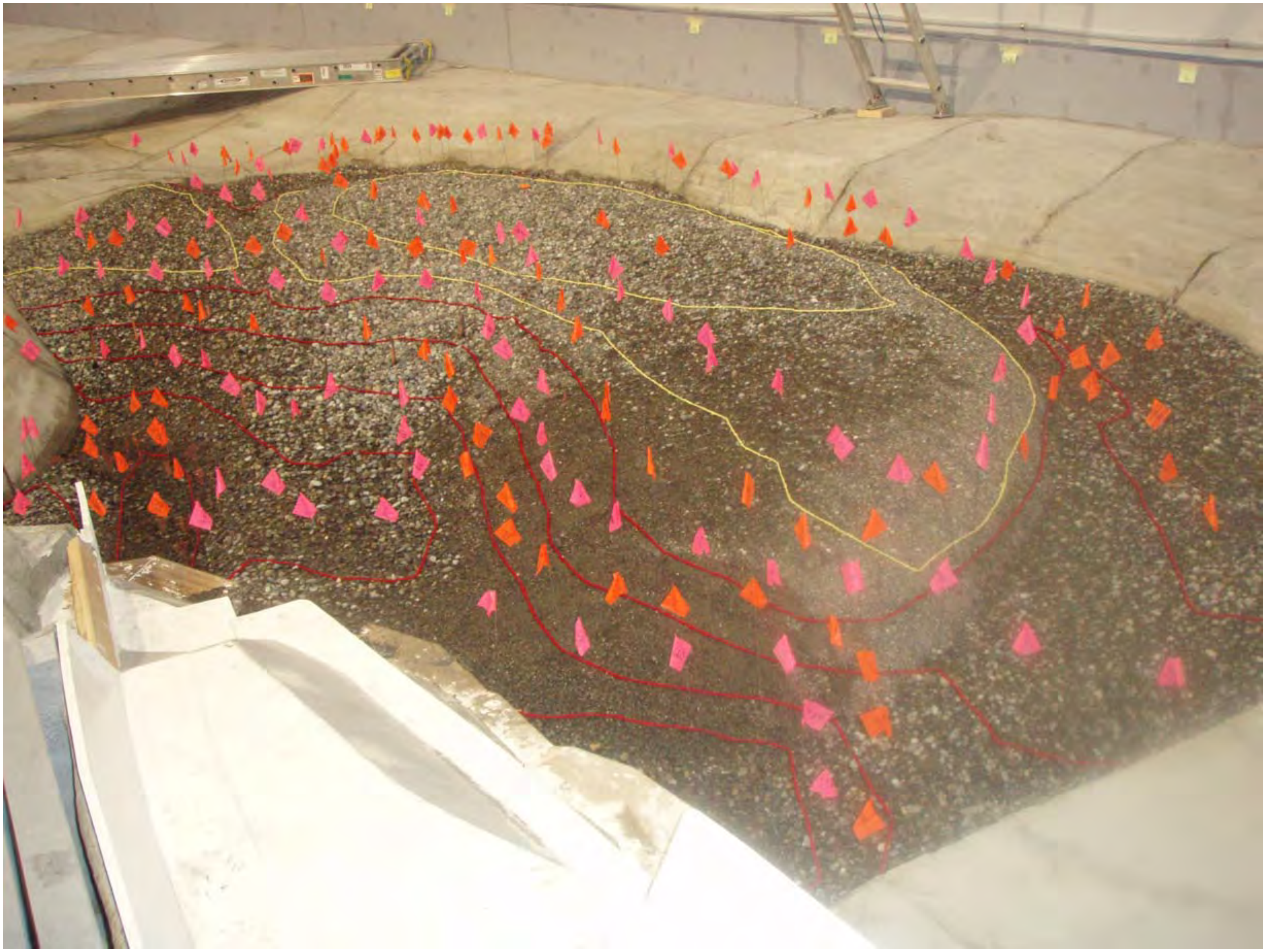

Photo 1 – post 70 Kcfs scour test with deflector concept 20 and training wall in place

Photo 2 – post 70 Kcfs scour test with deflector concept 20 and training wall in place