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Feasibility of Reintroduction of Anadromous Fish Above or Within the Hells Canyon Complex

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Editor

Technical Report
Appendix E.3.1-2

Hells Canyon Complex
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Introduction and Overview

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1. INTRODUCTION

Over a period of approximately 70 years, anadromous fish above the present-day Hells Canyon Dam on the Snake River were gradually extirpated from their historical distribution range. This extirpation was caused by the construction of federal and private dams and by the degradation of fish habitats from various land uses. Immediately before construction of Brownlee Dam, only a few tributary basins still produced chinook salmon (*Oncorhynchus tschawytscha*) and steelhead (*O. mykiss*). Fall chinook salmon were limited to reaches below Swan Falls Dam. To sustain remaining fish runs after Brownlee Dam was completed, Idaho Power Company (IPC) attempted to provide fish passage, but passage of downstream migrants was unsuccessful. Then, to sustain numbers of anadromous fish, a portion of the remaining spring chinook and steelhead stocks were transferred to mitigation hatcheries. Early mitigation attempts at a fall chinook hatchery failed, and this failure led, several years later (1980), to a settlement agreement between state and federal agencies and IPC (Settlement Agreement 1980). This agreement defined the requirements for IPC fall chinook mitigation in conjunction with the federal project mitigation requirements for the lower Snake River in the development of Lyons Ferry Hatchery. The agreement also modified production goals for spring chinook and steelhead at the IPC hatcheries. Pacific lamprey (*Lampetra tridentata*) also occurred naturally in reaches above the HCC and were extirpated in reaches above large impassable tributary dams, as were Pacific salmon (*Oncorhynchus* spp.). However, it is unknown whether Pacific lamprey followed the same chronology of decline as Pacific salmon did. For example, Pacific lamprey were able to pass Swan Falls Dam (Stanford 1942). Also, it is unknown whether accessible tributary habitat that was unsuitable for Pacific salmon (such as the Malheur River) was used by Pacific lamprey. Upon completion in late 1967, Hells Canyon Dam became the upstream terminus for all anadromous fish in the Snake River. Since that time, anadromous fish downstream of Hells Canyon Dam and those associated with other major tributaries to the Snake River have steadily declined. Accordingly, all wild Snake River stocks of Pacific salmon are currently protected under the Endangered Species Act.

The feasibility of reintroducing anadromous fish above Hells Canyon Dam has been discussed in numerous forums. In the late 1980s, reintroduction was evaluated during a workshop initiated by Senator James McClure (Armour 1990). The workshop participants concluded that reintroduction was possible if three prerequisites could be met: 1) smolt passage problems at existing lower Snake and Columbia river dams were solved; 2) flows in the lower Snake reservoirs were improved to enable successful smolt passage; and 3) a reintroduction program were not carried out at the expense of existing fisheries programs in the Snake and Columbia rivers. In the final recommendations to the National Marine Fisheries Service, the Snake River Salmon Recovery Team (Bevan et al. 1994) recommended that the issue of reintroduction for fall chinook salmon be examined again in the future, especially if benign devices such as smolt collectors were successfully developed.

The issue of the feasibility of reintroducing anadromous fish was also identified by regional interests represented in the Aquatic Resources Work Group (ARWG) as part of the relicensing process of the Hells Canyon Complex (HCC). In addition, the issues of anadromous fish passage and habitat availability continually arise in discussions relating to other IPC projects along the mainstem Snake River above the HCC, projects that are also involved in the process of relicensing (IPC 1998, FERC 2002).

This chapter discusses the approach IPC took to address the feasibility of reintroducing anadromous fish above the HCC and previews each of the subsequent chapters in this study report. The scope of this study was not limited to the immediate vicinity and production potential of anadromous fish in the HCC. Rather, the study looks at the entire historical distribution of anadromous fish, including the habitat and passage barriers throughout that range.

1.1. Issues, Problem Statements, and Desired Future Conditions

The ARWG developed the following draft list of issue statements relating to the feasibility of reintroducing anadromous fish above the HCC:

1. The status of anadromous runs (including Pacific lamprey) and available habitat in the Snake River basin immediately prior to the HCC construction.
2. The feasibility of reestablishing anadromous fish above the HCC to Bliss Dam, including tributaries contained within the HCC.
3. Available habitat in the mainstem and tributaries above the HCC.
4. Opportunities and alternatives from the HCC, or above the HCC, for improving downstream anadromous fish flows for spawning, incubation, and passage.

In addition, the ARWG developed draft statements of problems concerning the feasibility of reintroducing anadromous fish:

1. The HCC and other barriers block access for anadromous fish to upstream mainstem and tributary habitat.
2. Present availability of suitable anadromous fish habitat above and within the HCC is unknown. Factors that may influence availability include other dams, irrigation withdrawals, water quality, and spawning habitat.
3. The loss of anadromous fish above the HCC has altered the trophic structure and nutrient cycle, both above and below the HCC.

Lastly, the ARWG developed a draft statement about the desired future condition (DFC) for anadromous fish associated with the HCC:

> Recovery and long-term persistence of self-sustaining, harvestable populations of anadromous fish, including Pacific lamprey, distributed across the species' native range.

1.2. Objectives

Chapters 2 through 11 and the 14 technical appendices of this report address 9 major objectives of our study:

Chapter 2	Describes the history of events that led to decisions regarding anadromous fish associated with the construction of the HCC (Chapman 2001a).
Chapters 3, 4, 5 and special appendices	Describe the historical distribution and chronology of decline of anadromous fish in the Snake River basin above the present-day Hells Canyon Dam (Chapman 2001b, Pratt et al. 2001).
Chapters 3, 4, 5 and special appendices	Evaluate historical and existing conditions of the habitat within the historical range of distribution of anadromous fish and describe potential limiting factors to reintroduction (Chandler and Chapman 2001a, Chandler et al. 2001, Pratt et al. 2001).
Chapter 6	Estimates the abundance of anadromous fish during the predevelopment era and immediately before construction of the HCC (Chapman and Chandler 2001a).
Chapters 7 and 8	Describe the methods used to estimate production potential and evaluate the current production potential if passage were available (Chapman and Chandler 2001b, 2001c).
Chapter 9	Examines options for passage as part of any reintroduction alternative (Aurdahl et al. 2001).
Chapter 10	Evaluates stocks of anadromous hatcheries in the Snake River basin for suitability of reintroduction (Chandler and Abbott 2001).
Chapter 10	Examines the risks of introducing pathogens above the HCC (Chandler and Abbott 2001).
Chapter 11	Develops and evaluates reintroduction alternatives and evaluates the feasibility of reintroduction (Chandler and Chapman 2001b).

2. Geographic Area

The study area includes the entire historical distribution of anadromous fish above the present location of Hells Canyon Dam (Figure 1). This area—including a large portion of southern Idaho, eastern Oregon, and northern Nevada—also includes 10 major river basins: the Powder, Burnt, Malheur, Owyhee, Bruneau, Wood (Malad)[1], Boise, Payette, and Weiser rivers and Salmon Falls Creek. The area also includes the mainstem Snake River from Hells Canyon Dam to Shoshone Falls (the natural limit of the historical distribution of anadromous fish). Smaller tributary basins to the Snake River include drainages that drain directly into the HCC—such as Pine Creek, Indian Creek, and the Wildhorse River—and Rock Creek, which is located toward the upper end of the historical range of distribution. Multiple small tributaries are included in the study area, such as Sinker, Succor, Reynolds, and Brownlee creeks, among many others. The area totals approximately 44,500 square miles (mi^2). The study area represents 56% of the entire Snake River basin that historically produced anadromous fish (Figure 2). The area affected by construction of the HCC includes approximately 12% of the entire area of the Snake River that produced anadromous fish (Figure 2) and 22% of the area above the Hells Canyon Dam that historically produced anadromous fish. In Chapters 4 and 5, we discuss each of the major basins in greater detail (Chandler and Chapman 2001a, Chandler et al. 2001).

3. METHODS

The following is an overview of the methods IPC researchers used for various aspects of the study. Methods relating to the geographic database and analysis are presented here because they were used in several chapters. More detailed methods on other aspects of the study are presented within the individual chapters.

3.1. Database Development

Because of the geographic extent of the study area and the importance of an unambiguous frame of reference for stream names and locations of various features within the area of historical distribution, IPC developed a unique database application named DynStream. DynStream links directly to a Microsoft® Access® table with assigned database fields. DynStream incorporates the stream networks that are included in the area of historical distribution into a visual display on the computer screen. The source for the stream network that is included in DynStream is the Pacific Northwest 1:100,000 River Reach File System (PSMFC 1998). DynStream users can pan out and zoom in on a particular section of the stream network, an ability that is an important feature of the display. The function for viewing features of the landscape—lakes, reservoirs, canals, roads, and cities—can be turned on and off. In addition, mile markers along streams were added to the stream network and can be displayed to help users locate specific stream segments. The Access data table, displayed alongside the stream network, is populated immediately from the DynStream program. Several of the data fields have drop-down boxes for entering data codes, a feature that helps reduce data-entry errors.

[1] The Wood River basin was not a producer of anadromous fish because of a natural barrier approximately three miles above the confluence with the Snake River. The study area of 44,500 mi^2 includes the Wood River basin.

When the user types a stream name or selects a stream from the visual display, all streams in the stream network having the same name are displayed. The user can then scan the list and, based on the parent stream, select the correct stream. Once the stream is selected, it is highlighted in the visual display to allow the user to verify that the correct stream has been chosen. Once the stream is chosen, several location and identifier fields within the Access table are automatically populated. These location fields include the basin identification code (LLID) (a unique number based on the latitude and longitude of the point where that stream intersects its parent stream), the stream name, and the parent stream name. Each major basin was assigned a basin ID, though the streams within each basin have an LLID. Currently, four Access data tables incorporate various types of data, for later spatial representation; these tables are entitled *Fish*, *Habitat*, *H_2O Quality*, and *Points*.

When the level of information in a reference source allowed, detailed locations or stream sections were entered into DynStream, based on either Universal Transverse Mercator (UTM) or on specific river miles. Often, particular references, especially those made during the early development of DynStream or those relative to land uses, were inferred to a stream basin rather than to particular river sections. In those instances, the location designated in the database was at a Hydrologic Unit Code (HUC) scale of 4th, 5th, or 6th code, depending on the specificity of the record.

The database design allows all records pertaining to the various Access data tables to link easily to IPC's central Geographic Information System (GIS) (from ArcInfo™[2]) for spatial analysis and displays.

3.2. Historical Distribution and Land Uses

Describing the history of the Snake River above Hells Canyon Dam as it pertains to anadromous fish involved a detailed archival search for information for two purposes: 1) to establish what is known about the historical distribution and important spawning areas of the various species of anadromous fish and 2) to establish the major causes of declines in anadromous fish within their areas of historical distribution and a chronology of the changes in land use and development. Results of the archival search are presented in Special Appendices A through N (Pratt et al. 2001). In Chapters 3 through 5 (Chapman 2001b, Chandler and Chapman 2001, Chandler et al. 2001), we provide overviews of historical distributions and land uses in this reach.

We categorized the information gathered during the archival search by four time periods: pre-1860, 1860 to 1920, 1920 until the closure of Brownlee Dam in 1957, and from closure of that dam to closure of Hells Canyon Dam (1958–1967). The pre-1860 period precedes development of the Snake River basin. Much of the data for this period is anecdotal in nature, taken from the journals of explorers and trappers for the fur industry. Additionally, archaeological and anthropological records were used, when available, for information on fish distribution.

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[2] ArcInfo is a trademark of the Environmental Systems Research Institute, Inc.

The period between 1860 and 1920 was one of major changes in the landscape and the habitat of the Snake River basin. Impoundments and other major changes to the landscape began to alter stream habitats. This period included the gold rush, and placer mining occurred throughout the Snake River basin. The livestock industry began to establish itself, and the value of irrigated land began to be realized. Newspapers, professional journals, and federal agencies began to be established during this time, so additional sources of information from this time period are available, although much of the information is still anecdotal. Oral histories also provided information. Because declines in anadromous fish in the Columbia River basin had started to be noticed during this period, the U.S. Fish Commission began to investigate (Gilbert and Evermann 1894, Evermann 1896). From a scientific perspective, the reports of these investigations were especially valuable for providing information about the distribution of anadromous fish.

Federal water projects and most mainstem dams, including IPC's dams, were developed between 1920 and 1957. Most of the information available on the distribution and, to some degree, abundance of anadromous fish comes from this period. Most state agencies were established during this period, and therefore record keeping was more thorough than previously. In addition, agencies also produced annual reports, which were also available to us. If the presence of fish was documented at some location in a later period, we assumed that they were present earlier as well, unless we found clear documentation of temporary exclusion resulting from temporary dams or diversions.

The last period of decline, from 1958 to 1967, was the construction period for the HCC. During this period, efforts to maintain anadromous fish above the HCC ceased.

3.3. Geographic Data and Methods

Because information on the historical distribution of anadromous fish was limited, we also used a GIS to model the potential distribution of anadromous fish, based on stream access. For example, natural waterfalls are obvious features that prohibit access to upstream reaches. In addition to vertical falls, steep gradients can also naturally limit access to portions of river basins. We assumed, based on information in Platts (1974), that a sustained stream gradient of 20% or greater was a natural passage barrier to adult anadromous fish. Of course, there will be exceptions to this assumption, depending on the features of individual streams, such as the presence of plunge pools, the heights of vertical drops, and the volumes of water. However, over the large geographic scale of this analysis, we feel the assumption was reasonable. To identify stream sections with gradients of 20% or more, we used Digital Elevation Models (DEMs) at a 30-m-pixel sampling resolution and a 1:24,000 map scale. A DEM is a digital representation of surface relief that incorporates a matrix of elevation values across a regularly spaced grid interval (cell). The raster representation of stream channels required that we consider distances from cell centroid to cell centroid when modeling for gradient barriers. With a 30-m cell resolution, the greatest possible distance between two cells was 42.4 m. To determine a 20% change in gradient from one grid cell centroid to the next, we chose to use the conservative measure of 42.4 m, which, when multiplied by the 20% slope, equals a threshold of 8.5 m in elevation. Thus, any change of elevation greater than 8.5 m from one grid cell to the next constituted a potential barrier to passage. Each potential barrier was sorted by stream order, and a basin area was generated from the location of the barrier to determine the area of effect.

Based on the literature survey described in section 3.2, we compared examples of known distributions to predicted distributions (for verification) and found general agreement. In cases where we found disagreement between known distributions and our predictions, we extended the stream access to match the documented distribution. We also used 7.5-minute quadrangle maps to verify the gradient of the stream against the predicted barriers. Chapters 4 and 5 (Chandler and Chapman 2001, Chandler et al. 2001) include maps that depict areas that are limited by gradient access.

3.4. Assessment of Existing Habitat above Hells Canyon Dam

Describing the current conditions of potential habitats for anadromous fish in and above the HCC was essential to assessing whether anadromous fish could be successfully reestablished in this reach. In Chapters 4 and 5 (Chandler and Chapman 2001, Chandler et al. 2001), we describe the conditions of current habitats and current limiting factors. For data sources, we used assessments of biological conditions, assessments of total maximum daily load (TMDL), land management plans from federal agencies, and habitat evaluations conducted by state and federal agencies. In addition, state management agencies, such as the Departments of Environmental Quality, Fish and Game, and Water Resources, provided valuable data.

While analyzing gradient barriers (discussed in more detail in section 3.3) provided estimates for the upstream extent of potential anadromous distribution within a basin, we also needed a means of estimating the downstream extent of anadromous production within a basin. We assumed that water temperature would determine the downstream extent of juvenile anadromous salmonid production. We further assumed that a maximum weekly average temperature (MWAT) of 22 °C or higher during summer would create conditions within stream reaches that are unsuitable for rearing salmonids (Hicks 1998). McCullough (1999) noted that salmonids, specifically chinook salmon, tolerate temperatures up to about 22 to 24 °C. These maxima correspond to a somewhat lower temperature limit for the MWAT. McCullough (1999) suggested that the optimum temperature for growth—about 15.6 °C—should be the temperature standard for stream management. In light of this proposed standard, a downstream habitat boundary formed by an MWAT of 22 °C tends to overestimate the habitat available to rearing salmon and steelhead. However, for our purposes, a 22 °C MWAT provides an appropriate conservative limit because using a lower temperature would likely exclude areas that could be productive, especially in smaller tributaries at lower elevations.

Data on water temperatures were collected in many of the Snake River basins over a wide range of elevations, primarily by the U.S. Forest Service (USFS), the Bureau of Land Management (BLM), and state agencies. Descriptions or coordinates for each measuring location were obtained with the temperature data and overlaid on the 30-m DEM to obtain approximate elevations of the stream channels. We determined the MWAT for each location and regressed the MWAT against elevations within each basin. We then used the regression to estimate the elevation at which the MWAT reached 22 °C. Results of these regressions are presented in

Appendices 1 through 7 of Chapter 4 (Chandler and Chapman 2001a). We were not able to acquire temperature data that represented an appropriate elevation range for all of the basins. To estimate the downstream limit of fish for these basins, we used literature that described the distribution of fish before closure of the HCC (where available), information from neighboring basins, and judgments based on our knowledge of the basin. We discuss our assumptions about the distribution of anadromous fish for each basin downstream of the HCC in Chapter 4 (Chandler and Chapman 2001a).

We obtained data on distributions of land use and land ownership (Chandler and Chapman 2001a) from the U.S. Geological Survey (USGS). This agency provides these data sets and the associated maps—thematic overlays registered to 1:250,000-scale base maps—as a part of its National Mapping Program. Data on land use provide information about urban or built-up land, agricultural land, rangeland, forest land, water, wetlands, barren land, tundra, and perennial snow or ice. The USGS first used manual interpretations of aerial photographs acquired from National Aeronautics and Space Administration's high-altitude missions. The USGS also incorporated information from earlier land-use maps and field surveys as needed. IPC also obtained information about land ownership from the BLM's Surface Management Status Maps, 1:100,000-scale quadrangle maps that indicate land ownership.

To reveal how intensely various land uses draw on irrigation and other water withdrawals in the study area, we used the number of water diversions within a 6th code HUC to calculate a diversion density. This was done for each 6th code HUC within the historic range. A high diversion density suggests not only decreased stream flows within the basin, but also potential problems with unscreened diversions within the basin.

Mainstem dams throughout the geographic area of distribution create obvious access problems. Multiple small dams and diversions distributed throughout the basins compound access problems. To indicate blocked basins, we plotted all dam locations for each basin using data from the Idaho, Oregon, and Washington Departments of Water Resources. This database includes dams measuring approximately 3 m or greater in height. In Chapter 4 (Chandler and Chapman 2001a), we discuss points of water diversion (diversion density) and distribution of dams.

We conducted specific field studies to describe the existing quality of known historical spawning areas in the mainstem Snake River. These studies are presented in Chapter 5 (Chandler et al. 2001). The focus of the studies was to describe the quality and dynamics of the hyporheic and potential spawning environments. We also used information from ongoing assessments of TMDLs and studies that IPC conducted on water quality to describe water quality conditions in the mainstem Snake River as they relate to relicensing.

3.5. Production Potential

In Chapter 6 (Chapman and Chandler 2001a), we discuss the methods and approach we used to estimate the historical production of anadromous fish in the reaches above the HCC. This discussion estimates run sizes for the predevelopment period and the period immediately before construction of the HCC. In Chapter 7 (Chapman and Chandler 2001b), we discuss the methods and approach we used to estimate the current production potential (smolt yield). Smolt yield estimates for each basin are presented in Chapter 8 (Chapman and Chandler 2001c).

We calculated the potential yields of smolts under each of three circumstances, called options A, B, and C. Option A estimates the smolt yield if passage were to become available at all IPC dams on the mainstem Snake River and assumes that all dams and reservoirs would remain in place. Option B estimates smolt yield if passage were to become available at all IPC dams on the mainstem Snake River and at all other man-made barriers to fish moving upstream or downstream. Option C estimates smolt yields from those reaches of the historical production area that are currently blocked by man-made obstacles in tributaries. Option C addresses blocked yield of smolts that is not associated with the effects of IPC dams on the mainstem Snake River.

To estimate smolt production, we used various estimators, or paradigms. These paradigms used estimates of basin areas and stream kilometers by stream order. Stream kilometers by stream order were estimated for each of the basin area descriptors by using the GIS and DEMs. We were able to create a stream network by applying a threshold value to select cells in the DEM that have a high accumulated flow (section 3.3 discusses development of the database). In its simplest form, flow accumulation is the number of upslope cells that flow into any given cell. Thus, the stream channels will have the highest accumulated flow. Additionally, the GIS software generated Strahler stream orders (Strahler 1964) from the drainage networks that were derived from the DEMs.

Depending on the particular paradigm, three aspects of basin area (Figure 3) are used in the paradigms discussed in Chapter 7 (Chapman and Chandler 2001b):

- *Effective basin* is the total basin area minus the area estimated to be unsuitable because of MWATs greater than 22 °C.

- *Effective useable basin* is the total basin area minus the area determined to be inaccessible because of gradient limitations and the area determined to be unsuitable because of temperature MWATs greater than 22 °C.

- *Blocked basin* is the total basin area that is blocked by man-made obstacles such as impassable dams.

Chapters 4 and 5 include maps depicting the basin areas and tables summarizing the stream miles for each basin in the study reach and the mainstem Snake River (Chandler and Chapman 2001a, Chandler and Groves 2001).

3.6. Passage Requirements

Fish passage around dams (both upstream and downstream) must be part of any plan to reintroduce fish into historical habitats. Our evaluation of possible passage systems included systems that are currently being used or that, historically, have been used to pass anadromous fish. Our evaluation also included cost estimates for the design, construction, and maintenance of such facilities. When we assessed the feasibility of implementing various options for upstream and downstream passage at HCC dams, we considered the specific construction and design of these dams. Additional considerations about the feasibility of passage are presented in Chapter 9 (Aurdahl et al. 2001).

3.7. Stock Assessment and Pathogen Risk

The stocks that are best suited for reintroduction into reaches upstream of the HCC are those hatchery stocks that originated in the upstream reaches. In Chapter 10, we look at the history of the development of these stocks and the influences that may have affected these stocks, such as exposure to other hatchery or wild stocks. We also include a pathogen history for each hatchery facility that currently produces these hatchery stocks (Chandler and Abbott 2001).

Reintroducing anadromous fish into historical ranges carries a risk of introducing or reintroducing pathogens into a basin, pathogens that could affect populations of resident fish. In Chapter 10, we also present some information from a workshop that IPC conducted with several local fish pathologists. Participants discussed pathogens that are of particular concern and what is known about the present distribution of these pathogens, both upstream and downstream of the HCC. At the workshop, the elements of assessing the risk of introducing pathogens during reintroduction of anadromous fish were outlined for consideration. In addition, the pathogen histories of resident hatcheries, as they relate to introducing pathogens into the basin upstream of the HCC, were presented.

3.8. Evaluation of Reintroduction Alternatives

Finally, in Chapter 11 we estimate the survival rates of smolts in the subbasins upstream from the HCC to the Lower Granite Dam tailrace and adult returns to Hells Canyon Dam, based on smolt-to-adult returns (SARs). We evaluate several scenarios for reintroduction and passage, based on assumed efficiency of passage systems at mainstem Snake River dams. Adult returns are compared with estimates presented in Chapter 8 for the escapements necessary to maintain the smolt production potential (Chapman and Chandler 2001c). Finally, we discuss the scenarios that were evaluated in the context of other aspects of reintroduction, such as feasibility.

4. STUDY APPROACH

Evaluating the feasibility of reintroducing anadromous fish involves many issues, and, therefore, providing passage alone will not ensure successful reintroduction. The entire life cycle of anadromous fish and the elements that affect this cycle have to be considered. Aspects of history, the quality of current habitats, the many land uses and their effects on habitat and passage, the limitations of passage technology at tributary and mainstem dams, the risks of introducing deleterious pathogens, the limitations because of the low SARs below Hells Canyon Dam, and the potential impacts to existing stocks that are federally protected all need to be carefully weighed in terms of costs, benefits, risks, and the likelihood of a reintroduction program being successful. The approach of our evaluation was to look at these many issues of reintroduction as a whole and to evaluate the evidence and uncertainties arising from our research to make judgments about the feasibility of reintroducing anadromous fish and about the many options for reintroduction.

We intended this study to be the first phase in addressing the question of feasibility and to highlight the many uncertainties of reintroduction. We also intended to identify areas within the historical distribution that have the greatest potential for successful reintroduction. It is clear that reintroduction over the entire historical range, as expressed in section 1, will not occur quickly, if ever. Initially, areas within the basin that offer the greatest likelihood of success should be chosen for reintroduction. If, based on this initial evaluation of feasibility, a decision is made to pursue reintroduction, a second phase of evaluations should be designed to begin resolving many of the uncertainties identified in this initial assessment.

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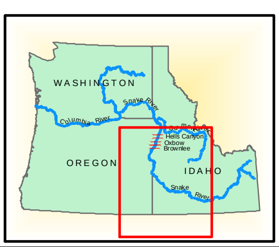

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Tech. Report E.3.1-2, Chapter 1, Figure 1

Major tributaries of the Hells Canyon Complex

25 12.5 0 25 Miles

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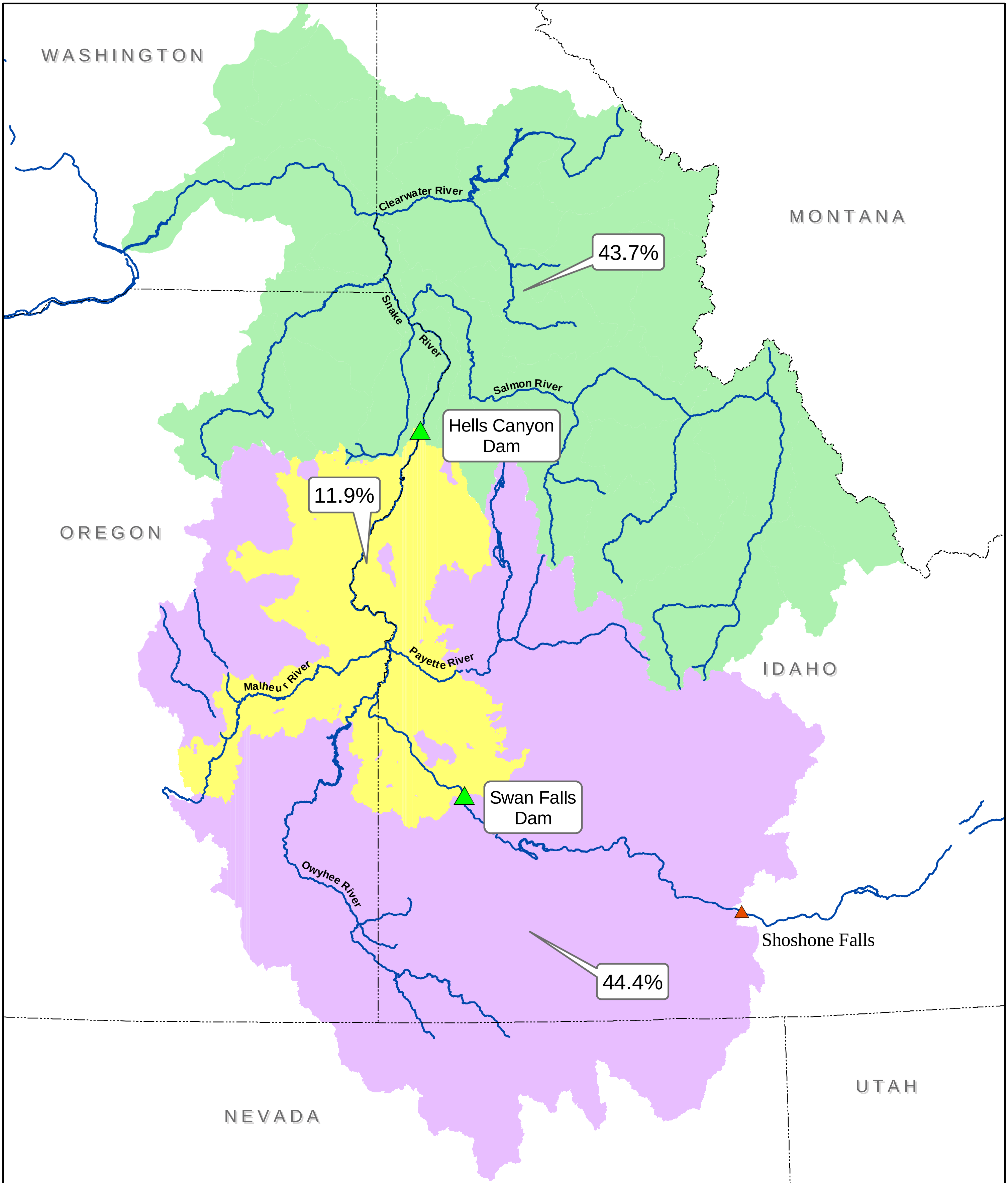

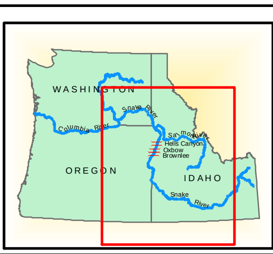

Present Day

Blocked Prior to HCC

Available Prior to HCC

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Tech. Report E.3.1-2_c1 Figure 2

Present and Historic Distribution of Anadromous Fish

50 25 0 50 Miles

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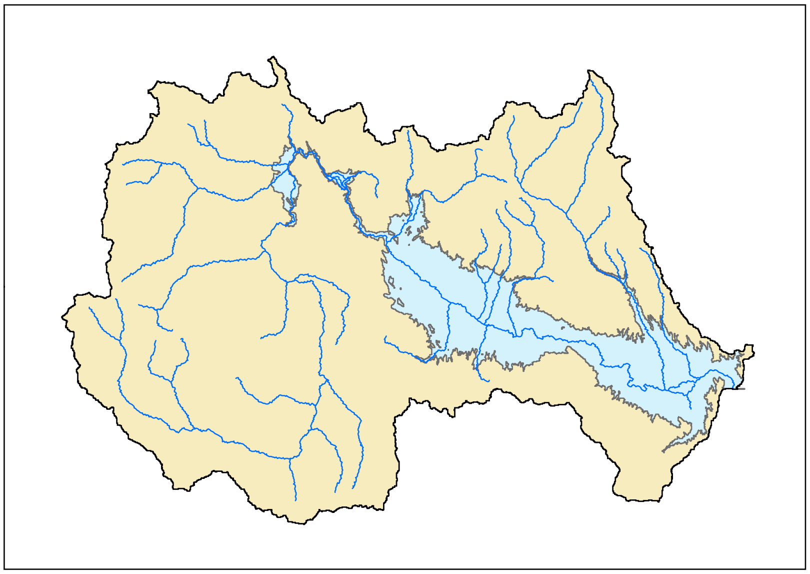
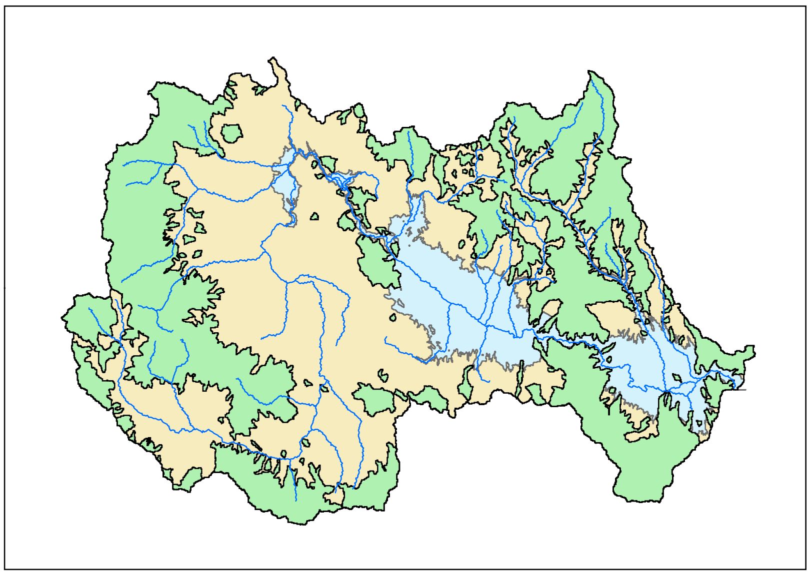
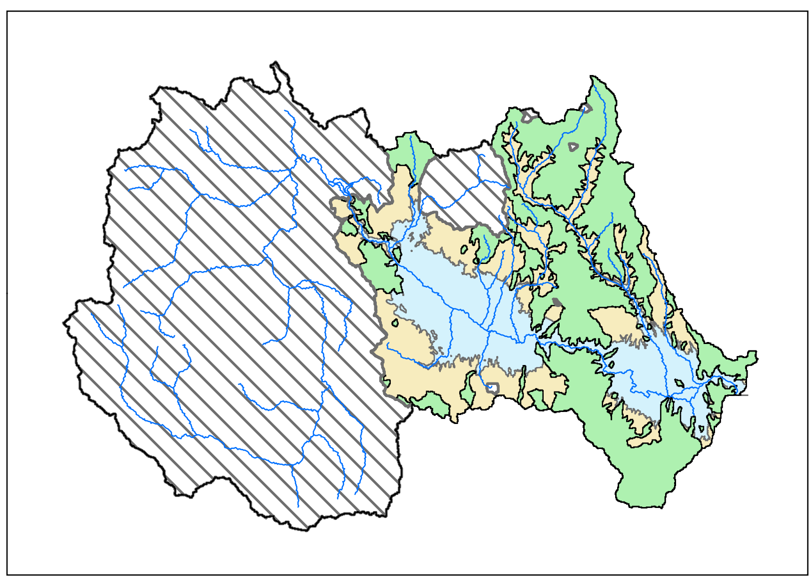


Effective Basin



Effective Useable Basin



Blocked Basin

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Features Legend

- Blocked Basins
- Gradient Limited
- Temperature Limited
- Available Habitat

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Tech. Report E.3.1-2_c1 Figure 3

Effective, Effective Useable, and Blocked Basins of the Powder River Watershed

0 3.75 7.5 15 22.5 30 Miles

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