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Effects of Water-Level Fluctuations on Riparian Habitat Fragmentation

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ABSTRACT

We investigated existing patterns of riparian vegetation and fragmentation in Hells Canyon. Analysis of existing fragmentation was based on the Idaho Power Company (IPC) cover-type map for the Hells Canyon Study Area. This map extends laterally 0.5 mi from the shorelines of the Weiser Reach, and Brownlee (including the Powder River Arm and Pool), Oxbow, and Hells Canyon reservoirs, and 0.25 mi from the shoreline below Hells Canyon Dam to the Salmon River. We divided the evaluation area into these 6 reaches and both states. We conducted a further analysis at a smaller resolution of 50 m above the shoreline for each reach. These divisions resulted in 22 evaluation strata.

The cover-type map spatially depicts 26 vegetation, natural feature, and land-use cover types within a Geographic Information System. We conducted our analyses on 3 riparian/wetland cover types: *Emergent Herbaceous Wetland, Scrub-Shrub Wetland,* and *Forested Wetland*. The remaining cover types comprised the landscape matrix. We also performed a separate analysis on only woody riparian vegetation (*Scrub-Shrub* and *Forested Wetlands*). We calculated 15 fragmentation metrics, such as mean patch size and density, edge density, mean nearest neighbor, and shape indices. We qualitatively compared results among strata to characterize current patterns of riparian habitat fragmentation.

Existing riparian vegetation, both along reservoir/river shorelines and within tributary drainages, was typically linear in nature, and patchy and fragmented across the landscape. Because of their gentle gradients, the Weiser Reach and Powder River Pool are the only sections that resemble an alluvial (i.e., floodplain) system. These reaches, therefore, support relatively continuous shoreline vegetation. Brownlee Reservoir, which is the most influenced by current project operations, has sparse and highly fragmented riparian vegetation. Oxbow and Hells Canyon reservoirs, and the river below Hells Canyon Dam have patchy but significant shoreline vegetation.

1. INTRODUCTION

1.1. State of Knowledge

Habitat loss and fragmentation are the major factors contributing to the decline in regional and global biodiversity (Harris 1984, Saunders et al. 1991). Fragmentation is the disruption of continuity and the subdivision of habitats into fewer, smaller, and increasingly isolated patches (Lord and Norton 1990, Rolstad 1991). Remnant habitat patches are often surrounded by a matrix of unsuitable areas for wildlife (e.g., farmland). Viability of wildlife populations, therefore, is strongly influenced by size, shape, and distribution of habitat patches in the landscape (Saunders et al. 1991, Donovan et al. 1995).

Theories of habitat fragmentation were influenced by those of island biogeography (MacArthur and Wilson 1967), which assert that the number of species on an island depends on its size and distance from the mainland. For example, smaller, farther islands will contain fewer species. Habitat fragmentation effects are believed to be similar. Persistence of a species in small habitat patches may depend on proximity to larger blocks of suitable habitat and connectivity among patches (Merriam 1984). The study of metapopulation dynamics (e.g., Fahrig and Poloheimo 1988, Gilpin and Hanski 1991, Harrison 1991) has resulted from the need to understand population demographics in a fragmented landscape.

The effect of fragmentation on a population depends on the species' life history, its resource requirements, and the scale at which it uses the environment (Forman and Godron 1986, Hansen et al. 1993). Hence, consequences of habitat fragmentation are species specific and scale dependent (Wiens 1989a, b; McGarigal and Marks 1995). For example, a species may persist regionally in well-dispersed habitat patches due to metapopulation dynamics. Alternatively, the same patches may leave another species isolated in an unsuitable habitat. Isolated populations may experience an increased risk of extinction due to decreased genetic heterozygosity and an increased susceptibility to disease and catastrophic events (Saunders et al. 1991).

Human-caused fragmentation (e.g., clearing, logging) leads to a disruption of natural ecological processes and landscape patterns, and alters plant and animal community composition and organization. For example, small forest fragments and edges tend to have a different physical environment than forest interiors (Saunders et al. 1991). Fragment edges typically are drier, sunnier, and warmer, resulting in a different plant composition and structure. Wildlife community organization will be affected as a different suite of species is attracted to the edge environment (Gates and Gysel 1978). For example, forest birds in fragmented agricultural landscapes may experience increased nest predation (Paton 1994), because abundance of some predators increases in such landscapes (e.g., American crows [*Corvus brachyrhynchos*], raccoons [*Procyon lotor*], and skunks [*Mephitis mephitis*]; André 1992, Faaborg et al. 1995). Brood parasitism by brown-headed cowbirds (*Molothrus ater*) also increases in fragmented landscapes (Brittingham and Temple 1983). The overall effects on a population are influenced by the landscape context, habitat structure, and community composition (Donovan et al. 1997, Tewksbury et al. 1998).

Natural physical and ecological processes (e.g., topographic variation, moisture gradients, and wildfire) also create fragmented landscapes (Saunders et al. 1991). Riparian ecosystems in arid areas of the western United States are naturally fragmented from the surrounding landscape. Streamside vegetation is typically narrow with an inherently high proportion of edge and a sharp gradient between riparian and arid upland vegetation. The effects of human-caused fragmentation in such systems are largely unknown (Tewskbury et al. 1998).

Negative fragmentation effects can be compounded in habitats that contribute disproportionately to a region's biodiversity. In the western U.S., riparian ecosystems comprise approximately 0.5% of the landscape (Ohmart and Anderson 1996) and have been reduced by more than 70% since presettlement times (Brinson et al. 1981, Dahl 1990, Noss et al. 1995). However, more wildlife species use riparian areas than any other vegetation type (Thomas 1979, Szaro 1980, Brinson et al. 1981, Knopf et al. 1988, Saab et al. 1995). Riparian habitats support a diversity and abundance of wildlife in all seasons because of high structural and vegetative diversity compared to surrounding uplands (Thomas 1979, Johnson 1989, Clary and Medin 1993, Hawkins 1994).

Many riparian ecosystems in the West have also been altered for hydroelectric development (Lewke and Buss 1977). Divergences from natural river processes can degrade riparian vegetation. Reservoir construction usually inundates riparian habitat, and reservoir management that includes large annual water-level fluctuations often prevents establishment of vegetation along newly created shorelines. The decline and fragmentation of woody riparian vegetation is often the most dramatic effect of dam-induced flow alterations (e.g., Bradley and Smith 1986, Akashi 1988, Rood and Heinz-Milne 1989). Thus, shoreline vegetation associated with reservoir systems can be minimal and fragmented (Nilsson and Keddy 1988), which may negatively impact wildlife communities (Mackey et al. 1987, Mack et al. 1990).

Unfortunately, because baseline data for most species and river systems are lacking, we often cannot empirically evaluate impacts of reservoirs and water-management strategies. Without baseline data, an ecosystem-level approach is needed to simultaneously conserve groups of species (LaRoe 1993, Noss et al. 1995). Maintaining biodiversity in the western U.S. hinges on conserving interconnected riparian ecosystems and their ecological functions (Noss 1983, 1992; Hawkins 1994; Noss et al. 1995).

1.2. Justification

This study was proposed as part of a comprehensive investigation of wildlife resources in Hells Canyon to help Idaho Power Company (IPC) meet Federal Energy Regulatory Commission (FERC) requirements for relicensing the Hells Canyon Complex (HCC). The FERC, which regulates the HCC (FERC License No. 1971), requires that license applicants provide descriptions of important wildlife resources and habitats occurring in the affected area (Federal Energy Regulatory Commission 1990). Riparian vegetation is an important and limited habitat in Hells Canyon (Holmstead 2001a). Information about current patterns of riparian vegetation will also be useful in addressing mitigation claims for habitat alteration due to the HCC and for developing protection, mitigation and enhancement measures.

1.3. Objectives

The main objective of this study was to describe the existing landscape pattern of riparian habitats along the Snake River and HCC reservoirs in Hells Canyon. The ultimate goal was to identify means for maintaining and enhancing wildlife biodiversity by conserving important riparian habitats in the multiple-use landscape of Hells Canyon. Understanding relationships among riparian vegetation, habitat fragmentation, and landscape pattern may also aid development of protection, mitigation, and enhancement measures.

2. STUDY AREA

2.1. Location

The Hells Canyon Reach of the Snake River is situated in west-central Idaho and northeastern Oregon (Figure 1). The Hells Canyon Study Area is located between the city of Weiser and the confluence of the Salmon and the Snake rivers (from approximately river mile [RM] 351 to RM 188). The Snake River, a major tributary to the Columbia River, is the focal point of Hells Canyon. Its generally northward flow forms part of the boundary between Idaho and Oregon. The HCC is located on the Snake River in the southern portion of Hells Canyon and includes three reservoirs—Brownlee, Oxbow, and Hells Canyon. The reach below Hells Canyon Dam is unimpounded, although the three-dam complex controls flows.

Federal agencies, including the Bureau of Land Management (BLM) and U.S. Forest Service, are responsible for managing the majority of public land in Hells Canyon. These areas fall within the jurisdictional boundaries of the Wallowa–Whitman National Forest, Oregon; Payette National Forest, Idaho; Nez Perce National Forest, Idaho; Four Rivers Field Office (FO) of the Lower Snake River District, BLM–Idaho; Cottonwood FO of the Upper Columbia-Salmon Clearwater District, BLM–Idaho; and Baker FO and Malheur FO of the Vale District, BLM–Oregon. Other agencies with natural resource jurisdiction in the greater project area include the U.S. Department of the Interior (USDI) National Marine Fisheries Service, USDI Bureau of Indian Affairs, USDI Fish and Wildlife Service, and state agencies from Idaho and Oregon.

The area upstream and downstream of Hells Canyon Dam can be broadly divided into 6 reaches, based on distinct geomorphic features, river characteristics, and legal project boundaries:

- The Weiser Reach, upstream of Brownlee Reservoir to the Weiser Bridge (approximately 12 mi; RM 351.2 to RM 339.2).
- Brownlee Reservoir (approximately 55 mi; RM 339.2 to RM 284.6).
- The Powder River Arm and Pool (9 mi) in Oregon, which enters Brownlee Reservoir at RM 296.
- Oxbow Reservoir (approximately 12 mi; RM 284.6 to RM 272.2).

- Hells Canyon Reservoir (approximately 25 mi; RM 272.2 to RM 247.0).
- Downstream of Hells Canyon Dam to the confluence of the Snake and Salmon rivers (approximately 59 mi, RM 247.0 to RM 188.2).

Generally, the lateral extent of these reaches includes all land within 0.5 mi of each shoreline above Hells Canyon Dam and all land within 0.25 mi of each shoreline below Hells Canyon Dam. However, the lateral extent of the study area can vary depending on which resources are being studied. The study area below Hells Canyon Dam is extremely difficult to access.

In the upstream reach, the Snake River can be characterized as a low-gradient (0.2 to 0.4 m/km) river, with several island complexes. Agricultural impacts are apparent with irrigation returns causing high turbidities and increased nutrient loading. Farmland and rural development on flat to gentle topography surround this reach. Brownlee Reservoir is a steep-sided reservoir with a maximum depth approaching 300 ft near the dam. Large rock outcrops occur throughout its entire length. The Powder River Arm and Pool are a low-gradient extension of Brownlee Reservoir. The “arm” encompasses approximately 8 mi from the confluence of the Powder River with Brownlee Reservoir, while the “pool” refers to the large pool at the western end.
Oxbow Reservoir is a small re-regulating reservoir surrounded by moderate to steep topography (20% to 75% slopes). Shorelines are primarily basalt outcrops and talus, except for alluvial fans created by small tributaries. Hells Canyon Reservoir is a re-regulating reservoir with maximum depths approaching 200 ft. Shorelines in the reservoir are generally very steep, and substrates are primarily composed of basalt outcrops and talus slopes. The Snake River in the downstream reach is a high-gradient river (1.8 m/km) with a wide diversity of aquatic habitat, including numerous large rapids, shallow riffles, and deep pools. Substrates are highly diverse, ranging from large basalt outcrops and boulders to cobble/sand bars. This unimpounded reach of the Hells Canyon is considered to be the deepest gorge in North America. The Hells Canyon Reach is surrounded at the upstream end by nearly vertical cliff faces.

2.2. Physiography

Hells Canyon is the deepest and one of the most rugged river gorges in the continental United States. It ranges between 2,000 and 3,000 ft deep from Weiser to Oxbow Dam. Below Oxbow Dam, the river enters a narrow, steep-sided chasm measuring up to 5,500 ft deep. From the confluence with the Grande Ronde River, the Snake River then flows into a lava-filled basin and through a much shallower canyon to Lewiston, Idaho (U.S. Department of Energy 1985). The elevation of the Snake River near Weiser, Idaho, is about 2,090 ft msl, descending to about 910 ft msl at the confluence of the Salmon River, about 59 mi below Hells Canyon Dam.

Throughout the canyon, topography is generally steep and broken, with slopes often dominated by rock outcrops and talus slopes. At the deepest points of the canyon, the walls rise almost vertically. Canyon walls are deeply dissected by numerous side canyons with tributaries to the Snake River. The Seven Devils Mountains to the east and the Wallowa Mountains to the west form the upper reaches of the canyon walls. These mountains form a series of jagged peaks reaching almost 10,000 ft, with subalpine and alpine conditions (U.S. Department of Agriculture 1990) to the west.

2.3. Land Features and Geology

Hells Canyon consists of a series of folded and faulted metamorphosed sediments and volcanics overlain unconformably by nearly horizontal flows of Columbia River basalt. This basalt group covered much of eastern Washington, northern Oregon, and adjacent parts of Idaho (Bush and Seward 1992). The older rocks in the series are Permian to Jurassic in age and represent at least two episodes of island arc volcanism and adjacent marine sedimentation similar to those found today in the Aleutian Islands west of Alaska. These rock units represent old island arc chains that were sequentially “welded” to the west coast of North America during the late Paleozoic and early to mid-Mesozoic eras by subduction of a tectonic plate beneath the North American continental tectonic plate (Asherin and Claar 1976, U.S. Department of Agriculture 1994).

In more recent geologic time, Hells Canyon was formed through erosion, by the Snake River, of the Blue Mountains in Oregon and Seven Devils Mountains in Idaho (U.S. Department of Energy 1985). The Snake River has existed since the Pliocene and probably cut to its present level during the Pleistocene. During the Pleistocene, glacial meltwater provided abundant runoff for down-cutting, while regional uplifting created weak points in the 2,000- to 3,000-ft-thick basalt plateau that overlaid the Blue and Seven Devils mountains. Resulting erosion formed the currently observed drainage pattern that established the Snake River (U.S. Department of Energy 1985). Northeast-trending, high-angle fault patterns characterize the extensive Snake River fault system running throughout the study area (Fitzgerald 1982).

Besides basalt, other rock types are also present within the study area. Extensive limestone outcrops are found in some tributary drainage areas, and local granitic outcrops also occur.

2.4. Soils

The soils throughout Hells Canyon are derived primarily from Columbia River basalt, covered in most areas with a thin mantle of residual soils from weathered native rock. Isolated areas contain deposits of windblown silt. Unconsolidated materials include ash-loess from the Mount Mazama eruption 6,900 years ago, river sands and gravel deposited during the Bonneville floods 15,000 years ago, and colluvium and talus deposited more recently. The amount of soil cover declines northward through Hells Canyon. Near Hells Canyon Dam (RM 247), most rock faces are nearly vertical with little soil cover (U.S. Department of Agriculture 1994).

Most soil complexes are well drained and vary from very shallow to moderately deep. Loams are the dominant textural class and vary from very stony to silty, often with a clay subsoil component (Natural Resources Conservation Service 1995).

2.5. Climate

From late fall to early spring, the climate of west-central Idaho and eastern Oregon is typically influenced by cool and moist Pacific maritime air. Periodically this westerly flow is interrupted by outbreaks of cold, dry continental air from the north, which is normally blocked by mountain ranges to the east. During the summer, a Pacific high-pressure system dominates weather patterns, resulting in minimal precipitation and more continental climatic conditions overall (Ross and Savage 1967). Hells Canyon, located in the High Desert region, is significantly influenced by the rain shadow of the Cascade Mountains to the west.

Climatological information is summarized for Weiser, Richland, Brownlee Dam, and Lewiston (Figure 2). Average annual precipitation is lowest at the southern end of the study area (Weiser, 286 mm), increases northward (Richland, 298 mm), peaks around Brownlee Dam (445 mm), and declines towards Lewiston (326 mm). The average annual precipitation ranges from about 380 to 500 mm (15 to 20 inches), depending on elevation. Nearly 45% of the average annual precipitation at Brownlee Dam (445 mm [17.8 inches]) falls from November through January, which strongly contrasts with the 9% average recorded for July through September. Thus, most precipitation occurs in spring and winter (Tisdale et al. 1969,Tisdale 1986, Johnson and Simon 1987), and little or no precipitation falls during the hottest months of summer. Average annual evapotranspiration is estimated to be about 1,300 mm (52 inches).

Mean annual temperatures are similar among the four weather stations. Generally, the climate tends to become drier and warmer downstream of Brownlee Dam. Climatological information from Brownlee Dam (RM 284.6) is probably characteristic of the central section of the study area. The canyon bottom area is dry with seasonal temperatures ranging from lows of about −5 °C in January to highs of about 35 °C in July (Figure 2). Temperatures below freezing are normally experienced from mid-November through mid-April. As a rule, winters in the canyons are mild, while summers on the canyon floor may be hot. Mean temperatures above 2,000 m (6,562 ft msl) range from –9 °C in January to 13 °C in July. By contrast, mean temperatures below 1,000 m (3,281 ft msl) elevation range from 0 °C in January to between 28 °C and 33 °C in July (Johnson and Simon 1987).

2.6. Vegetation

The types of vegetation growing along the canyon slopes of the middle Snake River are the result of 3 primary ecological factors: climate, topography, and soils. Climate exerts the strongest influence on the development of plant life. The relatively mild winters below the canyon rim have allowed the development of disjunct species. For example, hackberry (*Celtis reticulata*), which is most often found in the southwestern states, commonly occurs in the middle and lower Snake River area (Tisdale 1979, DeBolt 1992).

Within the context of regional climate, topography is a major influence on the development and distribution of vegetation (Tisdale et al. 1969; Tisdale 1979, 1986). The topographical complexity of Hells Canyon has produced a mosaic of vegetation types (Tisdale 1979, Bonneville Power Administration 1984). Grassland, shrubland, riparian (or wetland), and coniferous forest communities exist in close proximity. Interfingering of grassland and forest, for example, occurs at a number of sites throughout the canyon due to variations in aspect (Tisdale 1979).

Twenty-six cover types—for natural features, land use, and vegetation—were identified along the Snake River in the Hells Canyon vicinity (Holmstead 2001a). The area that was classified covered up to approximately 0.5 mi on both sides of the Snake River or associated reservoirs and extended from above Brownlee Reservoir at the town of Weiser, Idaho (RM 351.2), downstream to the confluence with the Salmon River (RM 188.2). The dominant cover types were *Grassland* (35.5%), *Shrub Savanna* (21.0%), *Lotic* (16.1%), *Shrubland* (6.6%), and *Cliff/Talus* (5.6%). All remaining cover types covered <5% of the area classified.

Wetland and Riparian Communities—A narrow band of diverse riparian communities intermittently follows the course of the Snake River and its many tributaries. Although limited in geographic area, this riparian zone is vital because of its biological diversity. Emergent wetland communities are composed mostly of broad-leaved pepperweed (*Lepidium latifolium*), marsh grass (*Heleochloa alopecuroides*), purple loosestrife (*Lythrum salicaria*), common cocklebur (*Xanthium strumarium*), hemp dogbane (*Apocynum cannabinum*), alkali saltgrass (*Distichlis stricta*), and purslane (*Portulaca oleracea*). Predominant shrub species in riparian areas include netleaf hackberry (*Celtis reticulata*), false indigo (*Amorpha fruticosa*), coyote willow (*Salix exigua*), common chokecherry (*Prunus virginiana*), poison ivy (*Toxicodendron radicans*), syringa (or mock orange, *Philadelphus lewisii*), Himalayan blackberry (*Rubus discolor*), and tamarisk (*Tamarix parviflora*).

Predominant tree species include water birch (*Betula occidentalis*), white alder (*Alnus rhombifolia*), black cottonwood (*Populus trichocarpa*), silver maple (*Acer saccharinum*), and peachleaf willow (*Salix amygdaloides*). Most weedy exotic species occur at and above the headwaters of Brownlee Reservoir (Holmstead 2001a).

Many shoreline sections have no riparian vegetation. Rather, upland vegetation on steep canyon slopes simply meets the rocky shoreline. Grassland and shrubland communities are common along the Snake River and its tributaries.

Herbaceous-Dominated Vegetation Types—The dry climate and typically stony, shallow soils of the canyon have favored the development of grassland steppe communities at the lower and middle elevations (Tisdale 1979, 1986). Commonly occurring grass species in the study area include bunchgrasses, such as bluebunch wheatgrass (*Pseudoroegneria spicata*), Idaho fescue (*Festuca idahoensis*), Sandberg bluegrass (*Poa secunda*), and annual grasses, such as cheatgrass (*Bromus tectorum*) and medusahead wildrye (*Taeniatherum caput-medusae*) (Holmstead 2001a). Other grasses, such as sand dropseed (*Sporobolus cryptandrus*) and red threeawn (*Aristida longiseta*), are locally common (Bonneville Power Administration 1984, Tisdale 1986).

Shrub-Dominated Vegetation Types—Shrub species comprise a large segment of the canyon's overall vegetation composition. Shrub-steppe vegetation types occur at mid-elevations in the Hells Canyon Study Area, especially in its southern region (Bonneville Power Administration 1984). Commonly occurring shrubs include big sagebrush (*Artemisia tridentata*), bitterbrush (*Purshia tridentata*), gray rabbitbrush (*Chrysothamnus nauseousus*), hackberry, serviceberry (*Amelanchier alnifolia*), and bitter cherry (*Prunus emarginata*) (Bonneville Power Administration 1984, Tisdale 1986, Holmstead 2001a). For the most part, sagebrush stands are limited to the area around Brownlee Reservoir. In these stands, the herbaceous layer is dominated by cheatgrass, with a variety of forbs also occurring.

Stands of hackberry can be found throughout the study area, either on lower slopes with rocky residual/colluvial soil or on alluvial terraces with sandy soil (Tisdale 1986). In these stands, hackberry is often mixed with a number of other shrub and tree species, including antelope bitterbrush, blue elderberry (*Sambucus cerulea*), and ponderosa pine (Bonneville Power Administration 1984). Poison ivy is also abundant. The herbaceous layer is most often dominated by bluebunch wheatgrass, with cheatgrass dominant in those areas moderately to heavily disturbed by past livestock use.

Tree-Dominated Vegetation Types—Although coniferous forest communities are generally restricted to the higher elevations of steep canyon slopes, they do reach down as far as the river at certain locations. For example, stands of ponderosa pine (*Pinus ponderosa*) or Douglas-fir (*Psuedotsuga menziesii*), typically with a common snowberry (*Symphoricarpos albus*) understory, extend to the river on north-facing slopes at sites around Oxbow and Hells Canyon reservoirs, and downstream of Hells Canyon Dam (Holmstead 2001a).

2.7. Land Use

The study area and vicinity is still dominated by the land-use patterns established in the early 1900s: irrigated and nonirrigated agriculture, livestock grazing, mining, large areas of open space, and scattered rural development. The bottomlands adjacent to the reservoirs are generally used for grazing, some farming, and rapidly expanding recreational activities.

2.8. Project Operations

2.8.1. Hells Canyon Complex Operations

Hells Canyon, on the Oregon–Idaho border, is the deepest canyon in North America and home to IPC's largest hydroelectric generating complex, the HCC. The HCC includes the Brownlee, Oxbow, and Hells Canyon dams, reservoirs, and power plants. Operations of the 3 projects of the complex are closely coordinated to generate electricity and to serve many other public purposes.

Currently, over 400,000 customers rely on IPC's hydro and thermal generation system for power. The HCC is an integral part of IPC's generation system. Its winter and summer operations are particularly important because energy needs are highest during those seasons. In wintertime, customers need extra electricity for lighting and heating. During the summer, they need extra electricity for air conditioning and irrigation pumping.

IPC operates the complex to comply with the FERC license, as well as to accommodate other concerns, such as recreational use, environmental conditions and voluntary arrangements. Among these arrangements are the 1980 Hells Canyon Settlement Agreement, the *Fall Chinook Recovery Plan* adopted in 1991, and, between 1995 and 2001, the cooperative arrangement that IPC had with federal interests in implementing portions of the Federal Columbia River Power System (FCRPS) biological opinion flow augmentation, which is intended to avoid jeopardy of the FCRPS operations below the HCC.

Brownlee Reservoir is 1 of the 3 HCC facilities—and IPC's only project—with significant storage. It has 101 vertical ft of active storage capacity, which equals approximately 1 million acre-feet of water. On the other hand, Oxbow and Hells Canyon reservoirs have significantly smaller active storage capacities—approximately 0.5 and 1.0% of Brownlee Reservoir's volume, respectively.

Brownlee Dam's hydraulic capacity is also the largest of the 3 projects. Its powerhouse capacity is approximately 35,000 cubic feet per second (cfs), while the Oxbow and Hells Canyon powerhouses have hydraulic capacities of 28,000 and 30,500 cfs, respectively.

Target elevations for Brownlee Reservoir define the flow of water through the HCC. However, when flows exceed powerhouse capacity for any of the projects, water is released over the spillways at those projects. When flows through the HCC are below hydraulic capacity, all 3 projects operate closely together to re-regulate flows through the Oxbow and Hells Canyon projects so that they remain within the 1-ft per hour ramp rate requirement (measured at Johnson Bar below Hells Canyon Dam) and meet the daily peak load demands.

In addition to maintaining the ramp rate, IPC maintains minimum flow rates in the Snake River downstream of Hells Canyon Dam. These minimum flow rates are for navigation purposes and IPC's compliance with 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).

2.8.2. Brownlee Reservoir Seasonal Operations

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

Brownlee Dam is one of several Northwest dams that cooperate to provide springtime flood control on the lower Columbia River and, between 1995 and 2001, to regulate flow in the lower Snake River. For flood control, IPC operates the reservoir cooperatively with the U.S. Army Corps of Engineers (COE) North Pacific Division, according to article 42 of the existing license.

After flood-control 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 dolomieui*) and crappie (*Pomoxis* spp.). The full reservoir also offers optimal recreational opportunities through the Fourth of July holiday.

As part of the flow augmentation reasonable and prudent alternative (RPA) implemented by the 1995 and 2000 FCRPS biological opinions, the Bureau of Reclamation (BOR) periodically releases water from BOR storage reservoirs in the upper Snake River to assist with the migration of anadromous fish past the lower Snake River FCRPS projects. From 1995 through the summer of 2001, IPC cooperated with the BOR and other federal interests in these flow augmentation efforts by shaping (or prereleasing) water from Brownlee Reservoir (and later refilling the drafted reservoir space with water released by the BOR from the upper Snake River reservoirs) and by occasionally contributing water to flow augmentation efforts. To facilitate IPC's cooperation with the flow augmentation RPA, in 1996 the Bonneville Power Administration

(BPA) entered into an energy exchange agreement with IPC. The agreement reimbursed IPC for any energy losses it incurred as a result of the company's participation through an energy exchange mechanism. The agreement expired in April 2001 and has not been renewed by BPA.

Later in the fall, Brownlee Reservoir's releases are managed to maintain constant flows below Hells Canyon Dam. These flow requirements, which are based on the *Fall Chinook Recovery Plan* that IPC adopted in 1991, as well as the minimum flow required by article 43, help ensure sufficient water levels to protect even the shallowest spawning nests, or redds, of fall chinook salmon (*Oncorhynchus tschawytscha*).

After fall chinook spawn, IPC attempts to have a full reservoir by the first week of December to meet winter peak demands.

Winter, December through February—Electricity demands in IPC's service territory—and throughout the Northwest—are critical during the winter. To meet peak winter demands and maintain system reliability, the water level in Brownlee Reservoir is approximately 2,075 ft msl by the first week in December. If the reservoir is filled to that level, the system can provide stable, reliable energy through the winter and reduce operating costs by minimizing the need for purchasing outside power.

During these months, IPC maintains minimum flows below Hells Canyon Dam to ensure sufficient water levels for fall chinook spawning nests. By January or February, IPC begins to draft the reservoir to meet elevation targets for flood control.

Spring, March through May**—**The COE's North Pacific Division defines flood-control requirements and coordinates flood-control efforts with IPC. During the spring, IPC complies with article 42 and responds to the COE request to lower the water level in Brownlee Reservoir. The lower water level provides space for excess spring runoff and helps prevent flooding, primarily on the lower Columbia and lower Snake rivers.

In IPC's license, FERC requires that the reservoir's elevation be at or below 2,034 ft by 1 March, a level that provides approximately 500,000 acre-feet of storage space for flood control. The license also stipulates that the COE may request an additional 500,000 acre-feet of storage space, if necessary. However, in past years when the snow pack was less than normal, the COE reduced the storage space requirement.

In the mid-1980s, the COE examined the reservoir's flood-control operation and developed a rule curve table for Brownlee Reservoir's target elevations. These target elevations define the space in the reservoir needed for flood control and are based on forecasted runoff at both the Brownlee and The Dalles projects. More recently, the rule curve procedure was improved. This new rule curve now provides a more gradual change in reservoir elevations to reach required storage volumes by targeted dates.

IPC initiated the new rule curve for water year 2000 flood-control requirements. Depending on the water year and COE mandates, flood-control requirements for Brownlee Reservoir may continue through June. In order to meet mandated target elevations for flood control, IPC may need to spill water through the HCC. Although there are no official refill target elevations, the COE controls how quickly the reservoir can be refilled once flood-control requirements are met.

Summer, June through August—After IPC is released from flood-control responsibilities, the company begins refilling Brownlee Reservoir. The refill target is 2,069 ft msl (about 8 ft below the full reservoir capacity of 2,077 ft) toward the end of May and full by the end of June. Meeting these targets ensures that enough water is stored in Brownlee Reservoir to meet peak summer electricity demands, provide suitable spawning habitat for bass and crappie, and offer optimal recreational opportunities.

In an effort to cooperate with federal efforts to meet flow objectives at Lower Granite Dam outlined in the 1995 and 2000 FCRPS flow augmentation RPA, since 1996 IPC has released water from Brownlee Reservoir to contribute to the federal flow augmentation program. If Brownlee Reservoir is full by 1 July and projections indicate that the space will refill on time, IPC has contributed up to 237,000 acre-feet of water from Brownlee Reservoir during the summer. IPC's cooperative contribution has been generally defined by reservoir space rather than a specific amount of storage water. To effectuate its contribution, IPC drafts Brownlee Reservoir to an elevation of 2,059 ft msl, which, if the reservoir is full, equals a contribution of approximately 237,000 acre-feet.

Also during these months, BOR projects upstream begin releasing 427,000 acre-feet of water to increase Snake River flows in an effort to meet the Lower Granite Dam flow objectives. Because BOR cannot release all of that water within the augmentation period, some of the federal water does not reach Lower Granite Dam during the flow augmentation period specified in the RPA. So, during July and August, IPC shapes (or prereleases) water from Brownlee Reservoir and later refills the drafted reservoir space with water released by the BOR from the upper Snake River reservoirs. In a typical year, Brownlee Reservoir shapes approximately 130,000 acre-feet of BOR water. The volume of water shaped fluctuates depending on the type of water year the Snake River Basin is experiencing.

As mentioned earlier, the BPA agreed to an energy exchange with IPC for IPC's cooperation with the flow augmentation RPA. Under this agreement, BPA reimbursed IPC for energy losses resulting from shaping BOR water and contributing water from Brownlee Reservoir. Again, that agreement was not renewed by BPA after it expired in April 2001.

Historically, there were some years when weather, stream flow, and power demands require further drafting of Brownlee Reservoir.

Fall, September through November—During the fall, Brownlee Reservoir is operated largely to benefit fall chinook below the HCC. After the delivery of flow augmentation water, Brownlee Reservoir releases are managed to maintain a constant flow below Hells Canyon Dam to provide stable conditions for spawning fall chinook. The spawning flow is based upon a minimum reservoir elevation of approximately 2,040 ft msl when the program starts in October, and forecasted inflows such that Brownlee Reservoir is full, around elevation 2,075 ft msl, by the first week in December. The minimum flow below Hells Canyon Dam is maintained through fry emergence in the spring and established by maintaining water over the shallow-most redd. Once this flow is set, it is considered the minimum flow necessary to keep embryos from desiccating until they emerge as fry in the spring. In other words, the spawning flow is maintained as a minimum flow until emergence is complete. It should also be pointed out that the lower the reservoir elevation in Brownlee Reservoir, the lower the power production capability of the plant. This situation, in turn, may require IPC to purchase power from other sources if the load demand cannot be met due to the loss in net head at the reservoir.

3. METHODS

We described the existing landscape pattern of riparian habitat based on the IPC cover-type map for the Hells Canyon Study Area (Holmstead 2001a). This map was developed using standard photo-interpretation techniques on July/August 1993 1:15,000-scale color-infrared aerial photos. Twenty-six vegetation, natural feature, and land-use cover types are represented (Appendix 1), and depicted spatially as cover-type polygons in a Geographic Information System.

The evaluation area extended along the Snake River from Weiser, Idaho, downriver to the confluence of the Snake and Salmon rivers, and included the Powder River Arm and Pool in Oregon. We divided the evaluation area laterally in each state into 2 resolutions: 1) The study area, which encompassed the boundaries of the cover-type map (0.5 mi from the shorelines of the Weiser Reach, and Brownlee, Oxbow, and Hells Canyon reservoirs, and 0.25 mi from the shoreline between Hells Canyon Dam and the Salmon River), and 2) Shoreline, which included lands within 50 m of the waterline in Holmstead (2001a) (Table 1). Evaluations of the study area included riparian vegetation along reservoir/river shorelines and in tributary drainages and ephemeral streams, whereas analyses within 50 m of shorelines were largely restricted to river/reservoir shoreline vegetation. Within each resolution, we subdivided the area into 6 river reaches: the Weiser Reach, Brownlee Reservoir, the Powder River Arm and Pool, Oxbow Reservoir, Hells Canyon Reservoir, and the river below Hells Canyon Dam. Then, within each reach, we analyzed each side of the river separately (i.e., Idaho and Oregon, except Powder River, which is only in Oregon). These divisions resulted in 22 evaluation strata (Table 1).

We used the raster version of the cover-type map to analyze fragmentation of riparian habitats within each of the 22 strata. Analyses were conducted on 3 of 4 of the riparian/wetland cover types, as defined in the classification scheme for map development (Appendix 1, Table 2). The riparian cover types were *Emergent Herbaceous Wetland, Scrub-Shrub Wetland,* and *Forested Wetland*. The remaining cover types comprised the landscape matrix. We performed an additional analysis on only woody riparian vegetation (i.e., *Scrub-Shrub* and *Forested Wetlands*). We assumed there was no difference in habitat quality within and among riparian polygons of the same cover-type. Inferences were restricted to the resolution and assumptions of the cover-type map (Holmstead 2001a).

We used the Patch Analyst extension (Elkie et al. 1999) in ArcView™ to calculate 15 fragmentation metrics (McGarigal and Marks 1995; Table 3)[1]. Metrics included mean patch size and density, edge density, and mean nearest neighbor. Other metrics described the shape, proximity, and interspersion of riparian patches. We qualitatively compared results among strata to characterize current patterns of riparian habitat fragmentation throughout the evaluation area.

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[1] ArcView is a trademark of the Environmental Systems Research Institute, Inc.

4. RESULTS

Riparian vegetation was typically found on <5% of the study area (Table 4, Figure 3) and <9% of the shoreline (Table 5, Figure 3). The exception was the Powder River Arm and Pool, where 10% of the study area and 11% of the shoreline was riparian vegetation. Woody riparian vegetation (i.e., *Scrub-Shrub Wetlands* and *Forested Wetlands*) composed, on average, 84% of the total riparian vegetation (Tables 6 and 7). This percentage, however, varied among reaches. Nearly all of the riparian vegetation was woody in Oxbow and Hells Canyon reservoirs and below Hells Canyon Dam, compared to 83% for Brownlee Reservoir, 64% for the Weiser Reach, and 44% for the Powder River Arm and Pool. Fragmentation patterns were generally similar between states within each reach.

Riparian habitat patches were typically small, fragmented, and isolated across the entire study area (i.e., full extent of the cover-type map). The mean riparian patch size was 0.63 ha and the mean woody riparian patch was 0.51 ha (Tables 4 and 6). However, there was a large range in patch sizes, as indicated by their large coefficients of variations. The Powder River Arm and Pool had the largest mean patch size of 1.97 ha, due to *Emergent Herbaceous Wetlands* at the western end of the pool (Figure 3, panel 6). The Weiser Reach also had large patches, with a mean size of 1.08 ha on both sides of the river. The smallest mean patch size was 0.24 ha on the Oregon side of Brownlee Reservoir. On the study area, the mean distance between riparian patches was 58.6 m and patch density was 6.97 patches/100 ha. Mean distance between woody riparian patches was 55.5 m. Most strata had low Mean Proximity Index (MPI) values, indicating that riparian patches were typically fragmented and isolated. The extreme exception was the Powder River Pool, where riparian vegetation was well connected. Woody riparian vegetation was most fragmented and isolated along Brownlee Reservoir and downstream of Hells Canyon Dam.

Riparian vegetation within 50 m of the shoreline was typically found in smaller, more isolated patches than compared to the entire study area. For all shoreline riparian vegetation, the mean patch size was 0.33 ha, with a mean distance between patches of 94.41 m (Table 5). For woody vegetation, the mean patch size was 0.28 ha, with a mean distance of 84.79 m between patches (Table 7). Shoreline vegetation was most significant on the Weiser Reach, where 61% of the riparian vegetation was along the shoreline or on islands, compared to an average of 21% for all other reaches. Furthermore, the mean distance between shoreline patches was 28.49 m and the MPI increased, again indicating well-connected shoreline vegetation on the Weiser Reach. Shoreline vegetation on Brownlee was the most isolated, with an average of 244.50 m between patches.

The amount of edge and edge density in the landscape was fairly high. The mean density of riparian edge for the study area was 33.11 m/ha. Riparian patches were typically thin and narrow (Figure 3), with an inherent high amount and proportion of edge. This is reflected in the shape index and fractal dimension metric. Mean shape indices were low, demonstrating that they were rectangular in nature (e.g., higher indices would result from complicated, convoluted shapes). Mean patch fractal dimensions were generally low, indicating that perimeters of patches were also simple in shape (i.e., linear). Brownlee Reservoir and areas downstream of Hells Canyon Dam had patches with slightly more complicated shapes in comparison to other reaches.

We interpreted the riparian vegetation patterns within each river/reservoir reach as follows:

1) The Weiser Reach is unique in that it contains several islands and that the surrounding landscape is relatively flat with few drainages. The shoreline vegetation on both the mainland and islands was characterized by a well-developed mix of riparian-vegetation types. The Weiser Reach had the largest woody riparian patches, which were fairly close together.

2) The shoreline of Brownlee Reservoir was largely unvegetated. Riparian vegetation was mainly found in tributary drainages, which were isolated, fragmented, and patchy.

3) The lower gradient of the Powder River has resulted in large, well-connected patches of riparian vegetation at the western end of the Powder River Pool. Much of the vegetation was *Emergent Herbaceous Wetlands*, but also included significant patches of *Forested Wetlands.* Fragmentation was typically higher along the steeper shorelines of the Powder River Arm.

4) Oxbow and Hells Canyon reservoirs had similar landscape patterns. They were characterized by a steep and deeply dissected landscape, containing tributary drainages and ephemeral streams in wooded draws, which were often connected with small patches of woody-shoreline vegetation. Oxbow Reservoir had a higher concentration of wooded draws across the landscape than Hells Canyon Reservoir.

5) Shoreline vegetation below Hells Canyon Dam was present in small, isolated, and clumped patches. The landscape is considerably steeper and rockier than Oxbow or Hells Canyon reservoirs, thus tributary vegetation was more limited in extent.

5. DISCUSSION

Existing riparian vegetation in Hells Canyon is typically linear in nature, and patchy and fragmented across the landscape. Except for the Weiser Reach, woody riparian vegetation in Hells Canyon is largely restricted to tributary drainages and ephemeral streams. Small, disconnected patches are found along the shorelines of Oxbow and Hells Canyon reservoirs and below Hells Canyon Dam. The shoreline of Brownlee Reservoir is largely unvegetated.

The existing pattern of riparian vegetation and fragmentation is the result of physiographic, HCC operational, and other anthropogenic processes. Deep, laterally confined canyon walls and the abundance of surficial bedrock and cobble provide a static streamside zone that is not conducive to extensive recruitment and survival of woody riparian plants (J. Braatne, University of Idaho, personal communication). Riparian vegetation is adapted to and dependent upon dynamic flow patterns and the repeated flooding of unconfined floodplains. The unique fluvial landscape of Hells Canyon has always provided extremely limited opportunities for the recruitment and survival of woody riparian plants (J. Braatne, University of Idaho, personal communication). For example, Blair et al. (2001) found little evidence of historic forested wetlands, except at the mouth of Pine Creek, where a cottonwood stand still exists today.

However, the lower gradients of the Weiser Reach and Powder River Pool allow development of significant shoreline vegetation.

Shoreline vegetation has been influenced by reservoir operations since the completion of Brownlee Dam in 1959. Current operations of the HCC are influenced not only by power-generation demands, but also by federal requirements for flood control and anadromous fish protection (Parkinson 2001). Large water-level fluctuations on Brownlee Reservoir have resulted in significant erosion and sparse shoreline vegetation (Holmstead 2001b), often consisting of weedy annuals (Krichbaum 2000, Holmstead 2001a, Braatne et al. 2002). However, shoreline vegetation along Oxbow and Hells Canyon reservoirs and downstream of Hells Canyon Dam has likely benefited by the daily water-level fluctuations during the growing season (Holmstead 2001a). Particularly, this irrigation effect may have increased the extent of hackberry downstream of Hells Canyon Dam (Blair et al. 2001), although scouring flows from spring run-off restrict this vegetation to a narrow band (Holmstead 2001a). Since the completion of the HCC, declines in the intensity and duration of scouring flows (i.e., flows >100,000 cfs) in Hells Canyon have potentially encouraged the downslope extension of hackberry via root suckers. Elevated summer flows in the Snake River (i.e., load following in the upstream projects) may have helped increase the vigor of riparian hackberry stands. Hackberry canopies are currently larger and more robust than shown in historic photos (Blair et al. 2000). Coyote willow, however, has decreased along with decreased sediment loads in the Snake River (Blair et al. 2001, Parkinson et al. 2002). Sediment loss is largely attributed to upstream dams on the Snake River and on major tributaries (e.g., Boise and Payette rivers) (Parkinson et al. 2002).

Anthropogenic factors before and after dam construction have also influenced riparian vegetation. Blair et al. (2001) conducted an extensive study of historic photographs and records, dating back to at least the early 1900s. Their study demonstrated that riparian vegetation (e.g., coyote willow and hackberry) throughout Hells Canyon had been severely degraded by agriculture, grazing, and mining since the early 1900s. In fact, woody vegetation has increased along Oxbow and Hells Canyon reservoirs, downstream of Hells Canyon Dam, and in tributaries largely due to decreased livestock-grazing pressure. Woody riparian vegetation has also increased in the Weiser Reach, due to past changes in water management at upstream reservoirs (Dixon and Johnson 1999). However, much of this increase is in nonnative tree species, such as Russian olive (*Elaeagnus angustifolia*), silver maple, tamarisk, and European willows (*S. rubens* and *S. alba*), which have been introduced by residential and agricultural influences (Dixon and Johnson 1999, Krichbaum 2000, Blair et al. 2001, Holmstead 2001a).

Beyond habitat loss, there is little empirical evidence documenting negative effects of riparian fragmentation in Western landscapes. A recent study by Tewksbury et al. (1998) in western Montana showed that nest predation was lower in riparian areas fragmented by agriculture than nearby unfragmented forested-riparian areas, where the red squirrel (*Tamiasciurus hudsonicus*) was the dominant nest predator. Skagen et al. (1998) found more migrating bird species in riparian oases (i.e., fragments) than in continuous-riparian corridors, and found no differences in species abundances. They concluded that all riparian habitats were important for migrating birds, regardless of continuity. Overall effects of fragmentation are a complicated interaction of landscape context, habitat structure, and community composition (Donovan et al. 1997, Tewksbury et al. 1998). Therefore, loss of riparian habitat, rather than effects resulting from fragmentation (e.g., population isolation, increased nest predation), should be considered in future protection, mitigation, and enhancement projects in Hells Canyon.

6. SUMMARY AND CONCLUSIONS

Within physiographic boundaries, current operations of the HCC influence riparian vegetation and fragmentation in Hells Canyon. Existing riparian vegetation, both along reservoir/river shorelines and within tributary drainages, was typically linear in nature, and patchy and fragmented across the landscape. Because of their gentle gradients, the Weiser Reach and Powder River Pool are the only sections that resemble an alluvial (i.e., floodplain) system. These reaches, therefore, support relatively continuous shoreline riparian vegetation. Brownlee Reservoir, which is the most influenced by current operations, has sparse and highly fragmented riparian vegetation. Oxbow and Hells Canyon reservoirs, and the river downstream of Hells Canyon Dam have patchy, but significant shoreline vegetation.

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Table 1. Evaluation strata used for the riparian fragmentation study in Hells Canyon, as divided by state, resolution, and reach.

Evaluation Strata		
State	**Resolution**	**Reach**
Idaho	0.5 mi above shoreline	Weiser to Brownlee Reservoir
Idaho	0.5 mi above shoreline	Brownlee Reservoir
Idaho	0.5 mi above shoreline	Oxbow Reservoir
Idaho	0.5 mi above shoreline	Hells Canyon Reservoir
Idaho	0.25 mi above shoreline	Hells Canyon Dam to Salmon River
Idaho	50 m above shoreline	Weiser to Brownlee Reservoir
Idaho	50 m above shoreline	Brownlee Reservoir
Idaho	50 m above shoreline	Oxbow Reservoir
Idaho	50 m above shoreline	Hells Canyon Reservoir
Idaho	50 m above shoreline	Hells Canyon Dam to Salmon River
Oregon	0.5 mi above shoreline	Weiser to Brownlee Reservoir
Oregon	0.5 mi above shoreline	Brownlee Reservoir
Oregon	0.5 mi above shoreline	Powder River Pool and Arm
Oregon	0.5 mi above shoreline	Oxbow Reservoir
Oregon	0.5 mi above shoreline	Hells Canyon Reservoir
Oregon	0.25 mi above shoreline	Hells Canyon Dam to Salmon River
Oregon	50 m above shoreline	Weiser to Brownlee Reservoir
Oregon	50 m above shoreline	Brownlee Reservoir
Oregon	50 m above shoreline	Powder River Pool and Arm
Oregon	50 m above shoreline	Oxbow Reservoir
Oregon	50 m above shoreline	Hells Canyon Reservoir
Oregon	50 m above shoreline	Hells Canyon Dam to Salmon River

Table 2. Cover types, habitat type classifications, and landscape types for the riparian-habitat fragmentation study in Hells Canyon.

Classification System		
Cover Type[a]	**Habitat Type**	**Landscape Type**
Emergent Herbaceous Wetland	Riparian	Habitat Patch
Scrub-Shrub Wetland	Riparian	Habitat Patch
Forested Wetland	Riparian	Habitat Patch
Standing Water	Water Surface	Water
Moving Water	Water Surface	Water
Forested Upland	Upland	Matrix
Shrubland	Upland	Matrix
Tree Savanna	Upland	Matrix
Shrub Savanna	Upland	Matrix
Desertic Woodland	Upland	Matrix
Desertic Shrubland	Upland	Matrix
Desertic Herbland	Upland	Matrix
Grassland	Upland	Matrix
Forbland	Upland	Matrix
Barrenland	Non-vegetated	Matrix
Cliff/Talus Slope	Non-vegetated	Matrix
Disturbed	Non-vegetated	Matrix
Shore and Bottomland Wetland	Non-vegetated	Matrix
Cultivated	Agriculture	Matrix
Pasture	Agriculture	Matrix
Orchard	Agriculture	Matrix
Urban	Human Developed	Matrix
Residential	Human Developed	Matrix
Industrial	Human Developed	Matrix
Parks/Recreation	Human Developed	Matrix
Roads	Human Developed	Matrix

[a] See Appendix 1 for cover type definitions.

Table 3. Landscape metrics used in the riparian-habitat fragmentation study in Hells Canyon.

Acronym	Definition[a]
PA	Patch area (ha), total area of a patch type.
TA	Total area of landscape under study (ha).
%LAND	Percent of landscape occupied by the patch type.
NP	Number of patches of a patch type.
PD	Patch density (number/100 ha).
MPS	Mean patch size (ha).
PSCV	Patch size coefficient of variation (%).
TE	Total edge (m) of a patch type.
ED	Edge density (m/ha).
CWED	Contrast-weighted edge density (m/ha), assigned weights to different types of edges. An edge between the terrestrial landscape and riparian vegetation was assigned a higher weight than that between water and riparian vegetation.
MSI	Mean shape index, measures the average perimter:area ratio for a patch type, MSI ≥1, without limit. MSI ≈ 1.00 when patches are simple (i.e., rectangular for grid data).
MPFD	Mean patch fractal dimension, a shape metric. MPFD ranges between 1 and 2, with 1 representing simple perimeter shapes. As MPFD approaches 2 the shapes are increasingly complex.
MNN	Mean nearest neighbor distance (m), of the same patch type.
MPI	Mean proximity index, measures the degree of isolation and fragmentation of a patch type. MPI ≥1, without limit. MPI = 0 if no patch has a nearby neighbor of the same patch type. MPI increases as patches become less isloated and fragmented.
IJI	Interspersion and juxtaposition index (%), measures the extent to which patch edges of the same type are interspersed. Higher values are from landscapes in which patch types are well interspersed (i.e., equally adjacent to one another).

[a] From McGarigal and Marks 1995.

Table 4. Riparian fragmentation metrics for each stratum of the Hells Canyon study area (0.5 mi above shorelines for all, except 0.25 mi above shoreline for downstream of Hells Canyon [HC] Dam).

Strata	PA[a]	TA	%LAND	NP	PD	MPS	PSCV	TE	ED	CWED	MSI	MPFD	MNN	MPI	IJI
Weiser, ID	106.22	2,401	4.42	81	3.37	1.31	208.84	82,660	34.42	30.59	2.21	1.15	41.67	76.07	95.30
Weiser, OR	83.36	2,423	3.44	99	4.09	0.84	202.79	76,300	31.48	27.81	2.05	1.14	48.80	40.54	96.63
Brownlee, ID	170.65	12,184	1.40	550	4.51	0.31	239.03	181,721	14.91	14.76	1.69	1.49	80.78	b	b
Brownlee, OR	154.55	13,658	1.13	637	4.66	0.24	277.37	168,839	12.36	12.26	1.61	1.50	88.89	b	b
Powder River, OR	174.47	1,832	9.52	90	4.91	1.94	448.85	78,200	42.70	41.31	1.90	1.13	55.90	519.70	49.62
Oxbow, ID	91.10	1,929	4.72	229	11.87	0.40	272.10	95,540	49.52	48.39	1.66	1.11	49.24	15.37	39.38
Oxbow, OR	78.12	1,839	4.25	239	13.00	0.33	205.50	94,840	51.58	49.80	1.69	1.11	41.03	18.79	51.89
Hells Canyon, ID	96.11	3,957	2.43	244	6.17	0.39	251.58	110,860	28.02	26.98	1.76	1.12	49.33	18.35	54.63
Hells Canyon, OR	108.22	3,868	2.80	241	6.23	0.45	187.50	120,520	31.16	29.82	1.83	1.12	56.01	17.19	59.90
Below HC Dam, ID	164.34	5,793	2.84	477	8.23	0.35	183.19	187,028	32.28	31.93	1.85	1.50	73.39	b	7.67
Below HC Dam, OR	196.88	5,882	3.35	565	9.61	0.35	196.55	210,505	35.79	35.33	1.76	1.50	59.98	b	b

[a] See Table 3 for fragmentation metric definitions.

[b] *Patch Analyst* could not calculate.

Table 5. Riparian fragmentation metrics for shoreline strata (50 m above shoreline) in Hells Canyon (HC).

Strata	PA[a]	TA	%LAND	NP	PD	MPS	PSCV	TE	ED	CWED	MSI	MPFD	MNN	MPI	IJI
Weiser, ID	57.06	698	8.17	58	8.31	0.98	154.02	57,860	82.87	70.13	2.36	1.16	26.50	51.97	99.55
Weiser, OR	58.73	765	7.68	85	11.11	0.69	198.57	59,940	78.37	67.00	1.92	1.12	30.48	54.19	100.00
Brownlee, ID	23.66	5,199	0.46	179	3.44	0.13	228.03	28,491	5.48	5.23	1.52	1.54	225.45	b	b
Brownlee, OR	29.93	5,536	0.54	202	3.65	0.15	577.03	26,008	4.70	4.58	1.44	1.55	263.55	b	b
Powder River, OR	32.59	292	11.16	38	13.01	0.86	275.45	24,660	84.44	75.87	1.71	1.11	78.21	188.02	99.57
Oxbow, ID	10.66	571	1.87	104	18.21	0.10	104.79	19,840	34.73	30.90	1.48	1.10	56.85	3.48	96.23
Oxbow, OR	13.06	563	2.32	107	19.01	0.12	154.93	22,260	39.59	34.71	1.47	1.09	51.12	3.49	98.41
Hells Canyon, ID	21.31	1,184	1.80	163	13.77	0.13	155.09	34,900	29.47	26.05	1.49	1.10	72.31	5.73	97.47
Hells Canyon, OR	23.19	1,185	1.96	150	12.66	0.15	167.21	37,480	31.63	27.61	1.57	1.10	75.37	7.59	99.13
Below HC Dam, ID	56.27	1,270	4.43	357	28.11	0.16	165.19	82,262	64.79	64.39	1.64	1.52	84.61	b	b
Below HC Dam, OR	62.36	1,272	4.90	410	32.23	0.15	159.21	88,137	69.28	68.54	1.57	1.51	74.01	b	b

[a] See Table 3 for fragmentation metric definitions.

[b] *Patch Analyst* could not calculate.

Table 6. *Scrub-Shrub* and *Forested Wetland* fragmentation metrics for each stratum of the Hells Canyon study area (0.5 mi above shorelines for all, except 0.25 mi above shoreline for downstream of Hells Canyon [HC] Dam).

Strata	**Pa[a]**	**TA**	**%LAND**	**NP**	**PD**	**MPS**	**PSCV**	**TE**	**ED**	**CWED**	**MSI**	**MPFD**	**MNN**	**MPI**	**IJI**
Weiser, ID	67.33	2,401	2.25	56	2.33	1.20	132.90	62,640	26.09	22.96	2.45	1.17	73.75	73.59	97.17
Weiser, OR	54.51	2,423	2.80	78	3.22	0.70	169.78	59,760	24.66	21.43	2.11	1.14	51.86	28.72	98.86
Brownlee, ID	143.12	12,184	1.17	516	4.23	0.28	219.02	195,060	16.01	31.13	1.73	1.12	84.55	9.70	14.60
Brownlee, OR	129.08	13,658	0.95	617	4.52	0.21	211.78	184,520	13.51	15.91	1.62	1.11	b	b	b
Powder River, OR	77.13	1,832	4.21	81	4.42	0.95	233.41	58,580	31.98	13.47	1.95	1.13	67.05	118.13	43.42
Oxbow, ID	90.99	1,929	4.72	228	11.82	0.40	271.79	95,380	49.44	48.30	1.67	1.11	49.44	15.40	39.42
Oxbow, OR	78.12	1,839	4.25	239	13.00	0.33	205.50	94,840	51.58	49.80	1.69	1.11	41.03	18.79	51.89
Hells Canyon, ID	95.90	3,957	2.42	240	6.07	0.40	249.81	110,380	27.90	26.88	1.77	1.12	51.24	18.59	54.06
Hells Canyon, OR	108.22	3,868	2.80	241	6.23	0.45	187.50	120,520	31.16	29.82	1.83	1.12	56.01	17.19	59.90
Below HC Dam, ID	162.82	5,793	2.81	478	8.25	0.34	183.63	225,000	38.84	38.39	1.92	1.14	74.42	9.79	23.75
Below HC Dam, OR	194.79	5,882	3.31	563	9.57	0.35	197.19	253,220	43.05	42.60	1.83	1.13	61.30	13.21	22.19

[a] See Table 3 for fragmentation metric definitions.

[B] *Patch Analyst* could not calculate.

Table 7. *Scrub-Shrub* and *Forested Wetland* fragmentation metrics for shoreline strata (50 m above shoreline) in Hells Canyon (HC).

Strata	**Pa[a]**	**TA**	**%LAND**	**NP**	**PD**	**MPS**	**PSCV**	**TE**	**ED**	**CWED**	**MSI**	**MPFD**	**MNN**	**MPI**	**IJI**
Weiser, ID	47.01	698	6.73	52	7.45	0.90	136.45	49,540	70.95	60.6	2.33	1.16	80.36	54.76	99.83
Weiser, OR	47.06	765	6.15	79	10.33	0.60	174.87	53,000	69.29	59.10	1.99	1.13	33.77	40.30	99.99
Brownlee, ID	19.04	5,199	0.37	153	2.94	0.12	179.87	31,320	6.02	51.82	1.44	1.09	b	b	b
Brownlee, OR	18.18	5,536	0.33	176	3.18	0.10	250.85	26,180	4.73	5.79	1.30	1.07	247.24	3.15	43.26
Powder River, OR	19.07	292	6.52	35	11.98	0.54	180.39	16,660	57.05	4.62	1.66	1.11	58.16	92.51	96.58
Oxbow, ID	10.66	571	1.87	104	18.23	0.10	104.79	19,840	34.73	30.90	1.48	1.10	56.85	3.48	96.23
Oxbow, OR	13.06	562	2.32	107	19.03	0.12	154.93	22,260	39.59	34.71	1.47	1.09	51.12	3.49	98.41
Hells Canyon, ID	21.09	1,184	1.78	158	13.34	0.13	153.78	34,420	29.07	25.72	1.50	1.10	76.23	5.82	97.33
Hells Canyon, OR	23.19	1,184	1.96	150	12.66	0.15	167.21	37,480	31.63	27.61	1.57	1.10	75.37	7.59	99.13
Below HC Dam, ID	54.60	1,270	4.30	346	27.25	0.16	162.64	97,100	76.48	74.43	1.66	1.11	95.57	3.80	44.43
Below HC Dam, OR	61.29	1,272	4.82	399	31.37	0.15	160.65	104,040	81.80	79.78	1.57	1.10	73.22	5.15	42.14

[a] See Table 3 for fragmentation metric definitions.

[B] *Patch Analyst* could not calculate.

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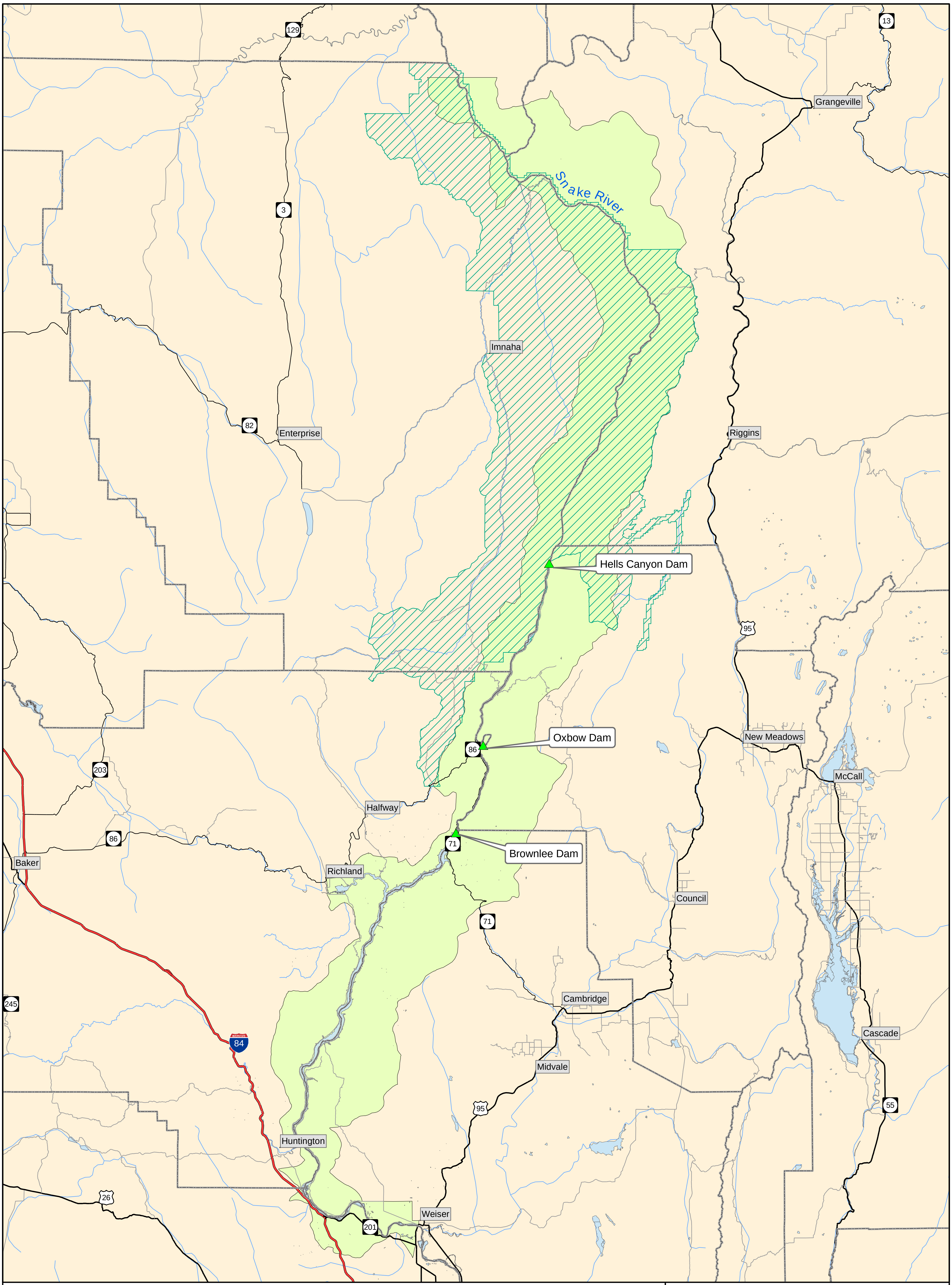

Vicinity Map

IDAHO POWER
An IDACORP Company

Features Legend

- ━ Primary Route
- ━ Secondary Route
- — Major Road
- — Minor Road
- - - County
- ~ Rivers
- 🟩 Study Area
- ▨ Hells Canyon National Recreation Area
- 🟦 Lakes

Hells Canyon Hydroelectric Project - FERC No. 1971

Tech. Report E.3.2-41 Figure 1

Hells Canyon Study Area

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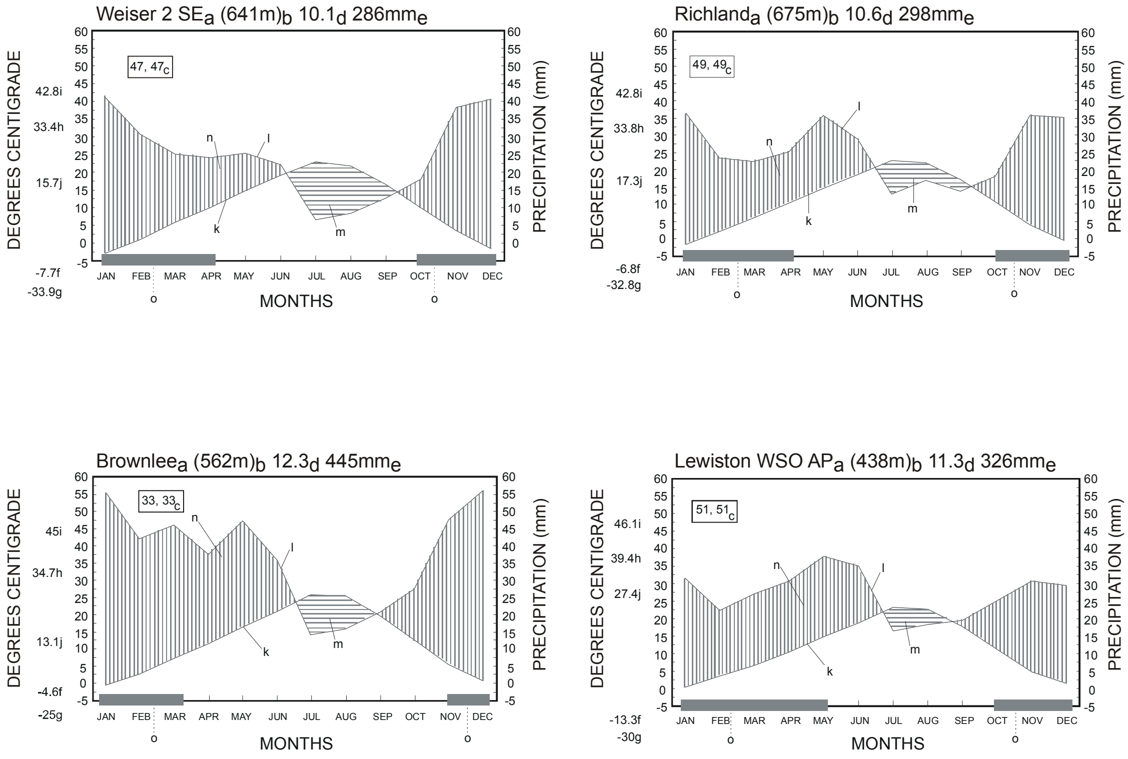

a: Station
b: Elevation
c: Number of years of observation (temperature, precipitation)
d: Mean annual temperature in °C
e: Mean annual precipitation in millimeters
f: Mean daily minimum of the coldest month
g: Lowest recorded temperature
h: Mean daily maximum of the hottest month
i: Highest recorded temperature
j: Mean daily temperature range
k: Monthly means of temperature in °C
l: Monthly means of precipitation in millimeters
m: Arid period (horizontal hatched)
n: Humid period (vertical hatched)
o: Months with an absolute minimum below 0 °C

Figure 2. Köppen climate diagrams for the Weiser, Richland, Brownlee, and Lewiston weather stations, Hells Canyon Study Area, Idaho-Oregon border.

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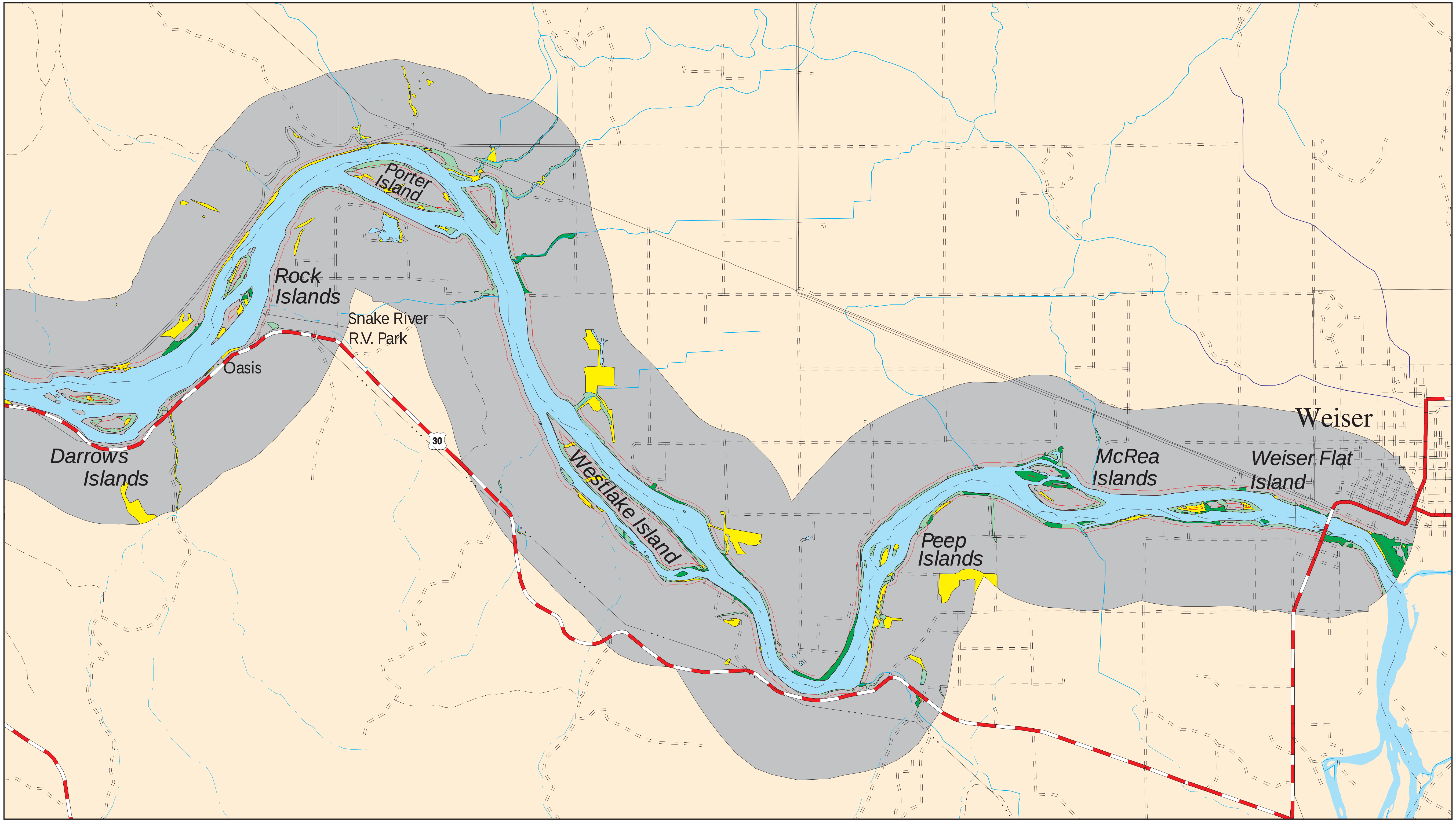
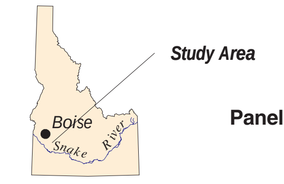
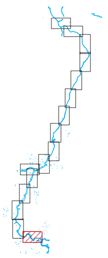




Vicinity Map

Panel 1 of 16



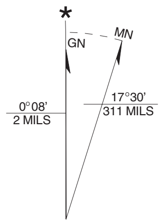
Geographic Information Services

Base Features Legend

- Primary Route
- Secondary Route
- Light Duty Road
- Unimproved Road
- Trail
- Railroad
- Transmission Line
- Perennial River or Stream
- Intermittent River or Stream
- Ditch or Canal
- Political Boundary
- IPC Project Facility
- ◆ Pump Station
- Spring
- ○ Well

Thematic Features Legend

- 🟦 Water Body
- 🟨 Emergent Herbaceous Wetland
- 🟩 Scrub-Shrub Wetland
- 🟩 Forested Wetland
- ⬜ Non-Wetland Covertypes
- 50m Above Full Pool



UTM GRID AND 1987
MAGNETIC NORTH DECLINATION
AT CENTER OF OXBOW QUADRANGLE

Tech. Report E.3.2 - 41 Figure 3

Riparian vegetation in Hells Canyon

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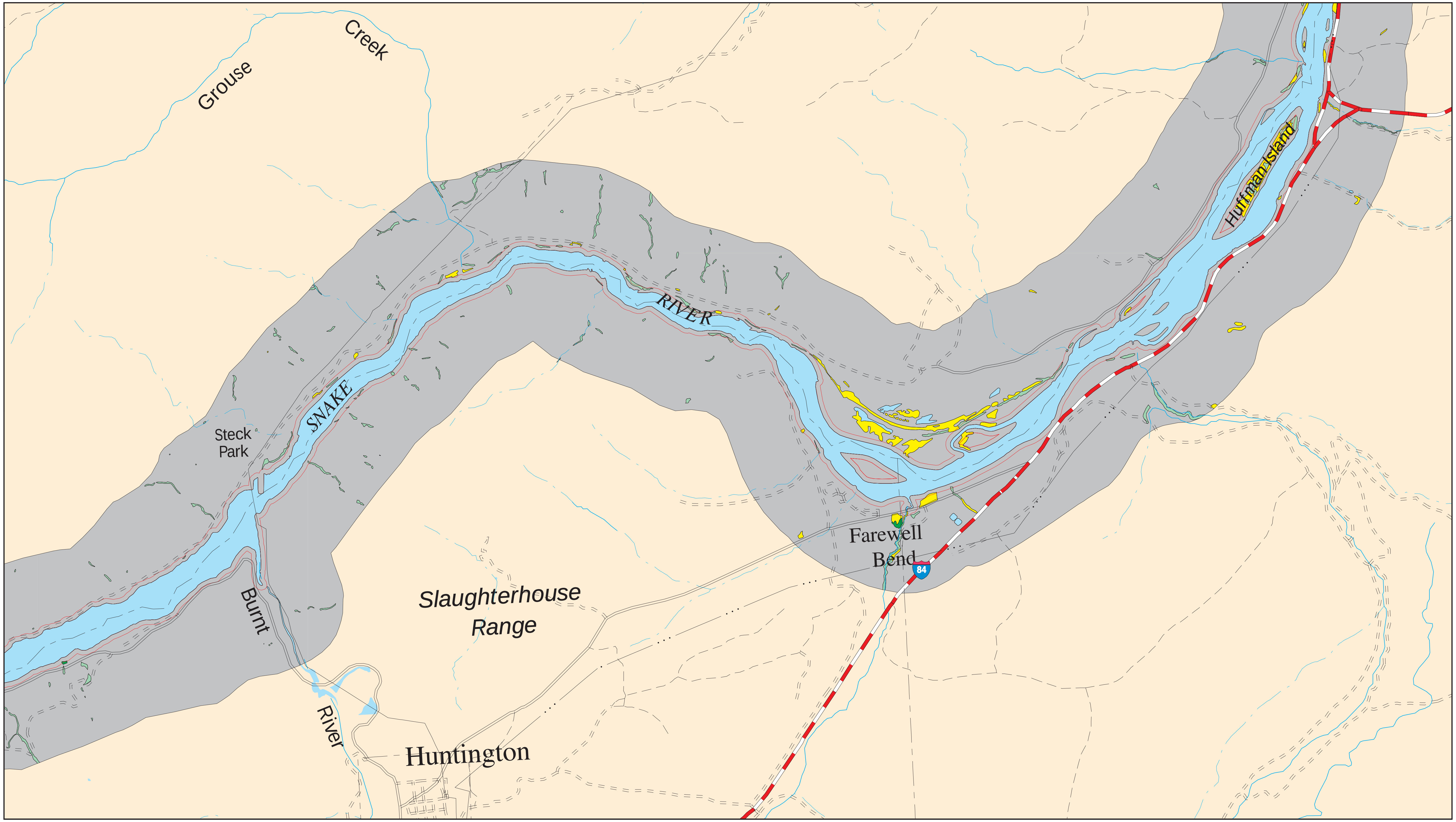
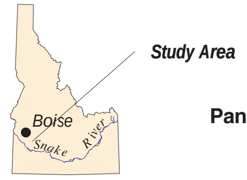
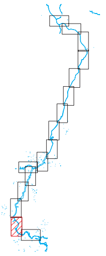




Vicinity Map

Panel 2 of 16



IDAHO POWER
Geographic Information Services

Base Features Legend

- Primary Route
- Secondary Route
- Light Duty Road
- Unimproved Road
- Trail
- Railroad
- Transmission Line
- Perennial River or Stream
- Intermittent River or Stream
- Ditch or Canal
- Political Boundary
- IPC Project Facility
- ◆ Pump Station
- Spring
- ○ Well

Thematic Features Legend

- Water Body
- Emergent Herbaceous Wetland
- Scrub-Shrub Wetland
- Forested Wetland
- Non-Wetland Covertypes
- 50m Above Full Pool

Tech. Report E.3.2 - 41 Figure 3

Riparian vegetation in Hells Canyon

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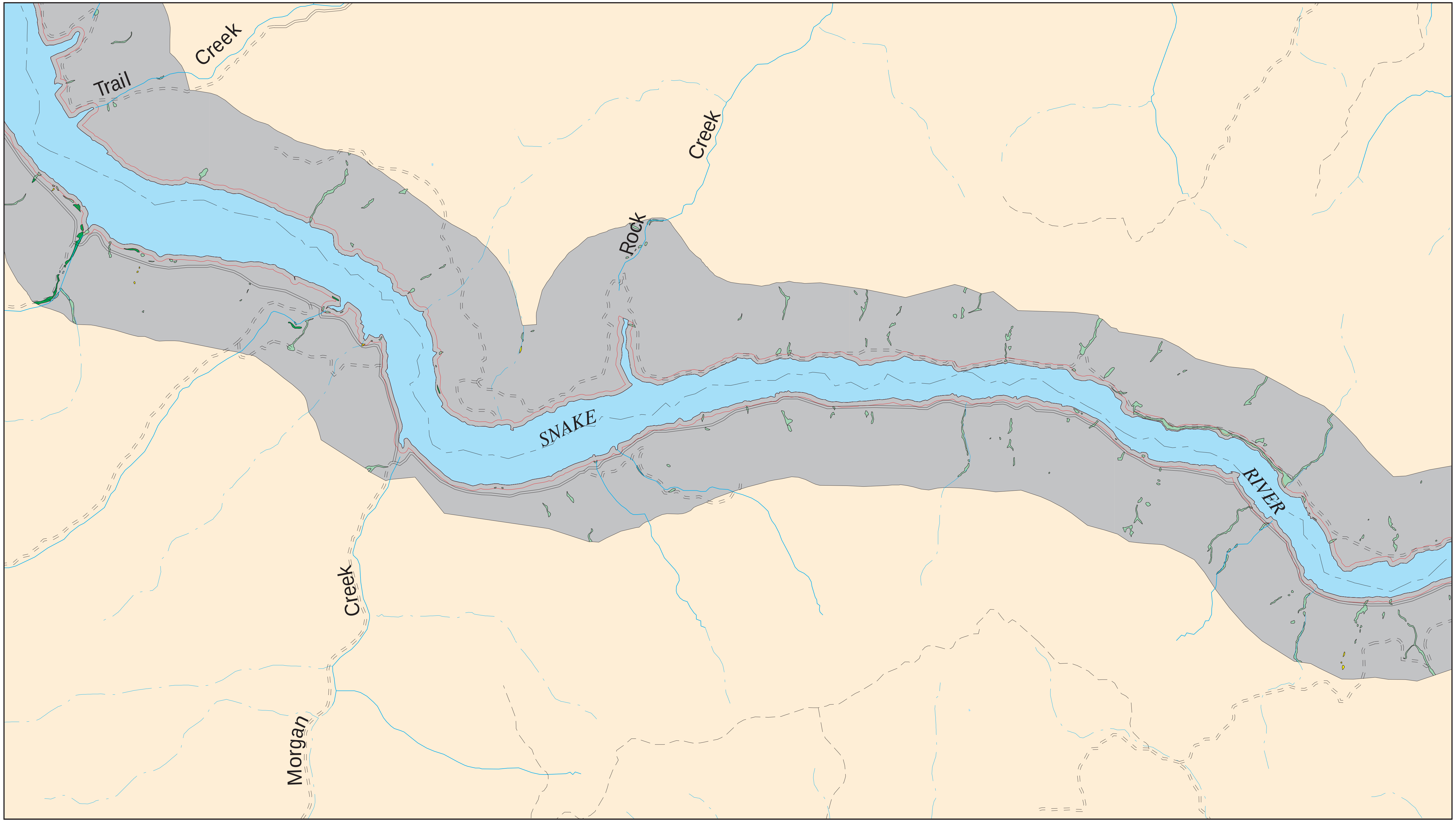
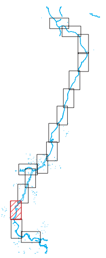


Vicinity Map

Panel 3 of 16



IDAHO POWER
Geographic Information Services

Base Features Legend

- Primary Route
- Secondary Route
- Light Duty Road
- Unimproved Road
- Trail
- Railroad
- Transmission Line
- Perennial River or Stream
- Intermittent River or Stream
- Ditch or Canal
- Political Boundary
- IPC Project Facility
- ◆ Pump Station
- Spring
- ○ Well

Thematic Features Legend

- 🟦 Water Body
- 🟨 Emergent Herbaceous Wetland
- 🟩 Scrub-Shrub Wetland
- 🟩 Forested Wetland
- ⬜ Non-Wetland Covertypes
- 50m Above Full Pool

N

Tech. Report E.3.2 - 41 Figure 3

Riparian vegetation in Hells Canyon

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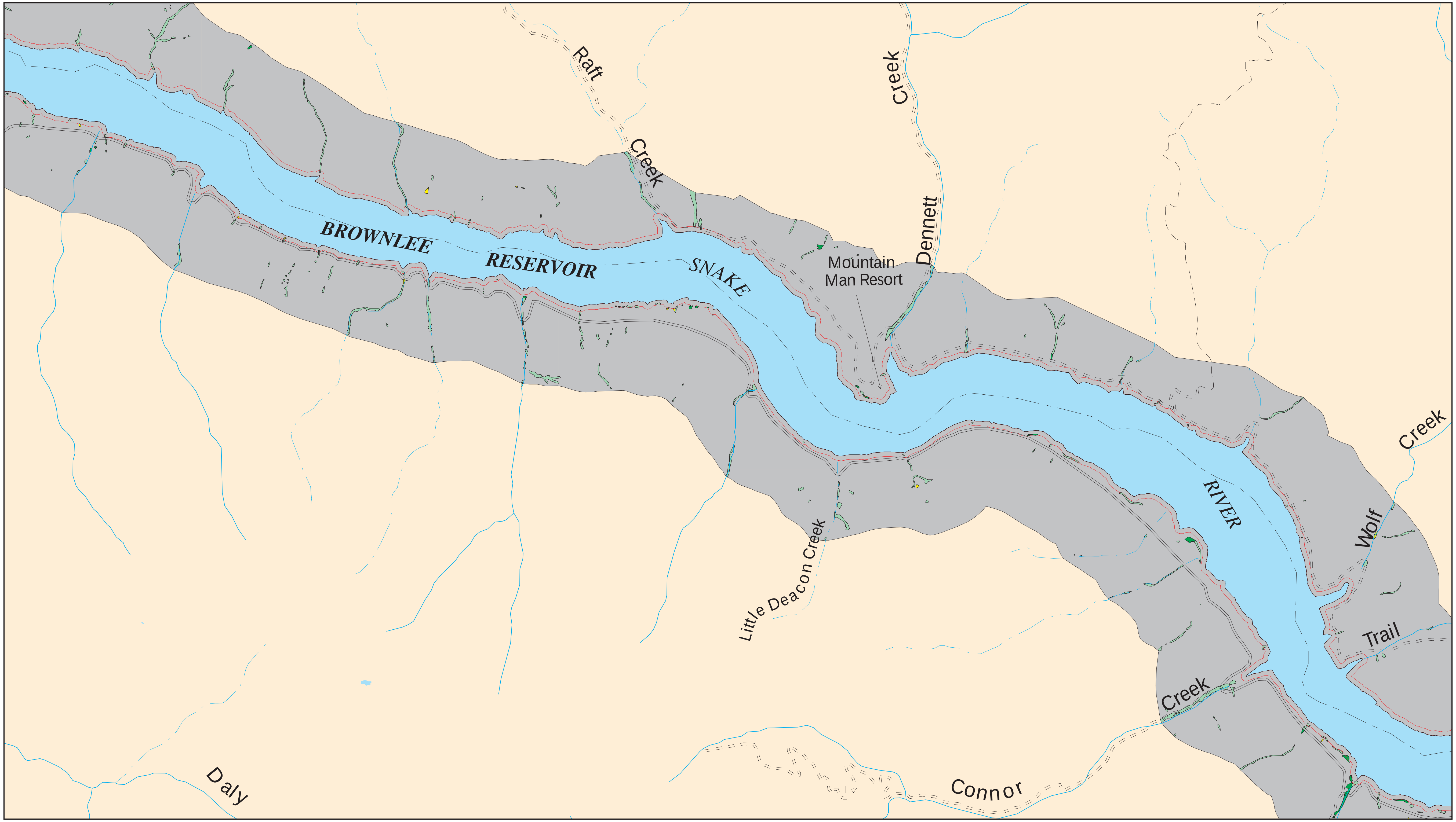
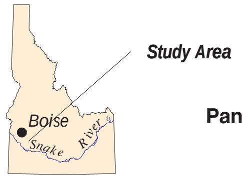
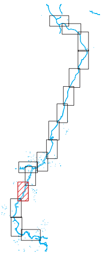




Vicinity Map

Panel 4 of 16



Geographic Information Services

Base Features Legend

- Primary Route
- Secondary Route
- Light Duty Road
- Unimproved Road
- Trail
- Railroad
- Transmission Line
- Perennial River or Stream
- Intermittent River or Stream
- Ditch or Canal
- Political Boundary
- IPC Project Facility
- ◆ Pump Station
- Spring
- ○ Well

Thematic Features Legend

- Water Body
- Emergent Herbaceous Wetland
- Scrub-Shrub Wetland
- Forested Wetland
- Non-Wetland Covertypes
- 50m Above Full Pool

N

Tech. Report E.3.2 - 41 Figure 3

Riparian vegetation in Hells Canyon

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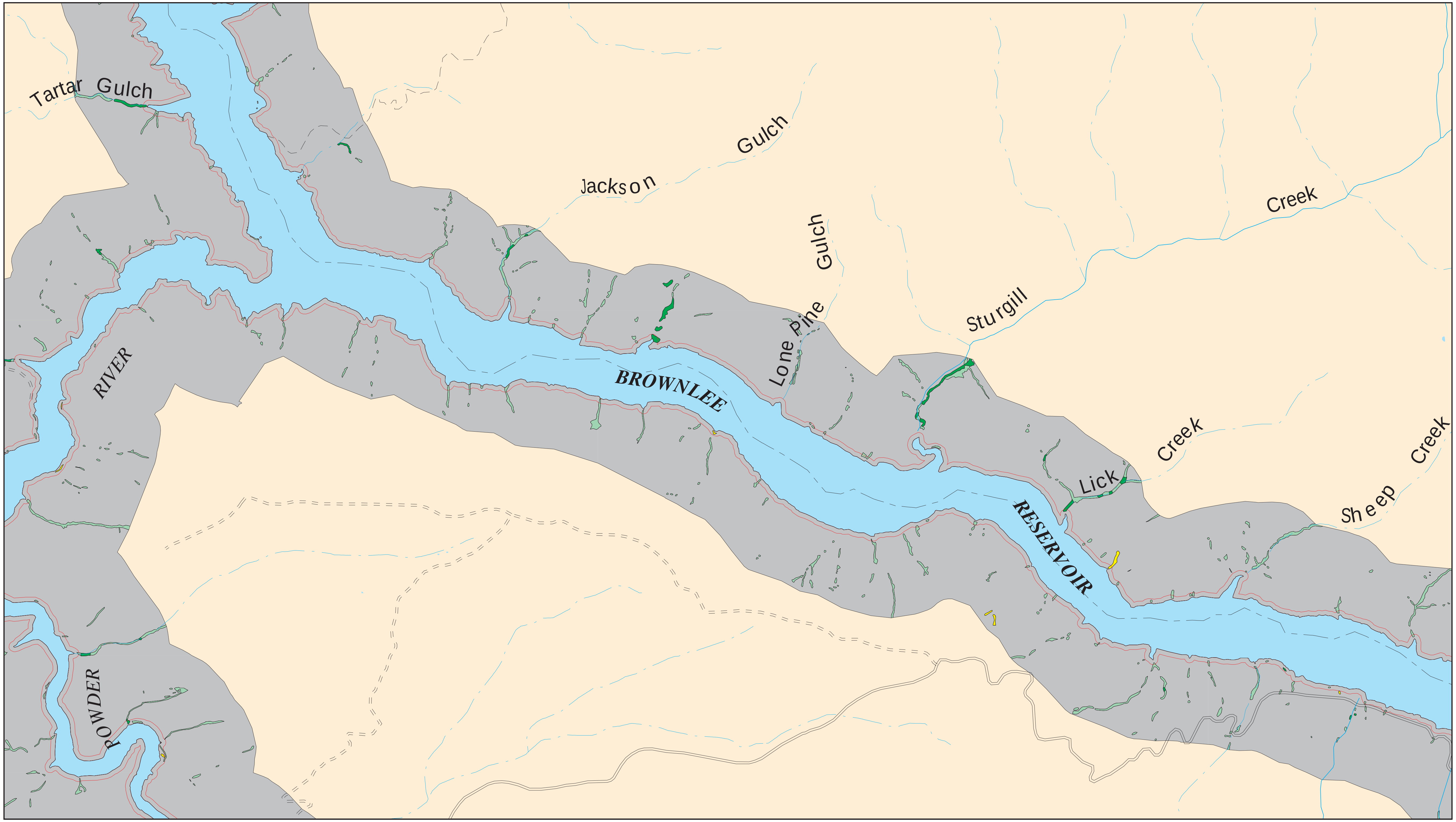
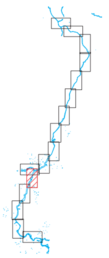


Vicinity Map

Panel 5 of 16



IDAHO POWER
Geographic Information Services

Base Features Legend

- Primary Route
- Secondary Route
- Light Duty Road
- Unimproved Road
- Trail
- Railroad
- Transmission Line
- Perennial River or Stream
- Intermittent River or Stream
- Ditch or Canal
- Political Boundary
- IPC Project Facility
- ◆ Pump Station
- Spring
- ○ Well

Thematic Features Legend

- 🟦 Water Body
- 🟨 Emergent Herbaceous Wetland
- 🟩 Scrub-Shrub Wetland
- 🟩 Forested Wetland
- ⬜ Non-Wetland Covertypes
- 50m Above Full Pool

Tech. Report E.3.2 - 41 Figure 3

Riparian vegetation in Hells Canyon

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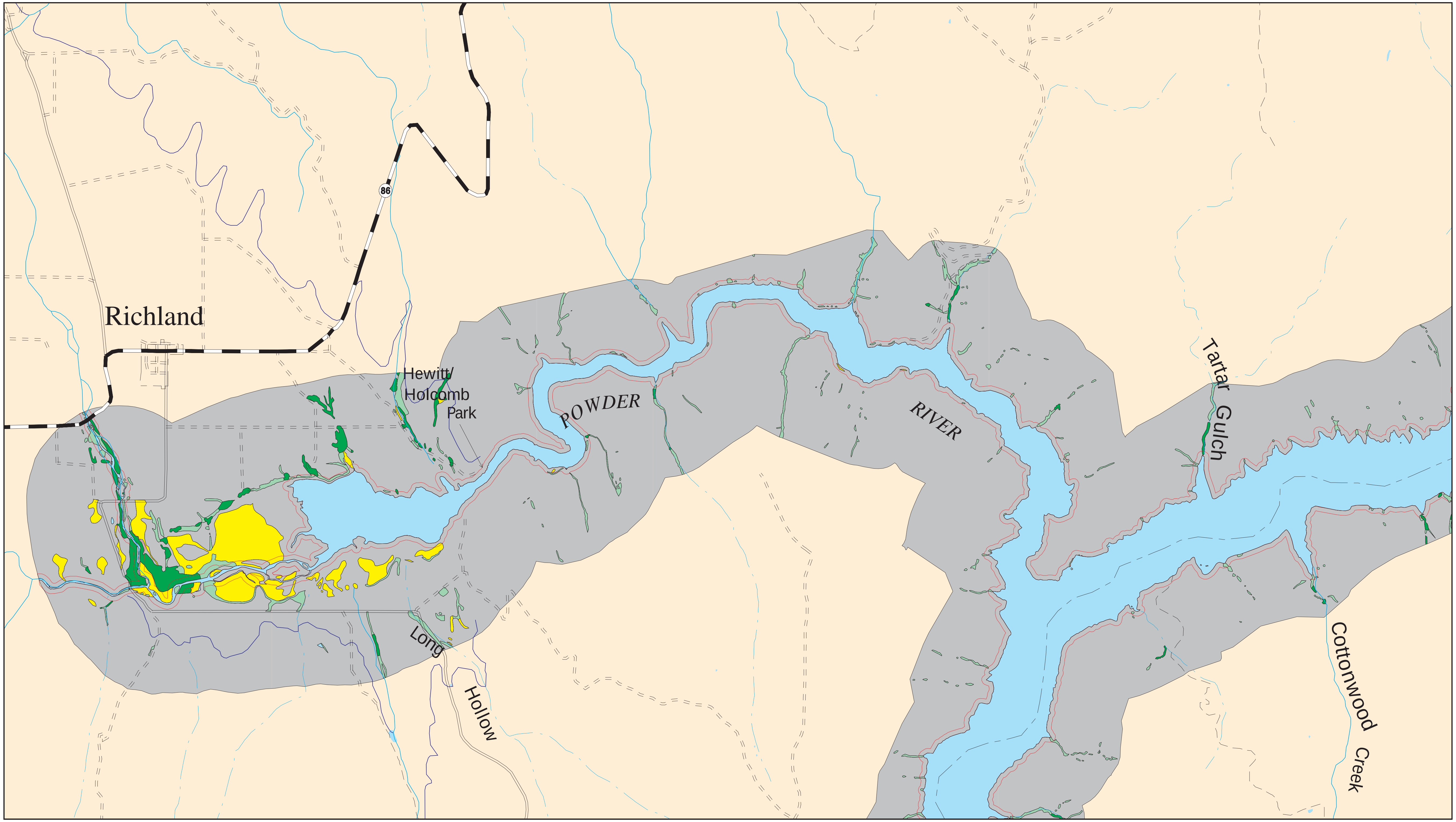
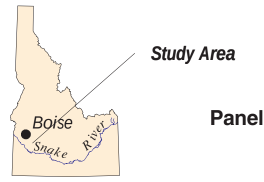
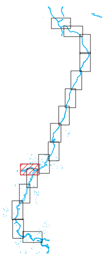




Vicinity Map

Panel 6 of 16



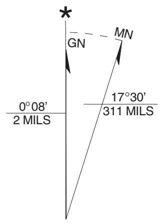
Idaho Power
Geographic Information Services

Base Features Legend

- Primary Route
- Secondary Route
- Light Duty Road
- Unimproved Road
- Trail
- Railroad
- Transmission Line
- Perennial River or Stream
- Intermittent River or Stream
- Ditch or Canal
- Political Boundary
- IPC Project Facility
- ◆ Pump Station
- ○ Spring
- ○ Well

Thematic Features Legend

- 🟦 Water Body
- 🟨 Emergent Herbaceous Wetland
- 🟩 Scrub-Shrub Wetland
- 🟩 Forested Wetland
- ⬜ Non-Wetland Covertypes
- 50m Above Full Pool



UTM GRID AND 1987
MAGNETIC NORTH DECLINATION
AT CENTER OF OXBOW QUADRANGLE

Tech. Report E.3.2 - 41 Figure 3

Riparian vegetation in Hells Canyon

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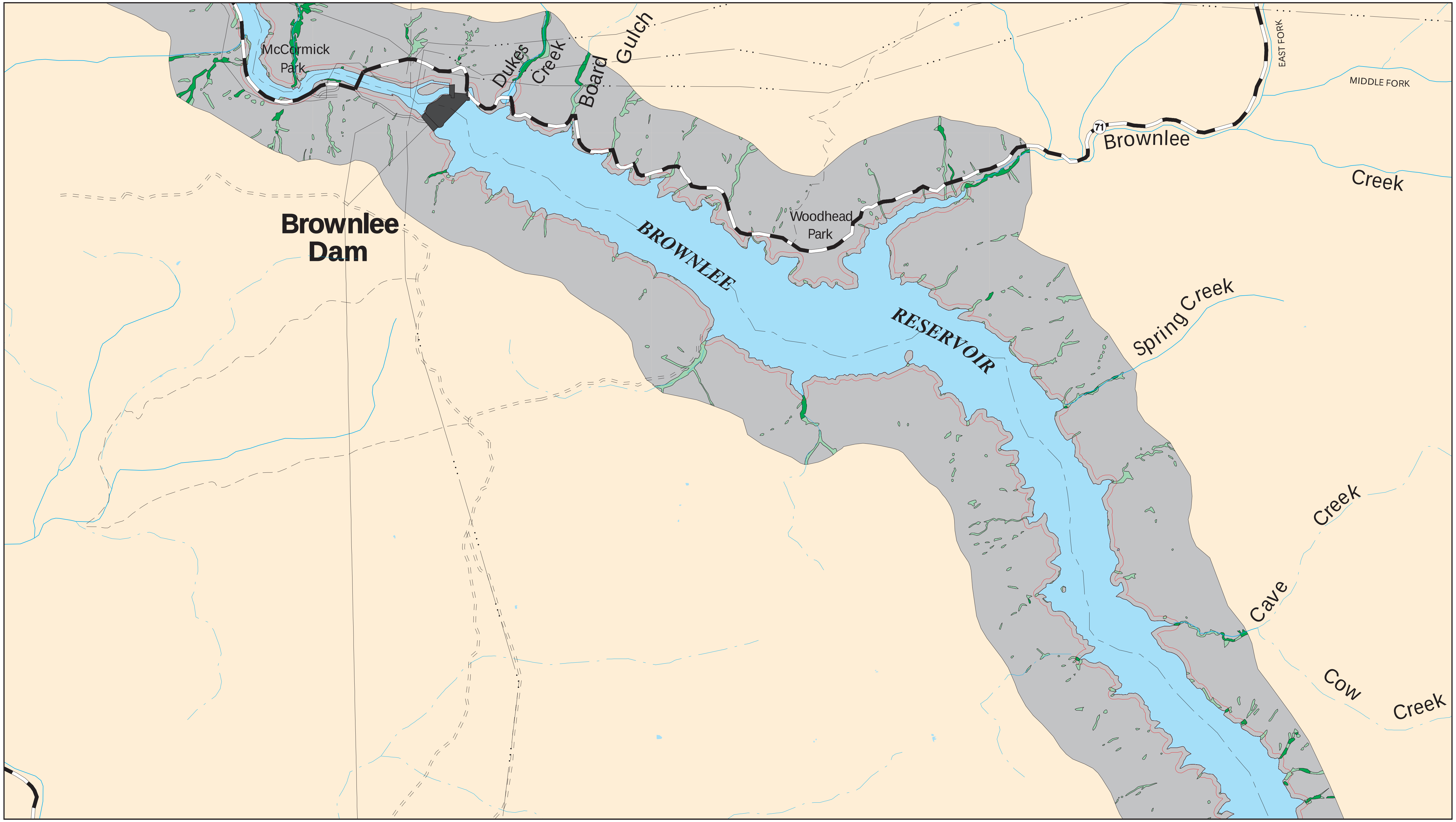
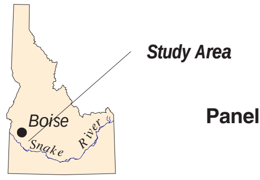
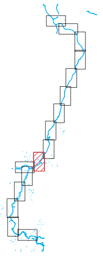




Vicinity Map

Panel 7 of 16



Geographic Information Services

Base Features Legend

- Primary Route
- Secondary Route
- Light Duty Road
- Unimproved Road
- Trail
- Railroad
- Transmission Line
- Perennial River or Stream
- Intermittent River or Stream
- Ditch or Canal
- Political Boundary
- IPC Project Facility
- ◆ Pump Station
- Spring
- ○ Well

Thematic Features Legend

- Water Body
- Emergent Herbaceous Wetland
- Scrub-Shrub Wetland
- Forested Wetland
- Non-Wetland Covertypes
- 50m Above Full Pool

N

Tech. Report E.3.2 - 41 Figure 3

Riparian vegetation in Hells Canyon

1 .5 0 MILES

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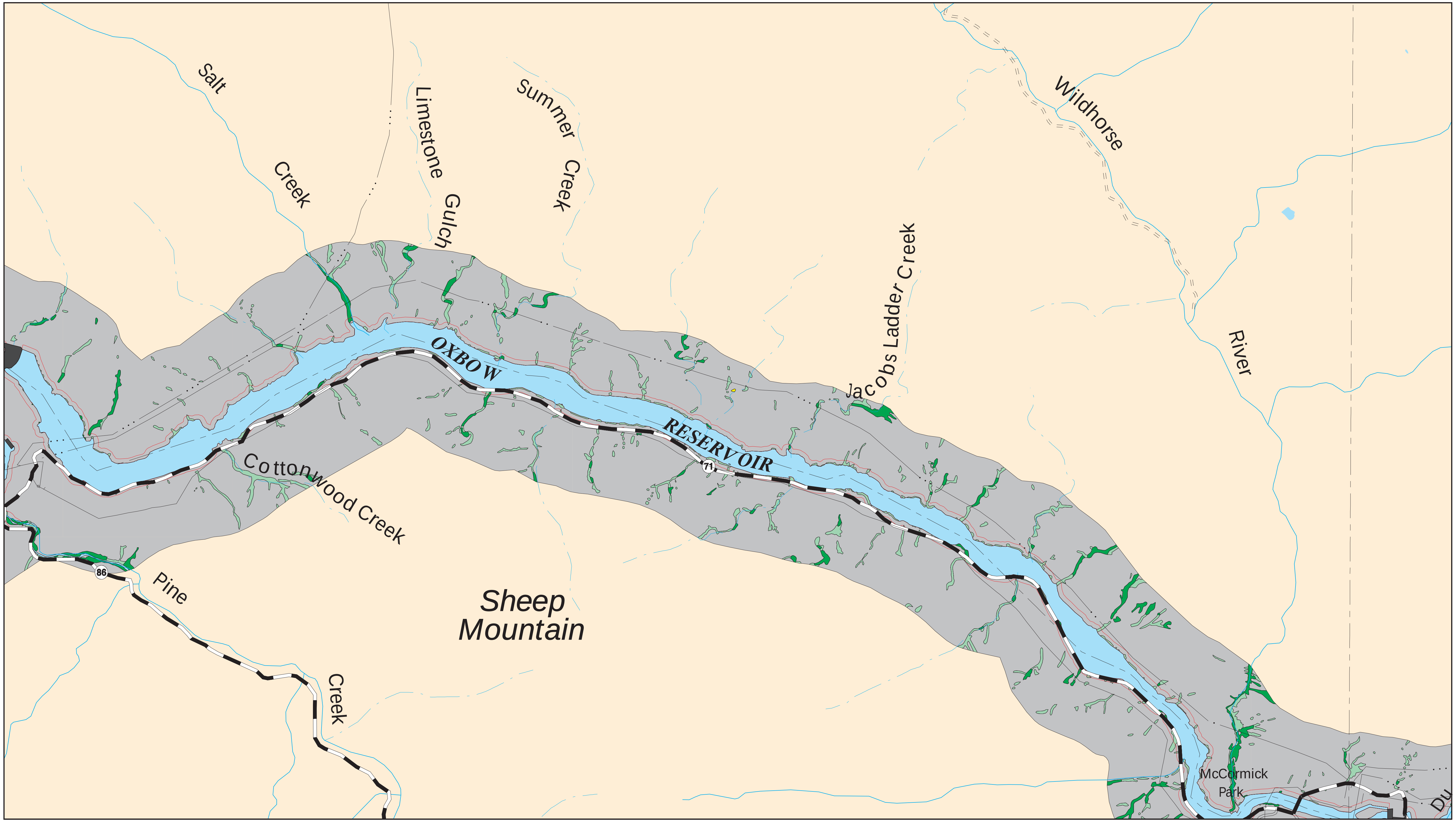
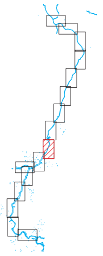


Vicinity Map

Panel 8 of 16



IDAHO POWER
Geographic Information Services

Base Features Legend

- Primary Route
- Secondary Route
- Light Duty Road
- Unimproved Road
- Trail
- Railroad
- Transmission Line
- Perennial River or Stream
- Intermittent River or Stream
- Ditch or Canal
- Political Boundary
- IPC Project Facility
- ◆ Pump Station
- Spring
- ○ Well

Thematic Features Legend

- 🟦 Water Body
- 🟨 Emergent Herbaceous Wetland
- 🟩 Scrub-Shrub Wetland
- 🟩 Forested Wetland
- ⬜ Non-Wetland Covertypes
- 50m Above Full Pool

N

Tech. Report E.3.2 - 41 Figure 3

Riparian vegetation in Hells Canyon

1 .5 0 MILES

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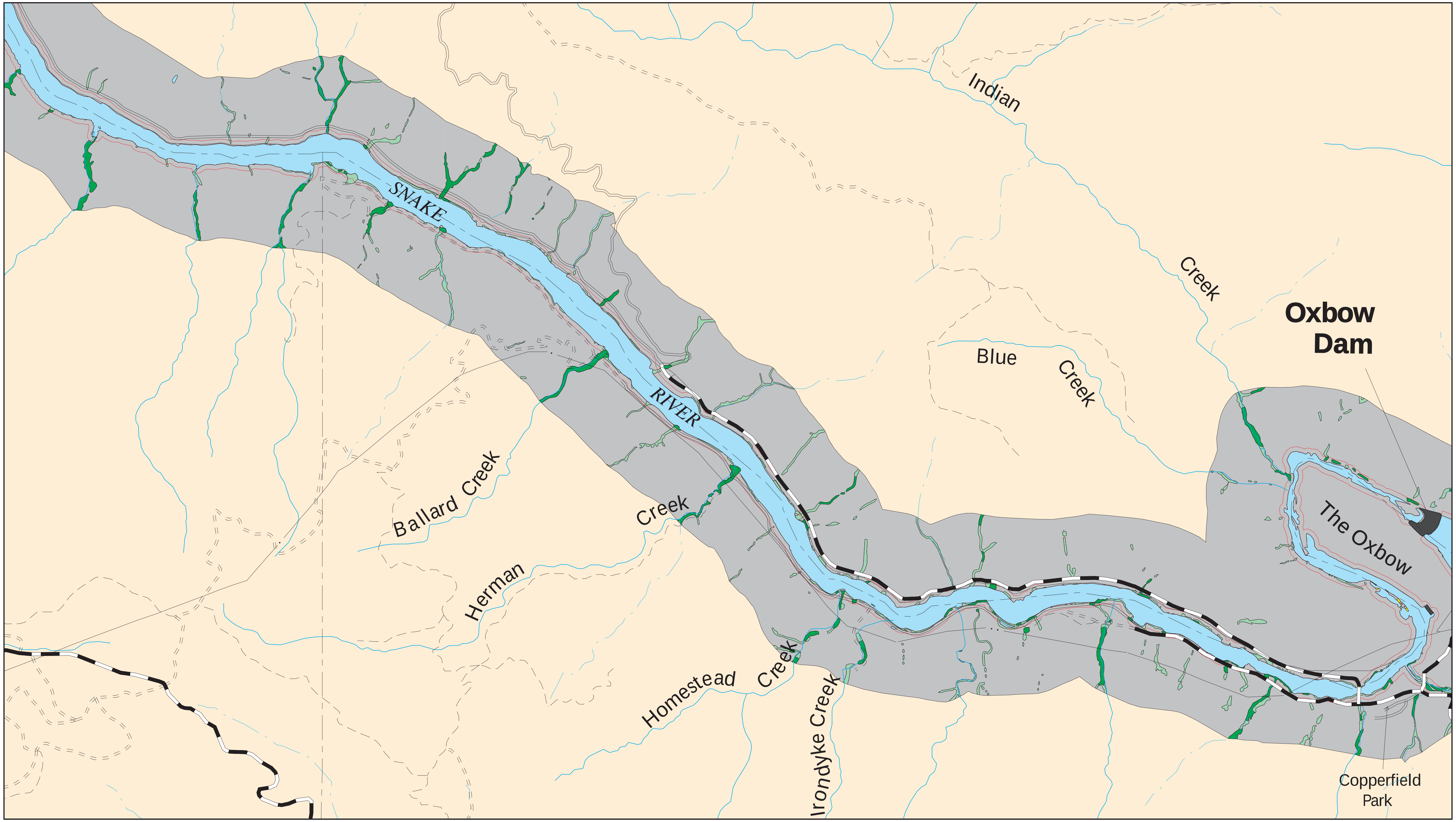
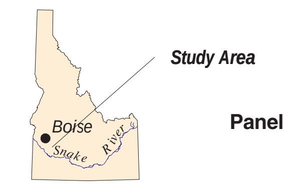
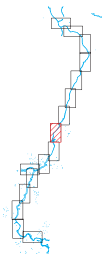




Vicinity Map

Panel 9 of 16



Geographic Information Services

Base Features Legend

- Primary Route
- Secondary Route
- Light Duty Road
- Unimproved Road
- Trail
- Railroad
- Transmission Line
- Perennial River or Stream
- Intermittent River or Stream
- Ditch or Canal
- Political Boundary
- IPC Project Facility
- ◆ Pump Station
- Spring
- ○ Well

Thematic Features Legend

- 🟦 Water Body
- 🟨 Emergent Herbaceous Wetland
- 🟩 Scrub-Shrub Wetland
- 🟩 Forested Wetland
- ⬜ Non-Wetland Covertypes
- 50m Above Full Pool

Tech. Report E.3.2 - 41 Figure 3

Riparian vegetation in Hells Canyon

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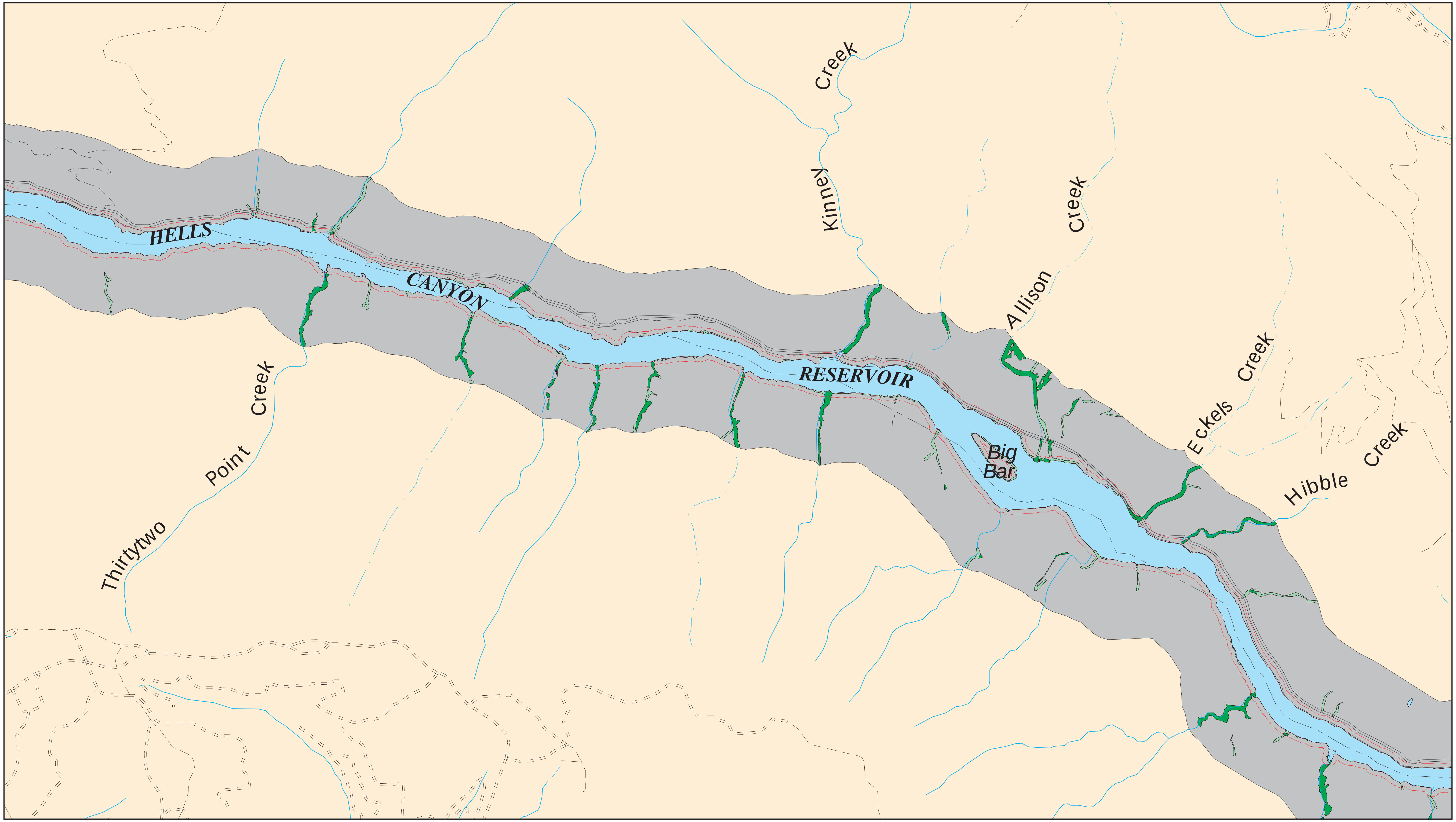

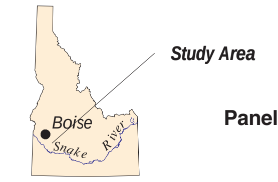

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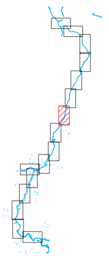
Panel 10 of 16



IDAHO POWER
Geographic Information Services

Base Features Legend

- Primary Route
- Secondary Route
- Light Duty Road
- Unimproved Road
- Trail
- Railroad
- Transmission Line
- Perennial River or Stream
- Intermittent River or Stream
- Ditch or Canal
- Political Boundary
- IPC Project Facility
- ◆ Pump Station
- Spring
- ○ Well

Thematic Features Legend

- Water Body
- Emergent Herbaceous Wetland
- Scrub-Shrub Wetland
- Forested Wetland
- Non-Wetland Covertypes
- 50m Above Full Pool

Tech. Report E.3.2 - 41 Figure 3

Riparian vegetation in Hells Canyon

1 .5 0 MILES

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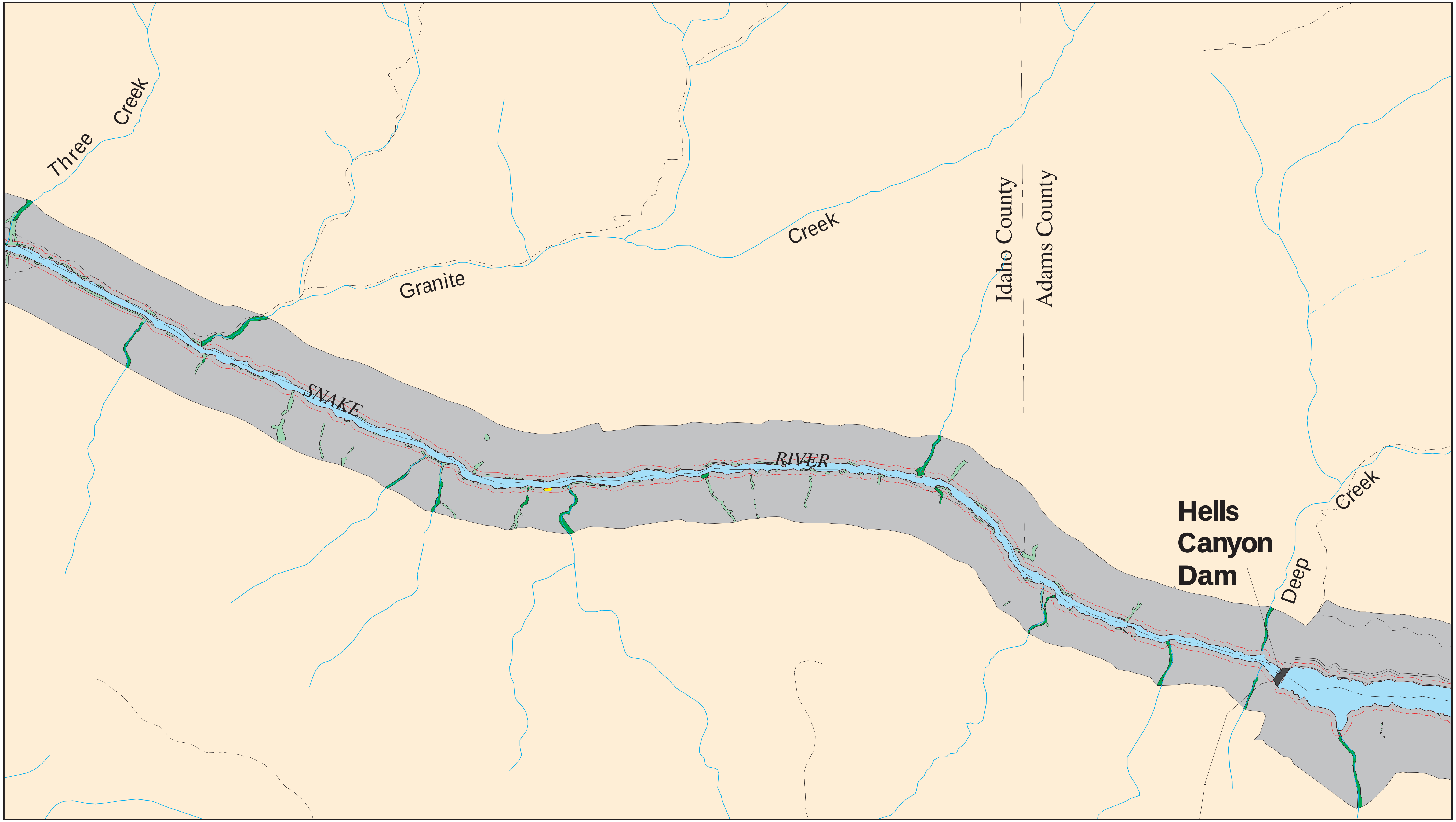
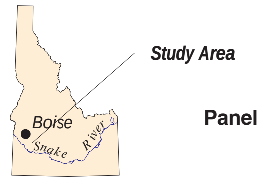
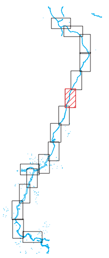




Vicinity Map

Panel 11 of 16



IDAHO POWER
Geographic Information Services

Base Features Legend

- Primary Route
- Secondary Route
- Light Duty Road
- Unimproved Road
- Trail
- Railroad
- Transmission Line
- Perennial River or Stream
- Intermittent River or Stream
- Ditch or Canal
- Political Boundary
- IPC Project Facility
- ◆ Pump Station
- Spring
- ○ Well

Thematic Features Legend

- 🟦 Water Body
- 🟨 Emergent Herbaceous Wetland
- 🟩 Scrub-Shrub Wetland
- 🟩 Forested Wetland
- ⬜ Non-Wetland Covertypes
- 50m Above Full Pool

Z

Tech. Report E.3.2 - 41 Figure 3

Riparian vegetation in Hells Canyon

1 .5 0 MILES

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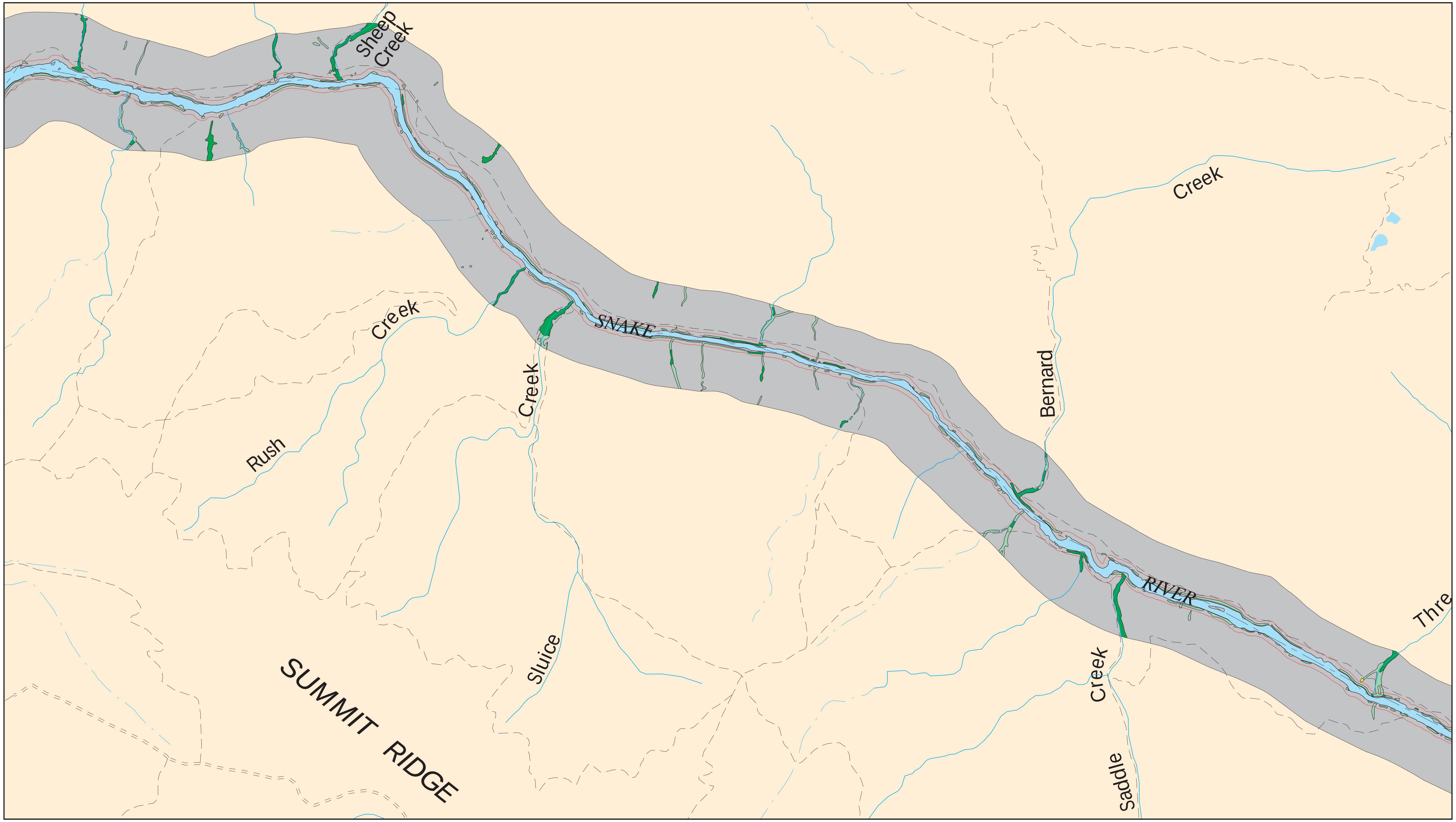
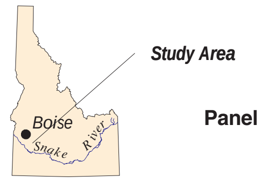
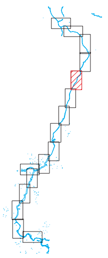




Vicinity Map

IDAHO POWER
Geographic Information Services

Panel 12 of 16



Base Features Legend

- Primary Route
- Secondary Route
- Light Duty Road
- Unimproved Road
- Trail
- Railroad
- Transmission Line
- Perennial River or Stream
- Intermittent River or Stream
- Ditch or Canal
- Political Boundary
- IPC Project Facility
- ◆ Pump Station
- ○ Spring
- ○ Well

Thematic Features Legend

- 🟦 Water Body
- 🟨 Emergent Herbaceous Wetland
- 🟩 Scrub-Shrub Wetland
- 🟩 Forested Wetland
- ⬜ Non-Wetland Covertypes
- 50m Above Full Pool

N

Tech. Report E.3.2 - 41 Figure 3

Riparian vegetation in Hells Canyon

1 .5 0 MILES

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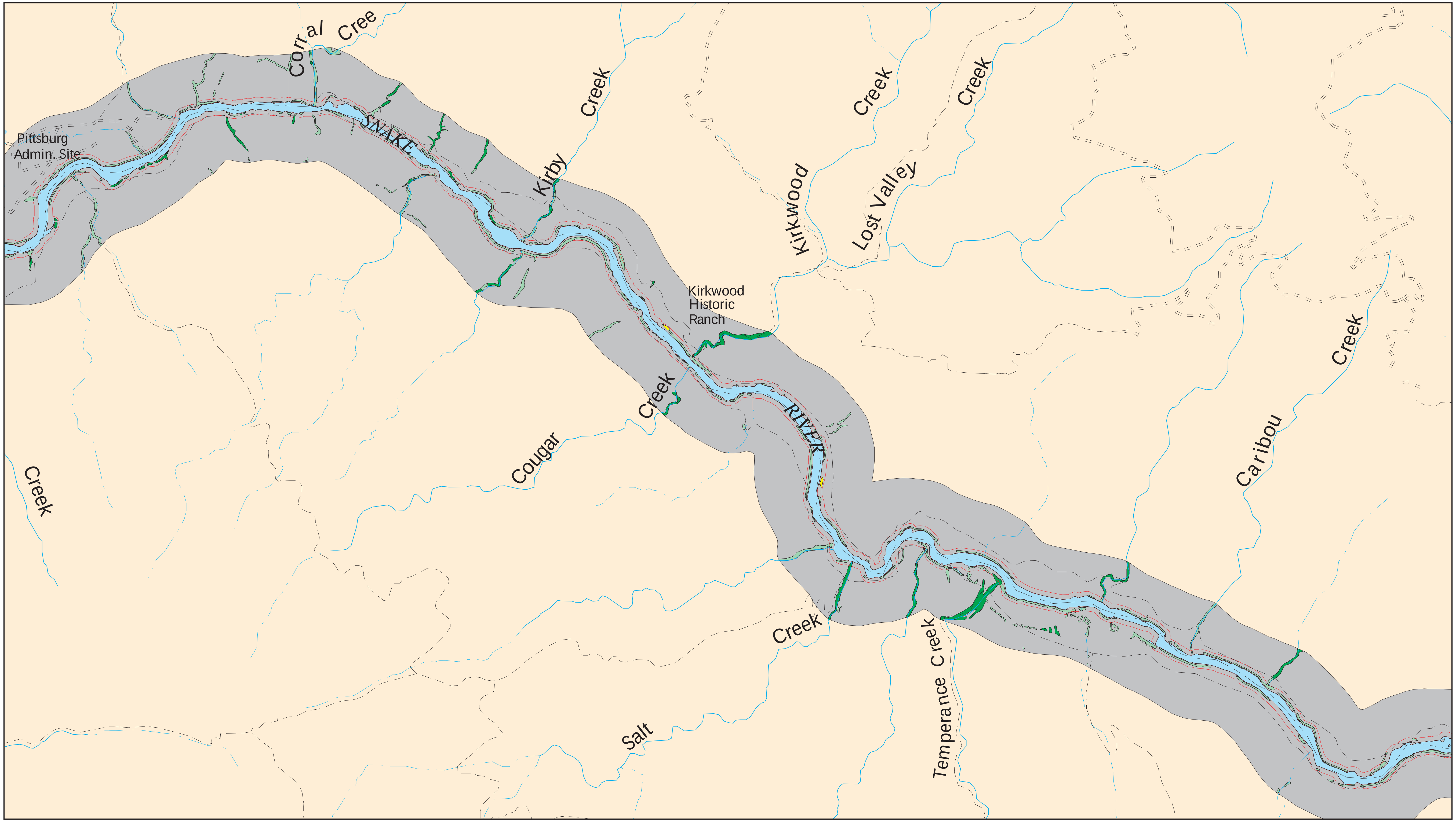
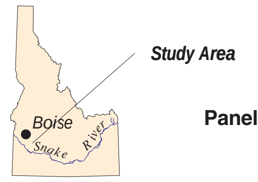
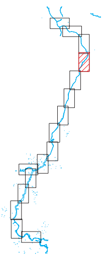




Vicinity Map

Panel 13 of 16



IDAHO POWER
Geographic Information Services

Base Features Legend

- Primary Route
- Secondary Route
- Light Duty Road
- Unimproved Road
- Trail
- Railroad
- Transmission Line
- Perennial River or Stream
- Intermittent River or Stream
- Ditch or Canal
- Political Boundary
- IPC Project Facility
- ◆ Pump Station
- Spring
- ○ Well

Thematic Features Legend

- 🟦 Water Body
- 🟨 Emergent Herbaceous Wetland
- 🟩 Scrub-Shrub Wetland
- 🟩 Forested Wetland
- ⬜ Non-Wetland Covertypes
- 50m Above Full Pool

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Tech. Report E.3.2 - 41 Figure 3

Riparian vegetation in Hells Canyon

1 .5 0 MILES

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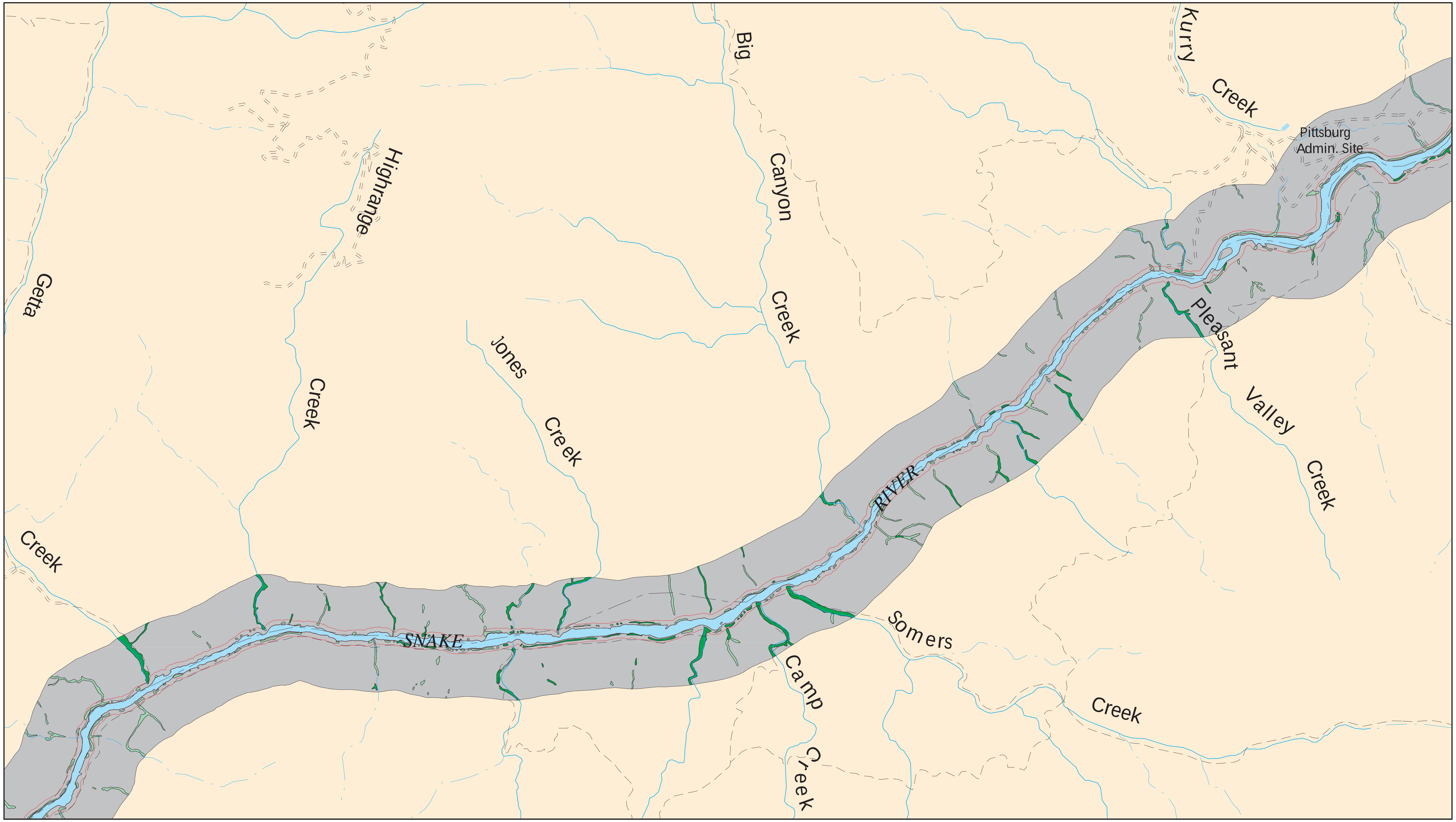
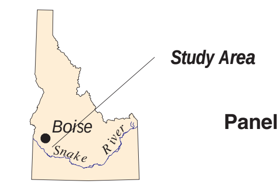
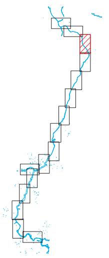




Vicinity Map

Panel 14 of 16



IDAHO POWER
Geographic Information Services

Base Features Legend

	Primary Route		IPC Project Facility
	Secondary Route	◆	Pump Station
	Light Duty Road	○	Spring
	Unimproved Road	○	Well
	Trail		
	Railroad		
	Transmission Line		
	Perennial River or Stream		
	Intermittent River or Stream		
	Ditch or Canal		
	Political Boundary		

Thematic Features Legend

🟦	Water Body
🟨	Emergent Herbaceous Wetland
🟩	Scrub-Shrub Wetland
🟩	Forested Wetland
⬜	Non-Wetland Covertypes
	50m Above Full Pool

N

Tech. Report E.3.2 - 41 Figure 3

Riparian vegetation in Hells Canyon

1 .5 0 MILES

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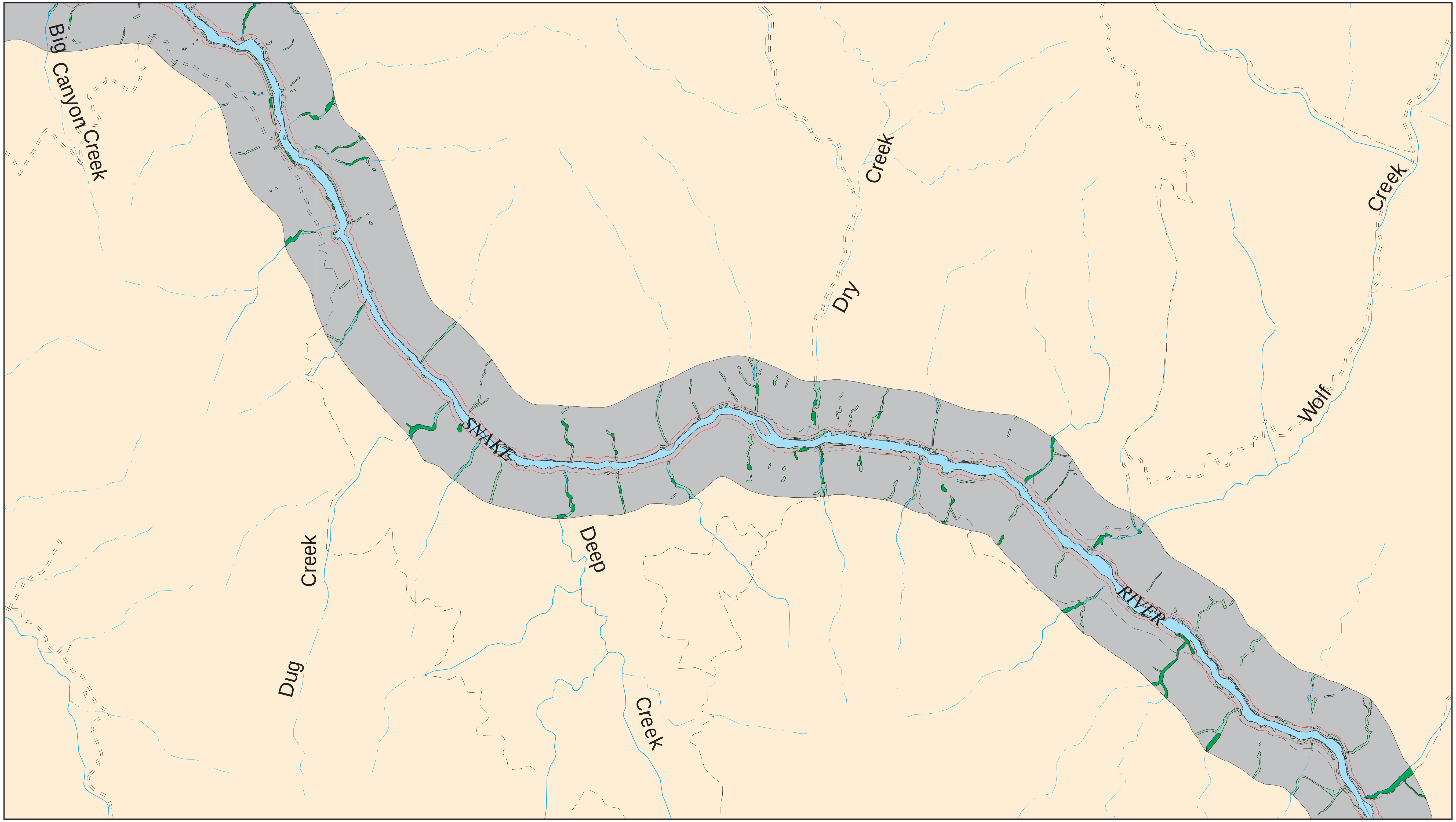
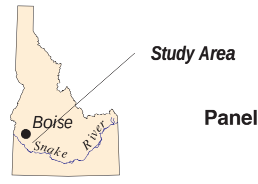
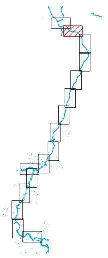




Vicinity Map

Panel 15 of 16



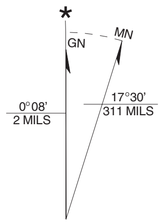
IDAHO POWER
Geographic Information Services

Base Features Legend

- Primary Route
- Secondary Route
- Light Duty Road
- Unimproved Road
- Trail
- Railroad
- Transmission Line
- Perennial River or Stream
- Intermittent River or Stream
- Ditch or Canal
- Political Boundary
- IPC Project Facility
- ◆ Pump Station
- ○ Spring
- ○ Well

Thematic Features Legend

- 🟦 Water Body
- 🟨 Emergent Herbaceous Wetland
- 🟩 Scrub-Shrub Wetland
- 🟩 Forested Wetland
- ⬜ Non-Wetland Covertypes
- 50m Above Full Pool



UTM GRID AND 1987
MAGNETIC NORTH DECLINATION
AT CENTER OF OXBOW QUADRANGLE

Tech. Report E.3.2 - 41 Figure 3

Riparian vegetation in Hells Canyon

1 .5 0 MILES

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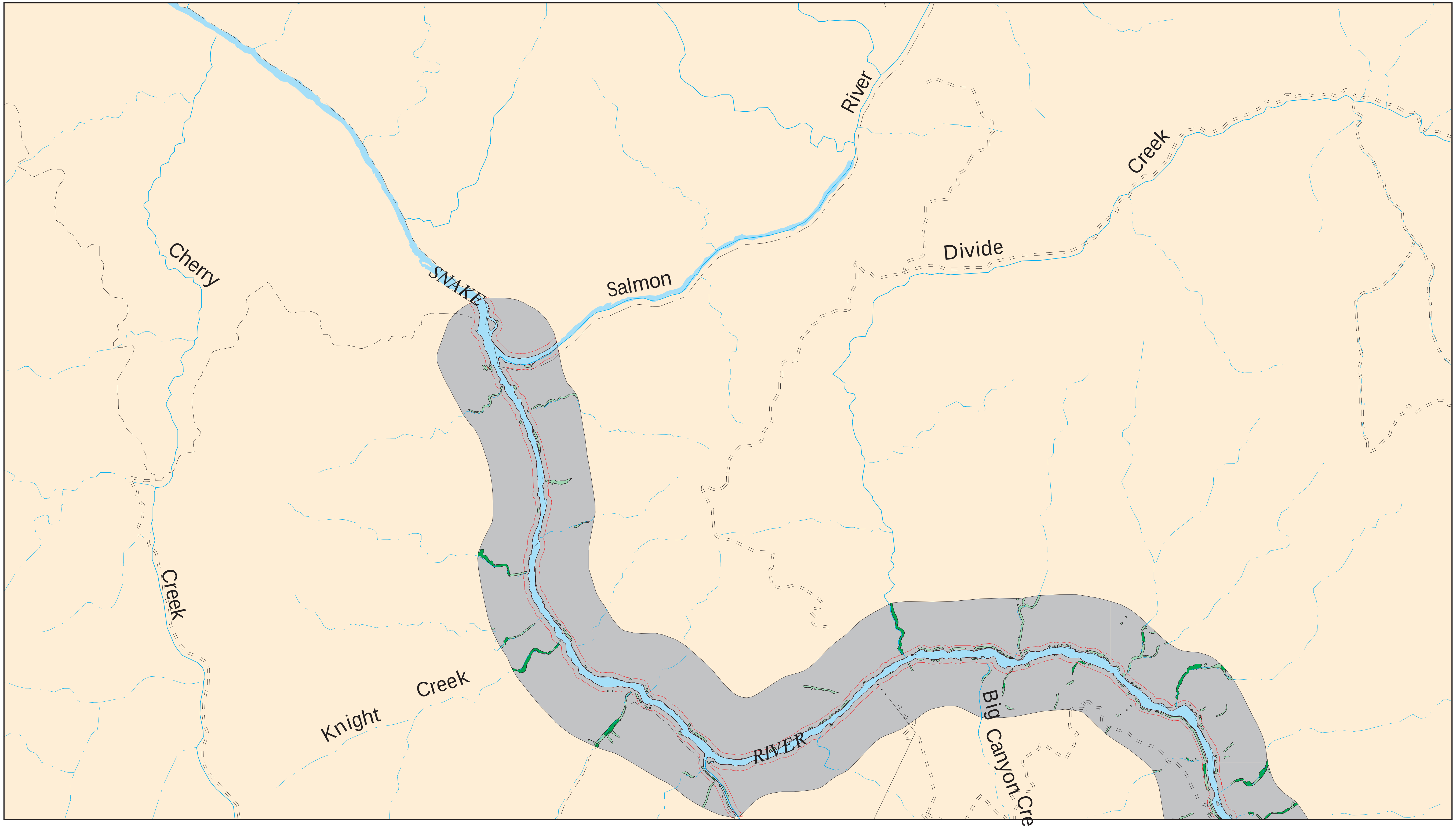
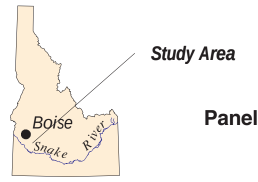
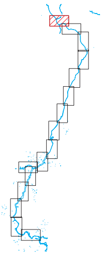




Vicinity Map

Panel 16 of 16



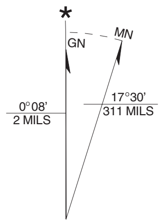
IDAHO POWER
Geographic Information Services

Base Features Legend

Primary Route	IPC Project Facility
Secondary Route	◆ Pump Station
Light Duty Road	Spring
Unimproved Road	○ Well
Trail	
Railroad	
Transmission Line	
Perennial River or Stream	
Intermittent River or Stream	
Ditch or Canal	
Political Boundary	

Thematic Features Legend

- 🟦 Water Body
- 🟨 Emergent Herbaceous Wetland
- 🟩 Scrub-Shrub Wetland
- 🟩 Forested Wetland
- ⬜ Non-Wetland Covertypes
- 50m Above Full Pool



UTM GRID AND 1987
MAGNETIC NORTH DECLINATION
AT CENTER OF OXBOW QUADRANGLE

Tech. Report E.3.2 - 41 Figure 3

Riparian vegetation in Hells Canyon

1 .5 0 MILES

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Appendix 1. Cover type definitions, codes and identification numbers used to define vegetation, natural feature, and land use cover types for the Hells Canyon Study Area.

Code	**Definitions**[1]
EHW	***Emergent Herbaceous Wetland*** – is usually dominated by emergent, erect, rooted, herbaceous hydrophytes excluding mosses and lichens. This cover type is only found in the riparian zone, and vegetation is present for most of the growing season in most years and is usually dominated by perennial plants. It has less than 30% cover of woody vegetation and a total vegetation cover of at least 30%. The lands in this cover type are usually saturated with or covered by water at least for part of the growing season. However, because of the difficulties in distinguishing between species and interpreting hydrologic indicators during remote sensing activities, some lands in this cover type may be dominated by upland species (FAC, FAC-, and UPL hydrologic indicator status; see Reed (1988)) and in areas without the necessary hydrologic regime to be considered “jurisdictional wetlands” by the U.S. army Corps of Engineers. Actual extent of “wetland” boundaries are not indicated on cover-type maps and must be determined on the ground through formal wetland delineation techniques.
SBW	***Shore & Bottomland Wetland*** – may consist of bare sand, gravel, or rocky areas along the riparian zone. If vegetation is present, it’s cover is less than 30%. Examples of this cover type include Rock Bottom, Unconsolidated Bottom, Streambed, Rocky Shore, and Unconsolidated Shore, as defined by Cowardin (1979). Actual extent of jurisdictional “wetland” boundaries are not indicated on cover-type maps and must be determined on the ground through formal wetland delineation techniques.
SSW	***Scrub-Shrub Wetland*** – is dominated by woody wetland vegetation less than 6 m (20 ft) tall in the riparian zone. It has a total vegetation cover of at least 30% and at least 30% cover of woody vegetation. Because of the difficulties in distinguishing between species and interpreting hydrologic indicators during remote sensing activities, some lands in this cover type are dominated by upland species (FAC, FAC-, and UPL hydrologic indicator status; see Reed (1988)) and in areas without the necessary hydrologic regime to be considered “jurisdictional wetlands” by the U.S. army Corps of Engineers. Actual extent of “wetland” boundaries are not indicated on cover-type maps and must be determined on the ground through formal wetland delineation techniques.
FW	***Forested Wetland*** – is dominated by woody wetland vegetation that is 6 m (20 ft) tall or taller in the riparian zone. It has a total vegetation cover of at least 30% and at least 30% cover of woody vegetation. Because of the difficulties in distinguishing between species and interpreting hydrologic indicators during remote sensing activities, some lands in this cover type are dominated by upland species (FAC, FAC-, and UPL hydrologic indicator status; see Reed (1988)) and in areas without the necessary hydrologic regime to be considered “jurisdictional wetlands” by the U.S. army Corps of Engineers. Actual extent of “wetland” boundaries are not indicated on cover-type maps and must be determined on the ground through formal wetland delineation techniques.
LS	***Lentic*** **(Standing Water)** – is non-moving open water habitat such as ponds and lakes.
LM	***Lotic*** **(Moving Water)** – is moving open water habitat such as rivers and streams.
FU	***Forested Upland*** – is dominated by trees (taller than 5 m) and has a tree canopy cover of at least 25%.
S	***Shrubland*** – an upland vegetation community, dominated by shrubs (including small trees shorter than 5 m) and has a shrub canopy cover of at least 25%. Total vegetation cover is greater than 25%.
TS	***Tree Savanna*** – an upland community, with a canopy cover of trees (taller than 5 m) between 5% and 25%. Total vegetation cover is at least 25%. The area between trees is typically dominated by grasses or other herbaceous vegetation.
SS	***Shrub Savanna*** – an upland community, with a canopy cover of shrubs (including small trees shorter than 5 m) between 5% and 25%.. This cover type has a total vegetation cover of at least 25%. The area between shrubs is typically dominated by grasses or other herbaceous vegetation.
DW	***Desertic Woodland*** – an upland community, with 1–25% total vegetation cover and trees (taller than 5 m) forming the dominant vegetation stratum. It includes sparsely vegetated types in non-desert areas.

Appendix 1. (Cont.)

Code	Definitions
DS	***Desertic Shrubland*** – an upland community, with 1–25% total vegetation cover and shrubs (and small trees shorter than 5 m) forming the dominant vegetation stratum. This cover type includes sparsely vegetated habitats in non-desert areas.
DH	***Desertic Herbland*** – an upland community with 1–25% total vegetation cover, and non-woody plants (including lichens and mosses) forming the dominant vegetation stratum. It includes sparsely vegetated types in non-desert areas.
G	***Grassland*** – an upland community with a total vegetation cover of at least 25%, and dominated by non-woody plants (including lichens and mosses), of which grasses (native or introduced) are dominant. This cover type may include prairies, rangeland, and upland subalpine meadows.
F	***Forbland*** – an upland community with a total vegetation cover of at least 25%, and dominated by non-woody plants (including lichens and mosses), of which forbs (native or introduced) are dominant. This cover type includes many weedy fields, old fields, and other types in early successional stages.
B	***Barrenland*** **(e.g. Sand Dunes)** – is an undisturbed (by direct human influence) upland area that has a total vegetation cover of 5% or less.
CTS	***Cliff/Talus Slope*** – consists of nearly vertical rock or bare soil faces, or slopes of unconsolidated rock material with a total vegetation cover of 5% or less.
D	***Disturbed*** – is land with more than 50% of the area disturbed by human activities and has a total vegetation cover of less than 15%. This cover type may include off-road vehicle areas, rural trash dumps, and soil borrow pits.
A	***Agriculture*** **(Cultivated)** – land that is principally used for the production of agricultural crops or products.
GP	***Grazing Land/Pasture*** – land that is principally used for pasture or grazing of domestic livestock.
U	***Urban*** – land that is principally located in a city and pertaining to city life (i.e. small business buildings and facilities).
R	***Residential*** – land that is principally associated with human housing. This cover type may include homes, garages, yards, gardens, sidewalks, driveways, and small livestock pens and pastures (1–2 acres).
I	***Industrial*** – land that is principally used for larger businesses and corporations such as office complexes, manufacturing plants, and warehouses.
PR	***Parks/Recreation*** – cultivated landscape that is principally used for human recreation such as city and county parks, roadside rest areas and picnic areas.
R	***Roads*** – consists of roadways for vehicle travel including major freeways and highways, local paved roads, improved gravel and dirt roads. This cover type may be mapped as a linear feature rather than a polygon.
FO	***Forested/Orchard*** – is artificially planted and cultivated trees for the production of fruit or nut crops, or timber.

[1] Wetland cover types follow the classification system described by Cowardin et al. (1979) and modified for Habitat Evaluation Procedures (HEP) (U.S. Fish and Wildlife Service 1981). Upland cover types generally follow the classification system used for HEP cover types as outlined in U.S. Fish and Wildlife Service (1981).