Kootenai River Habitat Restoration Project Master Plan

Chapter 2 – Kootenai Subbasin Ecosystem and Limiting Habitat Factors

Kootenai Tribe of Idaho

July 2009

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2 Kootenai Subbasin Ecosystem and Limiting Habitat Factors

Chapter 2 provides an overview of the Kootenai subbasin, river and floodplain stewardship implications for the river corridor, the characteristics of the river reaches in the project area, and the factors that limit habitat for focal aquatic species and other species within the project area. This chapter presents background information on the historical condition of the Kootenai River and subbasin and explains how human activities have affected the ecosystem. Chapter 2 builds on the project goals and objectives presented in Chapter 1, and provides the basis for developing the restoration strategies, treatments and habitat actions described in Chapter 3. The toolbox of restoration strategies, treatments and habitat actions is applied spatially to reaches within the project area in Chapter 4, resulting in implementation scenarios used to define a potential range of restoration levels of effort. The relationship among these chapters, and related terminology, is illustrated in Figure 2-1 on the following page.

In the context of this Master Plan, limiting factors are defined as physical, biological, and ecological conditions within the project area that: 1) limit the ability of the ecosystem to sustain diverse native plant and animal populations, and to accommodate natural disturbances; 2) limit the quality or availability of habitat that supports all life stages of endangered Kootenai sturgeon and other focal species; and 3) limit the ability of the ecosystem to sustain the local tribal culture, subsistence needs, and the economy. Limiting factors can be addressed by active restoration or changes in management. In contrast, constraints are components like roads, bridges and other infrastructure that cannot be changed by management or active restoration, but must be considered during the design process.

The Kootenai sturgeon is one of six focal species that are discussed in this chapter. The Kootenai sturgeon is given more attention throughout the document due to their federally endangered species status. The species is also considered an indicator species for ecosystem health, and the decline of the species suggests that ecosystem components are degraded, limiting, or missing. Although emphasis in this chapter is often placed on rehabilitating the Kootenai sturgeon population, the Kootenai River Habitat Restoration Project is directed towards restoring the broad range of habitats within the project area.

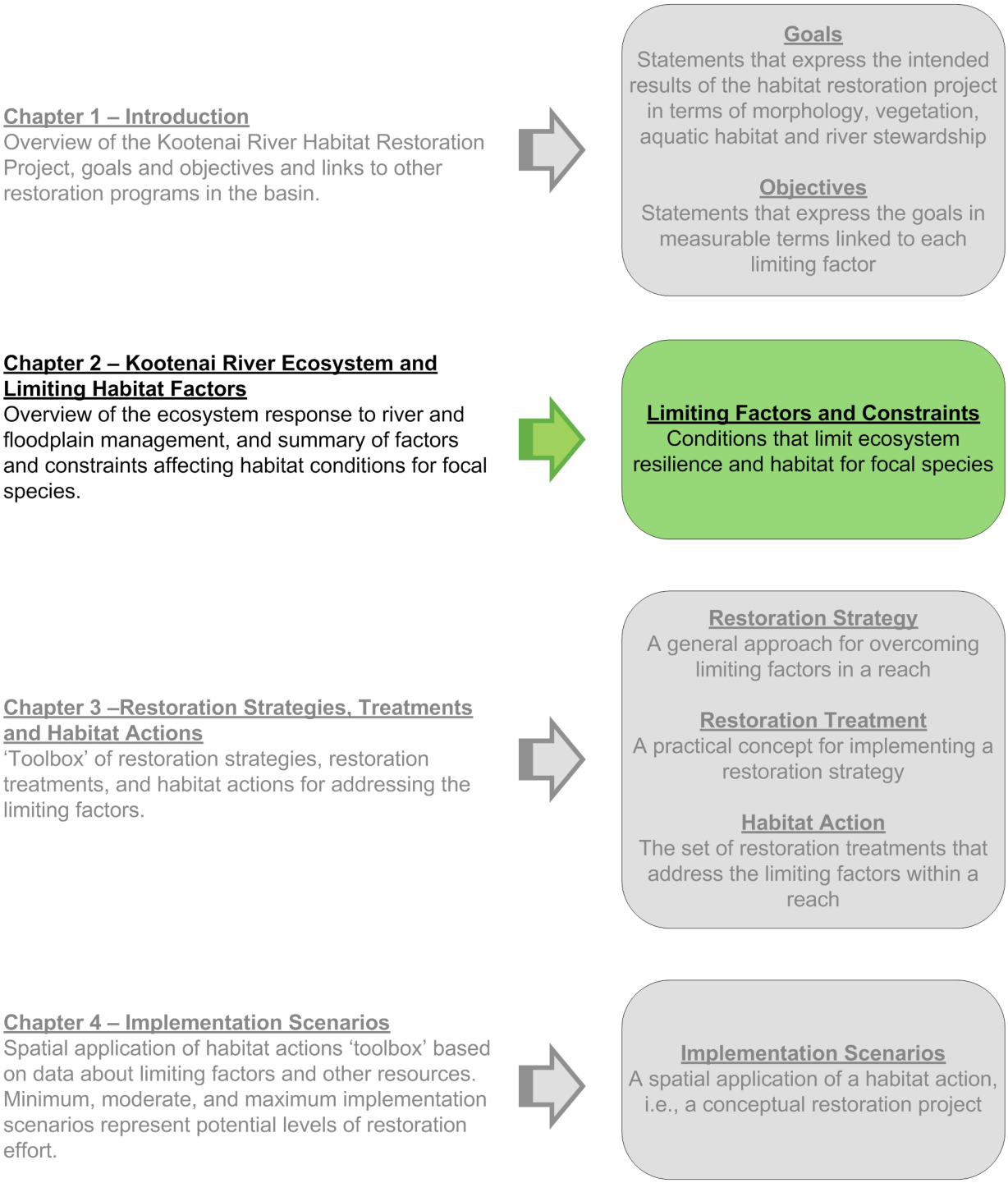

Figure 2-1. Relationship of Chapter 2 to other chapters in this Master Plan and related terminology.

While there is a great deal of literature supporting identification of limiting factors for many of the focal species (Fausch 1989; MBTSG 1996; Anders et al. 2002; Paragamian et al. 2002), a number of the limiting factors (particularly those related to Kootenai sturgeon) are derived from ongoing research and evolving recruitment failure hypotheses (Anders 1991; Duke et al. 1999; USFWS 1999; Anders et al. 2002; Anders 2004; Coutant 2004; Paragamian et al. 2005). The list of limiting factors identified in this Master Plan is therefore based on the best available information found in published papers, the gray literature, recent data collection, analysis completed as part of the Master Plan effort, and expert opinion provided by the Tribal staff, project design team members, co-managers, technical experts from partners agencies, and internal peer reviewers.

The four general categories used to organize the limiting factors in this Master Plan include:

- **River and floodplain management constraints** – features like roads, bridges and other infrastructure that cannot be changed by management or active restoration, but must be considered during the design process. River management has also resulted in changes to the rate and timing of flow and changes to temperature regimes. Although there is some flexibility in river management to address flow and temperature there are also significant constraints.
- **Morphological limiting factors** – physical conditions that are on a trajectory away from normative habitat conditions or exhibit departure from historical conditions. Although returning the physical environment to the conditions of pre-European settlement is not feasible, addressing the morphological limiting factors is aimed at restoring a trend towards more normative morphological conditions.
- **Riparian vegetation limiting factors** – processes or conditions that prohibit establishment of native plant communities. Riparian vegetation limiting factors are directly influenced by morphological limiting factors.
- **Aquatic habitat limiting factors** – missing components of the ecosystem that support habitat requirements for all life stages of the focal aquatic species. Aquatic habitat limiting factors are directly influenced by morphological limiting factors and riparian vegetation limiting factors.

2.1 Summary of Limiting Factors in the Project Area

Limiting factors in the project area are summarized in the following paragraphs and described in greater detail later in this chapter. Reach-specific limiting factors are summarized in Chapter 3.

2.1.1 Constraints from River and Floodplain Management

River and floodplain management has affected many aspects of the Kootenai subbasin ecosystem. River and floodplain management actions are recognized as elements within the river system that are of critical importance to our society, but pose constraints to ecosystem restoration. Constraints from river and floodplain management identified in this chapter include:

- **Dam controlled flow regime** – Flow regulation at Libby Dam is considered to be one of the major reasons for the continued decline of Kootenai sturgeon, burbot, and other focal species' populations. Regulated spring peak flows are less than half the pre-Libby

Dam (pre-dam) peak flows, while winter flows have increased by 300% relative to the pre-dam period (USFWS 1999). High spring flows similar to pre-dam conditions, which are thought to be necessary for successful Kootenai sturgeon reproduction, have rarely occurred during the May-July spawning season since the closure of Libby Dam in 1972. In addition, historically (i.e., pre-dam) higher flushing flows kept pockets of spawning substrate clean and exposed. The high winter flows necessary for reservoir drawdown also negatively impact burbot spawning migrations. The dam controlled flow regime and its departure from the pre-dam flow regime are described in more detail in Section 2.3.

- **Dam controlled sediment regime** – Flow regulation at Libby Dam has altered the sediment regime in the Kootenai River by trapping bedload and suspended load from the upper Kootenai subbasin and reducing the sediment transport capacity of the river. Pre-dam, these materials provided a greater sediment supply to the Kootenai River in the area addressed by this project. The dam controlled sediment regime and its departure from the pre-dam sediment regime are described in more detail in Section 2.3.
- **Dam controlled thermal regime** – Flow regulation at Libby Dam has led to typically warmer water temperatures in the winter and cooler water temperatures in the summer. Changes in the thermal regime have affected the focal species by influencing seasonal behavior patterns, most notably spawning cues for Kootenai sturgeon and burbot. The dam controlled thermal regime and its departure from the pre-dam thermal regime are described in more detail in Section 2.3.
- **Dam controlled nutrient regime** – Nutrients delivered from the upper Kootenai subbasin are sequestered in Lake Koocanusa. "Clean" water downstream from Libby Dam has resulted in reduced primary productivity with corresponding ecosystem effects including depressed fish populations (P. Anders, personal communication, 2008). Kokanee populations inhabiting Kootenay Lake dwindled following closure of Libby Dam and cessation of phosphorus mining in the subbasin. Nutrient augmentation programs directed towards rehabilitating nutrient levels in the Kootenai River and Kootenay Lake have resulted in measured biological responses (Andrusak 2003; Holderman et al. 2009a, 2009b). Effects of the dam controlled nutrient regime are described in more detail in Section 2.6.
- **Bank armoring** – Bank armoring can affect the assemblage of riparian vegetation, reduce channel and floodplain complexity, and decrease sediment delivery to the river. Armoring may impact vegetation recruitment, debris delivery to the river corridor, and diminish aquatic habitat complexity.
- **Levees and diking districts** – Levees simplify the floodplain by restricting flood flows to the main channel. Similarly, confinement of floodwater to the channel reduces the overall productivity of the river-floodplain system as the shallow water habitats that are created on the floodplain during high flows are excluded by the levee network. Therefore, levees have reduced backwater and off-channel habitats that historically provided diverse microhabitats, food sources, and resting areas for fish in the Kootenai subbasin. Locations of levees and diking districts are identified in Figure 2-4 in Section 2.3.
- **Transportation corridors** – Highway and railroad transportation corridors parallel the Kootenai River in portions of the project area. U.S. Highway 95 and the Union Pacific

railroad cross the river at Bonners Ferry. The Burlington Northern Santa Fe railroad parallels portions of the project area and has cut off portions of the floodplain. Transportation corridors and infrastructure are discussed in Section 2.3.

- **Floodplain land use** – Land use practices such as grazing, agriculture, tilling, groundwater pumping and vegetation clearing have altered the character of the floodplain and distribution of sediment, nutrients, and debris to the Kootenai River. Other resource management practices such as forestry and mining have altered the landscape. Development, removal of riparian buffers and installation of bank armoring have affected the assemblage of riparian bank vegetation, reduced channel and floodplain complexity, and altered sediment delivery to the river.
- **Backwater influence from Kootenay Lake** – Fluctuations in Kootenay Lake levels affect water surface elevations upstream past Bonners Ferry. Kootenai River habitat is affected by the dynamic conditions caused by the large fluctuations in water surface elevation between baseflow and mean annual peak flow. How these dynamic conditions interact with other factors to affect morphology, riparian vegetation and aquatic habitat is described throughout this Chapter. Kootenay Lake levels are controlled by both natural conditions and managed operations. The primary constraint posed by the Kootenay Lake backwater is the limited ability to manage the lake level for habitat benefits without negatively affecting other operational needs.

2.1.2 Limiting Factors for Morphology

Morphological limiting factors are derived from the effects of river and floodplain management in the Kootenai subbasin. Factors that have altered natural and historical morphological processes in the project area include:

- **River Response to altered hydraulics** – Departure from historical conditions has changed the hydraulics that influence existing channel behavior. Mean annual peak values for channel depth, velocity and shear stress are lower due to lower mean annual peak flows. The Kootenai River's response to altered hydraulics varies by reach due to differences in morphology, but in general, the response has caused negative impacts to aquatic habitat, ecological processes and KRWS behavior. Altered hydraulics are described in more detail in Section 2.4.1 and Appendix A.
- **River Response to altered sediment-transport** – Sediment transport in the project area is affected by a reduction in sediment supply from the watershed due to sediment trapping at Libby Dam and changes in sediment transport competence and capacity due to altered hydraulics. The effects of altered sediment tranport have implications for aquatic habitat including: 1) reduced supply of suitable spawning substrate delivered to the project area, and 2) increased embeddedness of coarse substrate with sand and finer sediment. Not only does altered sediment transport affect aquatic habitat, but it also affects channel morphology and vegetation processes. The Kootenai River's response to altered sediment transport is described in more detail in Section 2.4.2 and Appendix B.
- **Loss of channel and floodplain connection** – Floodplain conditions are characterized by floodplain surfaces that are too high and are no longer accessed due to reduced mean annual peak flows and levee construction. Implications of loss of floodplain connectivity

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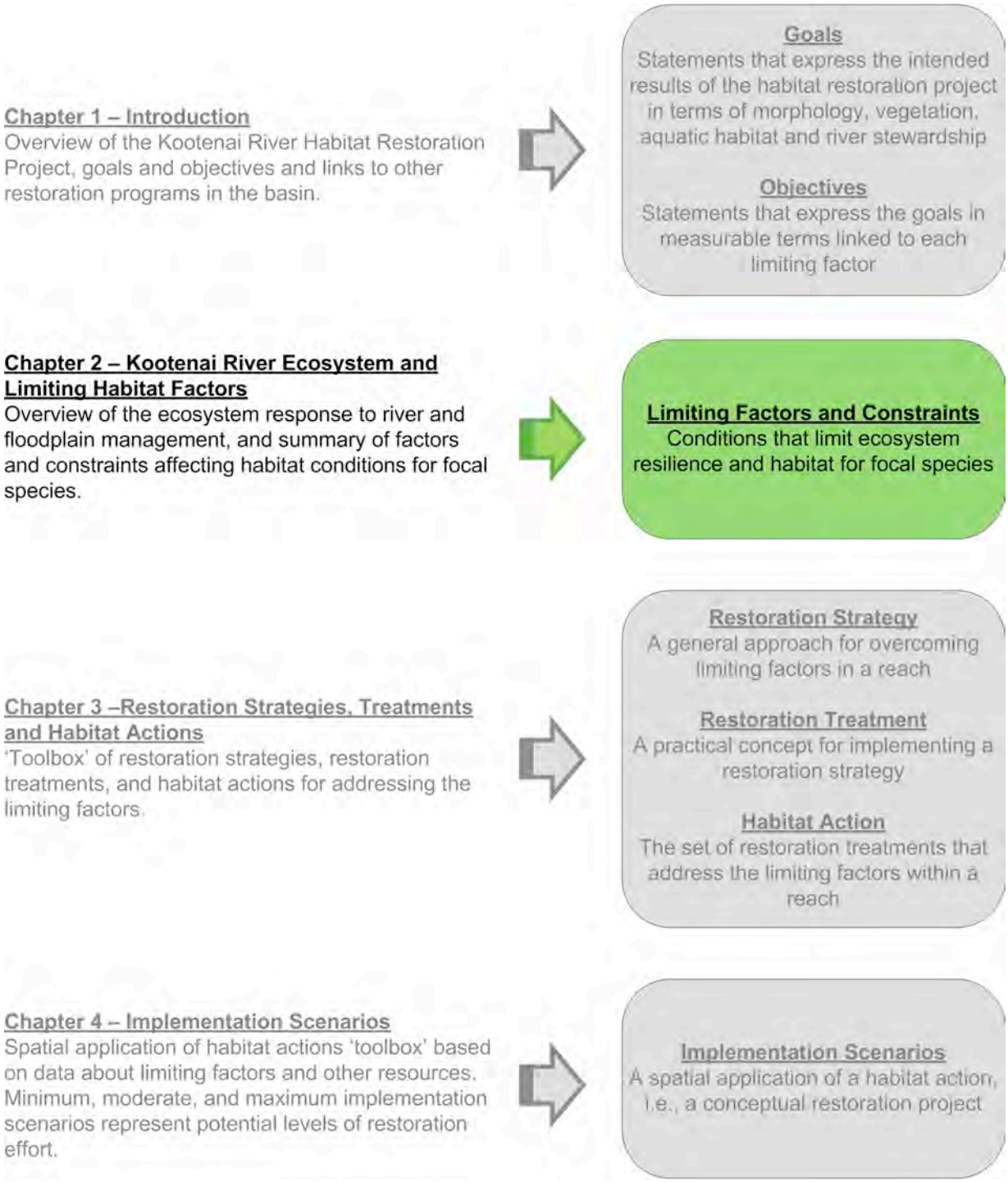

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- **Dam controlled flow regime** – Flow regulation at Libby Dam is considered to be one of the major reasons for the continued decline of Kootenai sturgeon, burbot, and other focal species' populations. Regulated spring peak flows are less than half the pre-Libby

Dam (pre-dam) peak flows, while winter flows have increased by 300% relative to the pre-dam period (USFWS 1999). High spring flows similar to pre-dam conditions, which are thought to be necessary for successful Kootenai sturgeon reproduction, have rarely occurred during the May-July spawning season since the closure of Libby Dam in 1972. In addition, historically (i.e., pre-dam) higher flushing flows kept pockets of spawning substrate clean and exposed. The high winter flows necessary for reservoir drawdown also negatively impact burbot spawning migrations. The dam controlled flow regime and its departure from the pre-dam flow regime are described in more detail in Section 2.3.

- **Dam controlled sediment regime** – Flow regulation at Libby Dam has altered the sediment regime in the Kootenai River by trapping bedload and suspended load from the upper Kootenai subbasin and reducing the sediment transport capacity of the river. Pre-dam, these materials provided a greater sediment supply to the Kootenai River in the area addressed by this project. The dam controlled sediment regime and its departure from the pre-dam sediment regime are described in more detail in Section 2.3.
- **Dam controlled thermal regime** – Flow regulation at Libby Dam has led to typically warmer water temperatures in the winter and cooler water temperatures in the summer. Changes in the thermal regime have affected the focal species by influencing seasonal behavior patterns, most notably spawning cues for Kootenai sturgeon and burbot. The dam controlled thermal regime and its departure from the pre-dam thermal regime are described in more detail in Section 2.3.
- **Dam controlled nutrient regime** – Nutrients delivered from the upper Kootenai subbasin are sequestered in Lake Koocanusa. "Clean" water downstream from Libby Dam has resulted in reduced primary productivity with corresponding ecosystem effects including depressed fish populations (P. Anders, personal communication, 2008). Kokanee populations inhabiting Kootenay Lake dwindled following closure of Libby Dam and cessation of phosphorus mining in the subbasin. Nutrient augmentation programs directed towards rehabilitating nutrient levels in the Kootenai River and Kootenay Lake have resulted in measured biological responses (Andrusak 2003; Holderman et al. 2009a, 2009b). Effects of the dam controlled nutrient regime are described in more detail in Section 2.6.
- **Bank armoring** – Bank armoring can affect the assemblage of riparian vegetation, reduce channel and floodplain complexity, and decrease sediment delivery to the river. Armoring may impact vegetation recruitment, debris delivery to the river corridor, and diminish aquatic habitat complexity.
- **Levees and diking districts** – Levees simplify the floodplain by restricting flood flows to the main channel. Similarly, confinement of floodwater to the channel reduces the overall productivity of the river-floodplain system as the shallow water habitats that are created on the floodplain during high flows are excluded by the levee network. Therefore, levees have reduced backwater and off-channel habitats that historically provided diverse microhabitats, food sources, and resting areas for fish in the Kootenai subbasin. Locations of levees and diking districts are identified in Figure 2-4 in Section 2.3.
- **Transportation corridors** – Highway and railroad transportation corridors parallel the Kootenai River in portions of the project area. U.S. Highway 95 and the Union Pacific

railroad cross the river at Bonners Ferry. The Burlington Northern Santa Fe railroad parallels portions of the project area and has cut off portions of the floodplain. Transportation corridors and infrastructure are discussed in Section 2.3.

- **Floodplain land use** – Land use practices such as grazing, agriculture, tilling, groundwater pumping and vegetation clearing have altered the character of the floodplain and distribution of sediment, nutrients, and debris to the Kootenai River. Other resource management practices such as forestry and mining have altered the landscape. Development, removal of riparian buffers and installation of bank armoring have affected the assemblage of riparian bank vegetation, reduced channel and floodplain complexity, and altered sediment delivery to the river.
- **Backwater influence from Kootenay Lake** – Fluctuations in Kootenay Lake levels affect water surface elevations upstream past Bonners Ferry. Kootenai River habitat is affected by the dynamic conditions caused by the large fluctuations in water surface elevation between baseflow and mean annual peak flow. How these dynamic conditions interact with other factors to affect morphology, riparian vegetation and aquatic habitat is described throughout this Chapter. Kootenay Lake levels are controlled by both natural conditions and managed operations. The primary constraint posed by the Kootenay Lake backwater is the limited ability to manage the lake level for habitat benefits without negatively affecting other operational needs.

2.1.2 Limiting Factors for Morphology

Morphological limiting factors are derived from the effects of river and floodplain management in the Kootenai subbasin. Factors that have altered natural and historical morphological processes in the project area include:

- **River Response to altered hydraulics** – Departure from historical conditions has changed the hydraulics that influence existing channel behavior. Mean annual peak values for channel depth, velocity and shear stress are lower due to lower mean annual peak flows. The Kootenai River's response to altered hydraulics varies by reach due to differences in morphology, but in general, the response has caused negative impacts to aquatic habitat, ecological processes and KRWS behavior. Altered hydraulics are described in more detail in Section 2.4.1 and Appendix A.
- **River Response to altered sediment-transport** – Sediment transport in the project area is affected by a reduction in sediment supply from the watershed due to sediment trapping at Libby Dam and changes in sediment transport competence and capacity due to altered hydraulics. The effects of altered sediment tranport have implications for aquatic habitat including: 1) reduced supply of suitable spawning substrate delivered to the project area, and 2) increased embeddedness of coarse substrate with sand and finer sediment. Not only does altered sediment transport affect aquatic habitat, but it also affects channel morphology and vegetation processes. The Kootenai River's response to altered sediment transport is described in more detail in Section 2.4.2 and Appendix B.
- **Loss of channel and floodplain connection** – Floodplain conditions are characterized by floodplain surfaces that are too high and are no longer accessed due to reduced mean annual peak flows and levee construction. Implications of loss of floodplain connectivity

are described in more detail with respect to riparian vegetation and aquatic habitat limiting factors in Sections 2.5 and 2.6, respectively.

- **Reduced channel boundary roughness and bank erosion** – Bank erosion and sediment loading have always played a role in the morphology of the Kootenai River. However, bank erosion rates are affected by river and floodplain management, the lack of bank vegetation, and the river's response to altered hydraulics and sediment transport. Preliminary comparisons using measured bank erosion data indicate that bank erosion accounts for approximately 15 to 30% of the measured bed material supply within the project area. Bank erosion and associated rates of channel migration, if accelerated, could cause excessive disturbance and have negative effects on aquatic habitat and ecological processes. Moreover, bank erosion and land loss is a costly problem that affects river stewardship as well as river and floodplain management. Bank erosion is discussed in more detail in Section 2.4.4 and Appendix E.

2.1.3 Limiting Factors for Riparian Vegetation

Factors that have altered the native riparian vegetation community in the project area are listed in the following bullets. Additional detail is presented in Section 2.5.

- **Lack of surfaces that support riparian vegetation recruitment** – Because fewer depositional surfaces are formed due to the altered hydrograph, altered sediment-transport regime and loss of floodplain channel connection, recruitment of riparian vegetation such as cottonwoods (*Populus* species) and willows (*Salix* species) has decreased.
- **Lack of outer bank vegetation** – Lack of vegetation on outer banks is due to floodplain modifications, streambank armoring and levees, vegetation clearing, and hydraulic processes such as bank erosion. Vegetation on outer banks contributes to bank stability, cover for aquatic species, and support of the food web; it also provides seed sources that support establishment of new plant communities.
- **Frequent scour and deposition of floodplain surfaces** – In upstream portions of the project area, deposited floodplain surfaces are scoured and re-deposited too quickly for plant communities to become established. In downstream portions of the project area, backwater effects from Lake Kootenay, combined with flows that are confined to the main channel, contribute to unstable depositional surfaces within the levee system.
- **Altered hydroperiod** (the length of time during the growing season when water is available in the rooting zone) – Changes to the hydrologic conditions in the Kootenai River as a result of dam operations have interrupted patterns of vegetation succession by impacting riverine and floodplain processes that maintain riparian plant communities, including sediment deposition and scour, seed dispersal, hydrograph recession, floodplain water storage, and the exchange of nutrients and organic matter between the river and floodplain. Altered hydroperiod is probably one of the most significant factors driving the reduced extents of riparian and wetland plant communities. Figure 2-11 shows the pre- and post-dam stage and discharge relationships.
- **Invasive plant species** – Non-native, invasive plant species have displaced native riparian vegetation resulting in less streambank cover, reduced streambank and floodplain

stability and loss of primary and secondary productivity. Some non-native, invasive vegetation out-competes native vegetation, homogenizing plant community structure and reducing species diversity, habitat complexity and ecosystem function.

- **Lack of native plant diversity and seed sources** – Agricultural and infrastructure development in portions of the floodplain (primarily in the Straight Reach and Meander Reaches) have removed native vegetation and reduced the availability of native seed sources for establishing and maintaining riparian vegetation communities.
- **Lack of nutrient sources for primary productivity** – Operation of Libby Dam and lack of vegetation in the project area have combined to reduce nutrient inputs to the river, or primary production from riparian vegetation.
- **Altered carbon balance** – In the Kootenai subbasin, extensive wetland acreage has been converted to cropland and pastureland. The depletion of wetland systems has likely contributed to decreased carbon availability, likely reducing the biological energy available to drive ecosystem processes and support the food web.

2.1.4 Limiting Factors for Aquatic Habitat

Factors that have altered the aquatic habitat conditions in the project area are listed in the following paragraphs. Specific factors that impact Kootenai sturgeon and other focal fish species are presented. Additional detail is presented in Section 2.6.

- **Insufficient depth for Kootenai sturgeon migration** – Higher width-to-depth ratios, shallower water depths due to lower peak flows and instream sediment deposition may affect Kootenai sturgeon during their upstream spawning migration.
- **Insufficient velocity for Kootenai sturgeon spawning sturgeon spawning, incubation, and early life stages** – Reduced velocities due to lower peak flows and higher width-to-depth ratios may affect Kootenai sturgeon spawning, incubation, and early life survival.
- **Lack of coarse substrate for egg attachment** – Deposition of finer sediments over coarse substrate on the streambed has created conditions that are not ideal for Kootenai sturgeon demersal egg attachment, embryo development, or free-swimming embryo survival.
- **Lack of cover for juvenile fish** – Changes in the riparian community, loss of bank vegetation cover, floodplain habitat simplification, reduction of interstitial cobble spaces on the streambed, and decreased large and small wood and associated habitat structure in the system have reduced refuge areas for juvenile fish and aquatic periphyton and invertebrates assemblages.
- **Lack of pool-riffle complexity** – Increased silt loading has filled in deep pools in the river, resulting in a more homogenous channel bed profile. This habitat simplification impacts fish and other aquatic organisms. Deep pools provide holding habitat for adult fish during winter and when migrating upstream to spawn as well as refuge areas for juvenile fish.
- **Simplified food web from lack of nutrients** – Changes in the nutrient flux as a result of nutrient sequestration in Lake Koocanusa, decreased floodplain connectivity in the

project area, and changes in the riparian vegetation community have led to decreased primary and secondary productivity.

- **Insufficient pool frequency** – Decreased frequency of pools in the Kootenai River system reduces available habitat for focal fish species. Bull trout, redband trout, Kootenai sturgeon, and other focal fish species require complex habitats with deep pools.
- **Lack of fish passage into tributaries** – Tributaries serve as important spawning and rearing habitat for many of the focal fish species, especially native trout and kokanee salmon. Altered sediment-transport and deposition patterns have caused aggradation of sediments in the deltas of many tributaries to the Kootenai River upstream of the project area. As a result, many of these deltas have become barriers to fish passage, especially at low flows. Other tributaries are blocked by natural falls and human-caused fish passage barriers such as road crossings, respectively.
- **Lack of off-channel habitat for rearing, primary, and secondary production and species diversity** – Decreased floodplain-channel connectivity has resulted in fewer off-channel habitats in the system. Off-channel habitats provide important rearing areas for juvenile fish, and for critical supporting primary and secondary biological production, including species richness and biodiversity.
- **Altered water quality** – Nutrient fluxes in the Kootenai River have changed over time with changes in land uses, closure of fertilizer production facilities and mines, and Libby Dam operation. Altered water quality affects primary and secondary productivity, and may decrease food availability for fish. Other water quality concerns include legacy heavy metals stored in the river bed sediment and point and non-point source pollutants discharged from agricultural fields and the urban corridor of Bonners Ferry and other municipalities in the Kootenai subbasin.

2.2 Kootenai Subbasin and Project Area Overview

From its headwaters in the Canadian Rockies, the Kootenai River flows over 400 miles traversing the international border separating the United States and Canada before joining the Columbia River at Castlegar in southeastern British Columbia. Draining portions of British Columbia, Montana, and Idaho, the geomorphic character of the river is shaped by glacially-influenced landscapes. In addition to political boundaries, the river system drains a diverse subbasin characterized by varied geology, climatic regimes, vegetation, and land uses. The following sections provide an overview of the Kootenai subbasin.

2.2.1 Location

The Kootenai subbasin overlays parts of southeastern British Columbia, northern Idaho, and northwestern Montana, covering a 16,180 square mile area. Nearly two-thirds of the Kootenai River's 485-mile-long channel and almost 70% of the Kootenai subbasin is located within British Columbia. The Montana portion of the Kootenai subbasin makes up about 23% of the total subbasin, while the Idaho portion is only about 6.5% (Knudson 1994). The primary focus of the Kootenai River Habitat Restoration Project is on the portion of the subbasin that lies within the

State of Idaho. Figure 2-2 on the following page shows the location of the Kootenai subbasin and the reaches comprising the project area.

2.2.2 Climate

The climate in the Kootenai subbasin is affected by both maritime and continental weather patterns. Maritime influences moderate the harsher continental climate. Winters are neither as wet nor as warm as Pacific coastal areas, but generally are not as cold and dry as areas to the east. Weather patterns are complex, with local variations stemming from differences in elevation. The average annual air temperature at Bonners Ferry is 46.9°F (9.8°C), reaching or exceeding 90°F (32.2°C) on half the days in July and August, and averaging 22°F (-5.6°C) in January. Mean annual precipitation in the Idaho portion of the subbasin is 30 inches, approximately 70% to 80% of which falls as snow between November and March.

2.2.3 Geology, Soils and Land Types

The Kootenai subbasin lies within ranges of the Rocky Mountains, trending north to northwest, that are separated by long straight valleys. These valleys tend to be relatively broad and flat. Quartzite-based and granitic rocks underlie the subbasin. Soils derived from quartzite deposits are significantly more stable and resilient on hill slopes and in stream channels than the coarse weathered granitic sands. Bedrock in the subbasin is typically covered with glacial till. The till derived from quartzite rocks is medium-textured with a moderate amount of rock fragments. That derived from granite is usually sandier and varies more in its rock-fragment content. The top portion of the glacial till is loose and permeable, while the lower part can be dense and impermeable. The dense layer can restrict water movement and root penetration. Deposits of outwash and alluvium transported by streams are found in valley bottoms. A layer of volcanic ash that is 0.5 to 1.5 feet thick covers most of the glacial material. The ash usually has a silt-loam texture with little gravel, cobble, or rock fragments. It normally has a high infiltration rate, high permeability, and a high water- and nutrient-holding capacity. Ash, however, is easily compacted and displaced by heavy equipment.

Upstream reaches of the Kootenai River in British Columbia flow through the Purcell Range, the southern Rocky Mountain Trench, and the southern Rocky Mountains. The Purcell Trench, which the Kootenai River enters at Bonners Ferry, is perhaps the most prominent structural feature of the lower part of the subbasin. Lying between the Selkirk and Purcell mountains, it is a glacially-enlarged, asymmetric, fault-bounded valley.

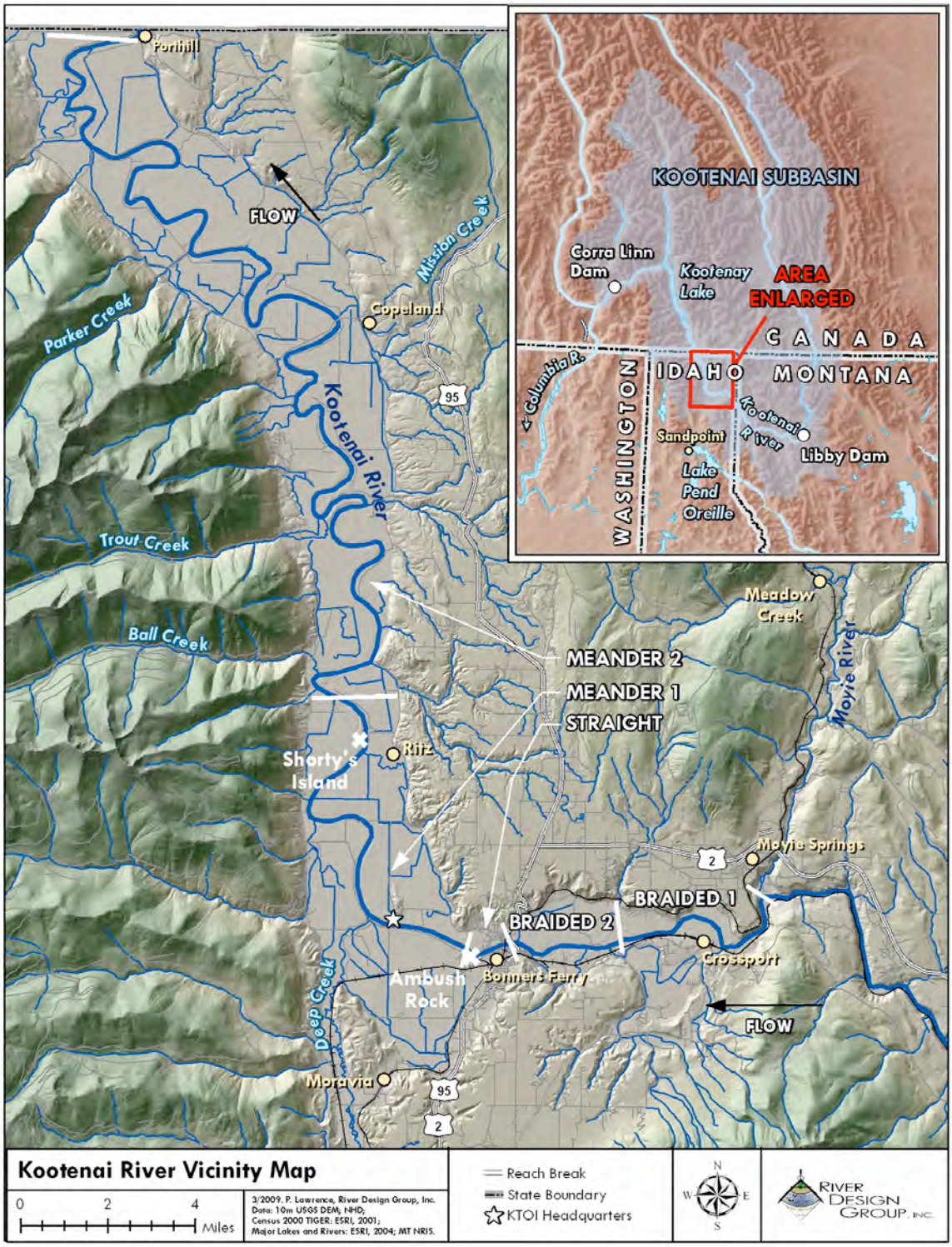


Figure 2-2. The Kootenai subbasin and location of the proposed Kootenai River Habitat Restoration Project.

The Purcell Trench is the glacially scoured basin that contains Kootenay Lake. The bottom of the trench, the lower slopes of the valley and alluvial terraces are covered with deposits of glacial

debris and older sediments. Other major structural features created by faults in this part of the subbasin include the Moyie River corridor and the valley between the Purcell and Cabinet mountains (Daley et al. 1981). Bonnington Falls marks the geologic structural outlet of Kootenay Lake. The falls, although presently inundated, historically formed a fish passage barrier that has isolated Kootenai sturgeon since at least the last ice age.

2.2.4 Geomorphology

The historical geomorphology of the Kootenai River was shaped by the region's geology and glaciation during the late Pleistocene and early Holocene. Repeated ice dam formation and destruction at the outlet of glacial Kootenay Lake influenced the Kootenai subbasin. The last ice dam failure approximately 10,000 years ago drained Kootenay Lake to near its current elevation. Fine sand and silts deposited during lacustrine periods, filled the bottom of the Purcell Trench, a north-trending glacially modified valley running from Coeur d'Alene, Idaho into Canada (Doughty and Price 2000). The deposited fines shaped the valley bottom forming the contemporary floodplains and terraces observed today. Additional discussion regarding geomorphology is provided in Section 2.4.3 and Appendix E.

Prior to Euro-American settlement in the Kootenai subbasin, the river interacted with the adjacent floodplain on an annual basis. The dynamic floodplain characterized by diverse riparian communities, side channels and ponds, and tributary streams exchanged materials with the river. Sediment, nutrients, large wood and debris mobilized by the river would have deposited on the adjacent floodplain. Similarly, these materials would have also have been reclaimed by the river during annual high water. Relict floodplain features mapped by the General Land Office (GLO) suggest the Kootenai River actively migrated within its floodplain, leaving channel scrolls that evolved into floodplain ponds, oxbows and other wetland habitats over time.

2.2.5 Habitat and Biota

The pre-European Kootenai River corridor was characterized by the primary river channel, connected backwater habitats, floodplain channels that were activated during flood runoff, and tributary streams that meandered across the floodplain to join the Kootenai River. Richards (1997) highlighted the historical floodplain conditions between Bonners Ferry and Kootenay Lake.

> The Kootenai River, like other river-floodplain ecosystems, was historically characterized by seasonal floods that promoted the exchange of nutrients and organisms among a mosaic of habitats, and thus enhanced biological productivity (Junk et al. 1989, Bayley 1995, Sparks 1995). Prior to the construction of Libby Dam, the Kootenai River was characterized by a four to six kilometer wide floodplain [the active river corridor is now generally limited to the primary channel] in the furthest downstream 128 km of the river [extending from downstream from Bonners Ferry to Kootenay Lake-approximately the Meander Reach]. Diking of this stretch of river, from the 1920s to the 1950s, eliminated approximately 50,000 acres of natural floodplain in Idaho alone. Estimated floodplain loss in British Columbia may be equal or greater.

Despite the diverse floodplain corridor, the Kootenai River historically supported a fish community with a relatively low species diversity (Table 2-1) compared to other drainages in the Columbia Basin. The low number of fish species inhabiting the Kootenai River is related to the isolation by Bonnington Falls. The multiple runs of anadromous salmon, steelhead, and lamprey that were historically common in other tributaries to the Columbia River did not develop post-glacially in the Kootenai River due to these barrier falls. Several of the land-locked species in the Kootenai River have anadromous life form counterparts (e.g., white sturgeon and kokanee) that inhabit water bodies connected to the ocean.

Table 2-1. Fish species in the Kootenai subbasin.

Native Species		**Introduced Species**	
Common Name	***Genus species***	***Common Name***	***Genus species***
Westslope cutthroat trout	*Oncorhynchus clarki lewisi*	Rainbow trout	*Oncorhynchus mykiss*
Redband trout	*Oncorhynchus mykiss subspecies*	Brown trout	*Salmo trutta*
Bull trout	*Salvelinus confluentus*	Brook trout	*Salvelinus fontinalis*
Kokanee salmon	*Oncorhynchus nerka*	Bluegill	*Lepomis macrochirus*
Mountain whitefish	*Prosopium williamsoni*	Pumpkinseed	*Lepomis gibbosus*
Burbot	*Lota lota*	Smallmouth bass	*Micropterus dolomieu*
White sturgeon	*Acipenser transmontanus*	Largemouth bass	*Micropterus salmonides*
Redside shiner	*Richardsonius balteatus*	Northern pike	*Esox lucius*
Peamouth chub	*Mylocheilus caurinus*	Yellow perch	*Perca flavescens*
Northern pikeminnow	*Ptychocheilus oregonensis*	Black bullhead	*Amerius melas*
Largescale sucker	*Catostomus macrocheilus*		
Longnose sucker	*Catostomus catostomus*		
Torrent sculpin	*Cottus rhotheus*		
Slimy sculpin	*Cottus cognatus*		
Longnose dace	*Rhinichthys cataractae*		

2.2.6 Focal Species

Six native Kootenai River fish species identified as focal species in the Kootenai Subbasin Plan (KTOI and MFWP 2004) were also used as indicators to evaluate potential habitat restoration actions presented in this Master Plan. These species include: Kootenai River white sturgeon, burbot, bull trout, westslope cutthroat trout, redband trout, and kokanee.

These species were chosen as focal species in the *Kootenai Subbasin Plan* because:

1. They are designated as a Federal endangered or threatened species or have been otherwise designated a priority species for conservation actions; and/or
2. They play an important ecological role in the Kootenai subbasin (for example as a functional specialist or as a critical functional link species); and/or
3. They possess economic or cultural significance to the people of the Kootenai subbasin.

The following estimates of current abundance of various species as a percent of their historical population level, is presented in the Kootenai Subbasin Plan (MFWP and KTOI 2004):

- Bull trout — 60% of historical levels
- Westslope cutthroat trout — 20% of historical levels
- Redband trout — 10% of historical levels
- Kokanee — 40-50% of historical levels
- White sturgeon and burbot — 0-10% of historical levels

Section 2.6.1 provides additional summary information on historical and current populations, habitat requirements, and limiting factors affecting the focal species populations. Additional information is provided below for the Kootenai sturgeon since it is listed as endangered under the Endangered Species Act (ESA) by the U.S. Fish and Wildlife Service (USFWS), and as an endangered species under the Canadian Species at Risk Act (SARA), and is thus an essential area of concern in the design and implementation of the Kootenai River Habitat Restoration Project.

2.2.7 Riparian and Wetland Communities

Historical riparian and wetland communities within the lower Kootenai subbasin have been documented in several reports (Jamieson and Braatne 2001; KTOI and MFWP 2004; Egger et al. 2007). The following section summarizes historical conditions of riparian and wetland communities in the portion of the Kootenai subbasin addressed by this project, as presented in the above referenced reports.

During pre-European settlement times, riparian and wetland plant communities in the lower Kootenai subbasin were more widespread and diverse than they are now. The intact and functioning ecosystem processes of the pre-European settlement Kootenai subbasin would have supported the following functions:

- Provided the array of habitats and ecological niches needed to support the various life stages of the native flora and fauna;
- Provided exchange of sediment, nutrients, large wood and debris between the river and floodplain environment to support overall system productivity;
- Provided above and below ground, transport of dissolved particulate materials and nutrients by river flow;
- Provided an interconnected corridor linked not only along the river, but also to associated tributary streams and adjacent uplands;
- Provided water quality benefits through streambank stabilization, sediment filtering, and dissipating stream energy to allow sediment deposition and streambank building; and
- Provided groundwater and aquifer recharge through floodwater retention.

Historically, the hydroecology of the Kootenai subbasin was predictable. It was characterized by a large, sustained, snow-melt driven runoff period in late spring, followed by a gradual recession in early autumn, and low winter flows (Burke 2006). The complex and expansive riparian and

wetland habitats of the lower subbasin were created and maintained by these hydrologic cycles. The frequent flood-pulse disturbances would have changed the floodplain landscape frequently and supported associated riparian and wetland plant communities. Channel movement combined with flooding would have driven vegetation successional processes by creating opportunities for early pioneering species like cottonwood and willow to establish. This dynamic, intact floodplain would have been characterized by: diverse riparian communities, side channels and ponds, and tributary streams that exchanged materials with the river on an annual basis. According to Jamieson and Braatne (2001), the lower Kootenai subbasin probably supported one of the largest and richest riparian forest and wetland complexes in the Pacific Northwest. Historically, the lower Kootenai River was thought to have included approximately 70,000 acres of contiguous floodplain and related riparian and wetland ecosystems (Jamieson and Braatne 2001). Of these 70,000 floodplain acres, approximately 22,000 acres were estimated to be wetlands (USEPA 2004).

Within the terraced/alluvial and glacio-lacustrine valley types, riparian and floodplain communities would have been extensive, spreading throughout the valley floor and forming in response to channel migration patterns and sediment deposition. The surface hydrology connection between the Kootenai River and its floodplain would have created and maintained side channels and off-channel wetlands, resulting in diverse habitats representing multiple age classes. In inter-gorge and other structurally-controlled reaches, these interactions would have been reduced, resulting in narrow strips of riparian communities and minimal wetland development.

Within the glacio-lacustrine valley type, natural sand levees would have driven plant community distribution. Exactly how plant communities were distributed in this valley type is not clear and much of the existing literature does not address this directly. To fill this data gap, the Kootenai Tribe is developing a model of historical vegetation and potential natural vegetation in the floodplain (Egger et al. 2007; Benjankar 2009). It seems logical, however, that the plant communities immediately adjacent to the river may have been dominated by grasses or upland shrubs rather than cottonwoods due to the high elevation of sand levees relative to the river. Given this topography, cottonwood communities would have occurred in narrow bands within the natural levees, but also would have been located further away from the channel in areas subject to scour and deposition, possibly where high flows occasionally breached natural levees. This process has not been documented in the literature, however, and other factors may have influenced plant community distribution in the glacio-lacustrine valley type. Figure 2-3 shows the low floodplain elevations relative to the river stage at average peak flows in the main channel. River stages used for comparison in Figure 2-3 are based on the U.S. Geological Survey (USGS) HEC-RAS Model (Berenbrock 2005) using a discharge of 30 kcfs and a downstream boundary condition at Porthill, Idaho of water-surface elevation 1,754 ft (mean Kootenay Lake backwater elevation at mean annual peak flow); floodplain elevations are based on LiDAR data. These data show that the lowest areas of the floodplain are located some distance from the main channel.

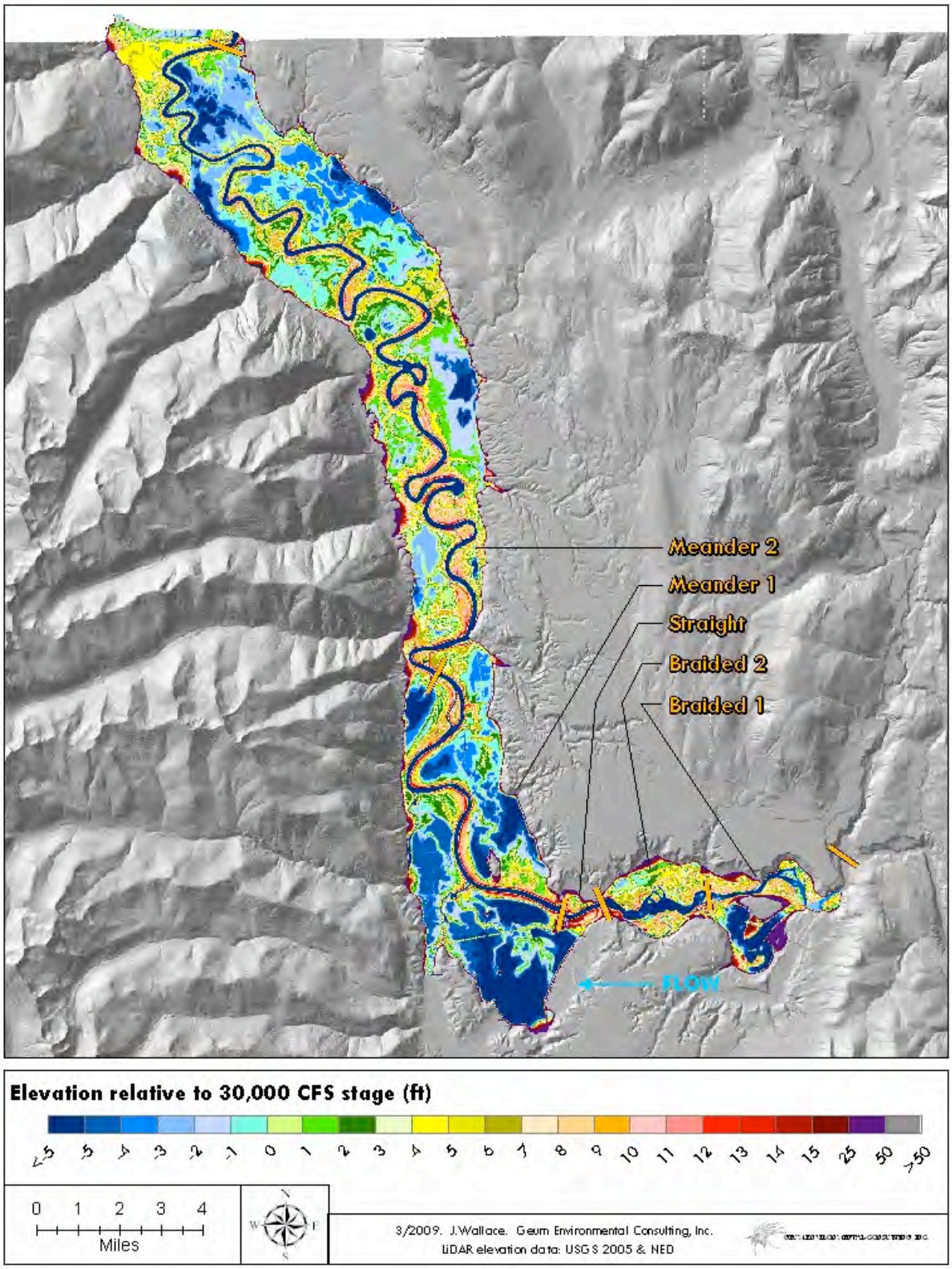


Figure 2-3. Kootenai River project area floodplain elevations relative to the 30 kcfs water-surface.

2.2.8 Delineation of Kootenai River Reaches within the Project Area

The 55-mile Kootenai River project area covered by this Master Plan extends from the Moyie River confluence with the Kootenai River, downstream to the international border. For the purposes of this Master Plan, the project area was delineated into three major reaches (Braided, Straight and Meander) based on geomorphic properties and then the Braided and Meander reaches were further delineated into two sub-reaches (Figure 2-2). The project reaches identified in the Master Plan are similar, although not entirely identical, to delineations identified during previous work on the Kootenai River (Paragamian et al. 2001; Burke 2006; USFWS 2008).

The river miles in the following reach descriptions represent defined locations along the river that were identified at a point in time. Because the river has shifted over time, actual lengths of reaches are usually slightly different than the calculated difference between two river mile designations (for example, the Straight Reach is 1.1 miles long if measured along the thalweg, but it extends from RM 152.7 to 151.7). This section also includes a description of adjacent river reaches, which although not directly addressed through the restoration treatments and actions identified in this Master Plan, are discussed in some of the analysis in this chapter.

Braided Reaches

Braided Reach 1 extends nearly 4 river miles (RM 160.9 to RM 156.2) from the Moyie River confluence downstream to the upstream extent of the backwater influence from Kootenay Lake. Braided Reach 2 extends approximately 2.2 river miles (RM 156.2 to RM 152.7) from the upstream extent of the backwater downstream to the U.S. Highway 95 bridge. The Kootenai River from Libby Dam to near the confluence of the Moyie River is characterized by a steeper gradient and confined channel morphology. The Kootenai River downstream from the Moyie River confluence enters a wider valley with a decreasing gradient. Multi-channel, meandering, riffle-pool characteristics predominate through the Braided Reaches. Gravel and cobble are dominant channel substrates found in the Braided Reaches.

Straight Reach

The Straight Reach extends 1.1 river miles (RM 152.7 to RM 156.2) from the U.S. Highway 95 bridge, downstream to Ambush Rock. This reach is marked by a narrowed river corridor with a confined floodplain that is laterally constrained by flood protection measures and floodplain development in the town of Bonners Ferry. The U.S. Highway 95 bridge and train trestle are also confining features in the reach. Historically, the reach was laterally constrained by hillslopes and bedrock. Channel substrate transitions from gravels to sand through the reach.

Meander Reaches

The combined Meander Reaches extend from the downstream end of Ambush Rock to Kootenay Lake. Meander Reach 1 begins at Ambush Rock and extends 9.7 river miles (RM 151.7 to RM 141.8) downstream to slightly below Shorty's Island. Meander Reach 2 spans 35.5 miles (RM 141.8 to RM 105.9) from the end of Meander Reach 1 to the international border. The Meander Reaches are situated in a low gradient lacustrine valley and channel substrates are dominated by sand and clay. Prior to levee construction, the Meander Reaches were laterally active.

The USFWS designated Kootenai River white sturgeon critical habitat is included in the Master Plan project area and spans 18.3 river miles (USFWS 2008) from upstream of Bonners Ferry (RM 159.7) downstream to below Shorty's Island (RM 141.4). The critical habitat reach spans a portion

of the Braided Reaches, the entirety of the Straight Reach, and the upstream portion of the Meander Reaches. Critical habitat includes the reach of the river where Kootenai sturgeon are known to spawn (Bonners Ferry downstream to Shorty's Island), as well as portions of the river where habitat conditions are believed to be conducive to successful egg adherence and embryo survival (Bonners Ferry to RM 159.7) but where spawning does not currently appear to be occurring.

Adjacent Reaches

The area upstream of the Braided Reaches is referred to as the Canyon Reach (RM 171.9 to RM 160.4). The Canyon Reach is characterized by confined morphology, cobble substrate and pool riffle bedforms. The Kootenai Tribe and their partners decided to exclude the Canyon from this Master Plan since habitat conditions in this reach are generally reported to be good, Kootenai sturgeon Critical Habitat is not included in this reach and because the reach is located in Canada.

The area downstream of Meander Reach 2 to Kootenay Lake is referred to as Meander Reach 3 (RM 105.6 to RM 76.8). Meander Reach 3 is similar in character to the other Meander Reaches and it includes the Kootenay Lake delta.

2.2.9 Summary

The historical Kootenai subbasin was characterized by a dynamic river-floodplain system that supported fish species exhibiting complex life histories. The spring freshet inundated off-channel habitats and exchanged organic material and sediment between the river and floodplain. Delivery and sequestration of nutrients, sediment and wood created a mosaic of diverse habitats. Riparian forests and extensive wetlands occupied the broad, low gradient Kootenai River floodplain. Sediment deposits formed natural levees paralleling both tributary streams and the Kootenai River, creating topographic high points that sustained upland vegetation species.

2.3 River and Floodplain Management in the Kootenai Subbasin

Management of the Kootenai River and its floodplain has resulted in several constraints that limit the restoration potential for the river corridor. As stated in Chapter 1, the purpose of this project is to develop habitat restoration strategies that are compatible with existing land uses and river and floodplain management priorities in the project area. However, to develop logical habitat restoration strategies, restoration treatments, and habitat actions that address limiting factors, it is necessary to understand the impacts that have resulted from land use and river management over time.

Dam operations in Montana and British Columbia, as well as historical and contemporary forestry and industrial land uses, agricultural, and residential and municipal development have affected the subbasin overall as well as river corridor conditions. The following paragraphs summarize constraints related to river, floodplain, and adjacent land use management.

Euro-American settlement of the Kootenai subbasin in the vicinity of present day Bonners Ferry, Idaho began in the mid-1800s. Early settlers farmed and ranched on the productive floodplain.

As the local population grew and the railroad brought access to distant markets, logging and mining became important forms of commerce. Primary land uses since the mid-1800s have included forestry, coal and hard rock mining, smelting, agriculture, hydroelectric dam operation, and city and residential development. Prior to regulation, frequent floods (i.e., nearly annual) inundated the floodplain, necessitating flood protection measures to ensure stable farming conditions and to enable development of Bonners Ferry. While Libby Dam was developed as part of a system-wide network of flood control dams to protect inhabitants of southern Washington and northern Oregon from Columbia River flooding, the towns of Libby and Troy, Montana, and Bonners Ferry, Idaho also benefited from these flood control measures. The following sections summarize historical and contemporary land uses in the Kootenai subbasin.

2.3.1 Forestry Practices

Forestry is the dominant industry in the Kootenai subbasin. The following excerpt from the Kootenai Subbasin Plan (KTOI and MFWP 2004) summarizes forestry practices in the subbasin.

> The forest products industry remains the most dominant employment and most extensive development activity in the subbasin. Roughly 90% of the drainage is forested. Logging and associated road building has occurred in nearly all of the lower elevation valleys and on many higher elevation ridges. Roadless areas larger than 5,000 acres are uncommon. Nine roadless areas totaling 139,600 acres exist in the Idaho portion of the subbasin (IPNF 1991). In the Montana portion, nine roadless areas totaling 241,500 acres are present, including approximately 60,000 acres of upper Libby and Lake Creeks within the Cabinet Mountains Wilderness Area (USDA 1987). The largest contiguous block of land without logging roads in the British Columbia portion of the Kootenay Basin is the 390,000-acre Kootenay/Mt. Assiniboine National and Provincial Parks (Rocchini 1981). Approximately 150,000 acres of the headwaters of the St. Mary River and Findlay Creek northwest of Cranbrook/Kimberley are within the Purcell Wilderness Conservancy. The total surface area of undeveloped areas amounts to about 10% of the Kootenai subbasin above Kootenay Lake.

2.3.2 Mining Practices

Hard rock mining has also influenced the Kootenai subbasin. Large-scale mining in both Canada and the United States degraded water quality and habitat in the Kootenai River and its tributaries. Industrial mining in the subbasin included Cominco Ltd.'s Sullivan Mine, one of the world's largest lead and zinc mining facilities that operated in Kimberley, British Columbia from 1917 to 2001. Wastewater from the mine was discharged into tributaries of the St. Mary River, a tributary to the Kootenai River. By 1979, wastewater treatment facilities, which removed heavy metals from the effluent before it entered the waterways, were completed at the mine (Knudson 1994).

Other industrial mining operations included the Cominco Fertilizers Ltd. plant also located in Kimberly, British Columbia. The following from Richards (1997) describes inputs and impacts of the fertilizer plant on the Kootenai River.

> The Cominco plant expanded from a lead smelter to the production of fertilizer in 1953 (Partridge 1983), and began discharging wastes into the St. Mary River, a tributary of the Kootenai River. Fertilizer production was doubled in 1962 and increased again in 1965. Water pollution control at the plant was improved in 1969, but it was not operating optimally until 1975 (Daley et al. 1981). Waste discharges from this plant increased phosphorus load throughout the Kootenai system, resulting in a four-fold increase from 1951 to the 1960s (Northcote 1973). By 1965, new production created more waste than the plant's disposal facilities could properly dispose of, and high levels of zinc, fluoride, ammonia, and phosphate combined to create toxic conditions for aquatic organisms in the St. Mary River. In 1968, a waste system was installed at the plant, which reduced the levels of toxic compounds being discharged into the Kootenai River (Partridge 1983). Fertilizer productions decreased in the 1970s and 1980s until the plant closed in 1987 (Knudson 1994).

The W.R. Grace Company's vermiculite mine northeast of Libby, Montana, discharged wastewater and vermiculite to Rainy Creek, a tributary to the Kootenai River downstream from Libby Dam. Rainy Creek was designated a federal Superfund site that necessitated an environmental clean up. A copper and silver mine near Troy, Montana, also discharged contaminated runoff to surface waters joining the Kootenai River. Each of these mining operations has affected Kootenai River tributaries due to discharge of mine waste.

The Kootenai Subbasin Plan (KTOI and MFWP 2004) also highlighted coal mining as a prominent mining activity in the subbasin, particularly along the Elk and St. Mary rivers. Large-scale, open-pit coal mining began in the Elk River watershed in the early 1970s.

Crestbrook Forest Industries continues to operate a paper pulp mill in Skookumchuck, British Columbia. Since 1968, Crestbrook Forest Industries' pulp mill in Skookumchuck has been the largest point source discharge directly into the Kootenai River. During the 1970s angler use of the river below Skookumchuck decreased due to the adverse effects caused by the mill (discoloration of the river, toxicity, and fish tainting problems). The following excerpt from Richards (1997) provides an overview of the Crestbrook Forest Industries' pulp mill clean up efforts.

> Attempts to reduce pollution at the mill began in 1981 when Crestbrook began disposing of its effluent during low flow periods. In 1992, a major upgrading of the mill began in order to reduce polluted effluent discharging into the river (Knudson 1994).

2.3.3 Agriculture

Agriculture is the dominant land use on the Kootenai floodplain from Bonners Ferry to Kootenay Lake. Flood control projects on the Kootenai River dating to the late 1800s were necessary to facilitate floodplain farming. Oats, wheat and barley production account for 62% of the agricultural output in the Bonners Ferry/Creston area, with livestock production accounting for 20% (KTOI and MFWP 2004). Other important cash crops include hops, a crop sensitive to soil moisture. Hay and grass seed production and livestock grazing are the most common agricultural activities in the rest of the subbasin (KTOI and MFWP 2004).

Richards (1997) provided an historical perspective on agricultural floodplain development in the vicinity of Bonners Ferry.

> Movement of the Kootenai River and tributary streams in the valley and springtime flooding formed numerous marshes and sloughs which, along with fertile soils, provided a variety of fisheries habitats (Partridge 1983). Early attempts at diking the river began in 1892 with a desire to reclaim this land for agricultural purposes, although there was little success until the 1920s (Northcote 1973). In order to prevent flooding, drainage districts were formed in the 1920s. This in turn channelized the natural meandering tributary streams into straight ditches between the mountains and the (Kootenai) river. By 1935, over 90% of the valley bottom in Idaho was in drainage districts (Partridge 1983). Topographic map comparison shows that an estimated 5,512 acres of wetland area was lost between 1928 and 1965.

Agriculture has been a critical element in the development of the Bonners Ferry area and the northern Idaho Panhandle. To build a diverse multi-crop agricultural industry, the native floodplain system of the Kootenai River was modified to support the farming-based economy. While essential to the prosperity of the region, agriculture has affected the Kootenai River. Historical plant communities were displaced as the swampy lowlands were filled with the rich soils plowed from the floodplain. Tributaries and flood channels were straightened to speed the drainage of water from newly cleared land. With the improving agricultural conditions, changes in the native plant communities, wildlife and fisheries, and water quality signified the transition from historical conditions to a growing agricultural industry.

Reclamation projects were funded through both government bonds and private backing. Based on review of historical news articles, the reclamation projects appeared to have benefited large agricultural interests on the Kootenai River floodplain from Bonners Ferry to the Canadian border.

The U.S. Bureau of Reclamation wrote in 1948, in a comprehensive report on the development of water resources in the Columbia River Basin (USACE 1948):

> Dikes have been constructed by private interests to protect some of the 50,000 acres of bottom land along the Kootenai between Bonners Ferry, Idaho, and the Canadian border. These dikes do not provide complete flood protection. Some of the lands are within the influence of backwater produced by artificial regulation and storage in Kootenai Lake by Canadian Interests.

Early news articles did not detail the origin of the materials that were used to build the dike network, however, Tolman (1923) related that floodplain soils were the likely material for building dikes. Draglines such as one purchased by Klockmann in 1919 would have been capable of excavating fill material from both the floodplain and the river channel. Burke et al. (2006) included channel dredging between 1900 and 1940 as one of the disruptive management activities implemented during land reclamation. Dredging has also been identified as one of the causative agents for streambank instability and channel longitudinal profile discontinuities in the Kootenai River (Wildland Hydrology 2008).

2.3.4 Development

Changes in the river corridor have enabled residential and agriculture development of the historical floodplain. In addition to the operation of Libby and Cora Linn dams for flood control, floodplain alterations including ditches and dikes, pumping stations, drainage channel networks, railroad and road embankments, and the Creston Valley Wildlife Management Area (Matt Neufeld, BC MoE, personal communication, 2008) have nearly eliminated river flooding between Bonners Ferry and Kootenay Lake. High runoff years may exact some agricultural losses due to high ground water and tributary flooding created by backwatering of tributary streams by the Kootenai River, however, relative to the historical conditions, flooding is an infrequent occurrence in the river corridor. Figure 2-4 displays the majority of known infrastructure in the project area.

Floodplain dikes and drainage ditch networks date to the late 1800s downstream from Bonners Ferry. Early efforts were limited by technology, personnel, and funding. However, organized agricultural interests formed drainage districts by the early 1920s. Districts acquired federal funding to initiate networks of dikes, replacing the berms erected in the late 19th century. During this period, floodplains were ditched and tiled to lower the water table and allow agricultural interests to farm the land earlier in the year than previously possible. The installation of pump stations also permitted lowering the water table to allow earlier planting. These activities in addition to land clearing and leveling, tributary stream straightening, and the draining of floodplain lakes and ponds, allowed farmers to expand the growing season and plant a wider variety of crops.

In addition to agriculture development, municipalities in the Kootenai subbasin also influence river function and ecology. The following excerpt from Richards (1997) highlights treated wastewater discharge to the Kootenai River.

> Major municipalities in the Kootenai River Basin served by secondary waste treatment facilities include: Cranbrook, Kimberly, Fernie, Creston, Sparwood, and Elkford, British Columbia; Libby, Montana; Bonners Ferry, Idaho; and Troy and Eureka, Montana (Knudson 1994; Woods and Falter 1982; Bonde and Bush 1975). The rest of the populations in the basin use septic tanks or smaller community systems. All municipalities in the drainage basin discharge effluent directly into the Kootenai River, or into the water table by subsurface seepage, therefore degrading water quality. In 1976, Cranbrook ceased sewage discharge by employing a spray irrigation system. Water quality effects downstream from Libby, Bonners Ferry, and Troy are not as great as the effects from cities on smaller-scale tributaries, due to the high volume of water, therefore greater dilution of the Kootenai River. All industrial and municipal operations in the Kootenai River Basin have an effect on the water quality of the Kootenai River. In turn, the degradation of water quality in the river affects the entire aquatic ecosystem.

Transportation Corridors

U.S. Highway 95 crosses the Kootenai River at Bonners Ferry near the upstream end of the Straight Reach. Built in 1983, the U.S. Highway 95 bridge has seven piers located in the active channel and an additional two piers and two abutments located in the floodplain. The spacing between piers is 155 feet. Riprap bank protection currently extends upstream and downstream on both banks adjacent to the bridge.

The Union Pacific and Burlington Northern Santa Fe (BNSF) Railroads parallel the Kootenai River along the northern and southern edges of the Braided Reaches, respectively. At several locations along the southern edge, the BNSF railroad embankment interacts with the active channel and isolates floodplain area, leaving portions of the historical floodplain disconnected from the river. The Union Pacific crosses the Kootenai River at Bonners Ferry near the upstream end of the Straight Reach, about 500 feet downstream from the U.S. Highway 95 bridge.

Because of the confined morphology of the Straight Reach, the bridges do not have a significant effect on river morphology; however, the riprap banks limit establishment of a riparian buffer and development of bank cover for aquatic habitat. The piers and abutments pose constraints to habitat restoration in the vicinity of the bridge by potentially limiting implementation of restoration treatments that could alter river hydraulics and potentially jeopardize bridge stability.

Water Intakes, Diversions and Points of Discharge

Several water intakes, points of diversion and points of discharge are located in the Kootenai River project area. Most of these facilities are privately managed and are associated with agricultural operations. Although the following paragraphs focus on the Bonners Ferry facilities and the Kootenai Tribal Sturgeon Hatchery, the discussion applies to all facilities, private and public, whose operations depend on water from the Kootenai River. In general, water intakes, diversions and points of discharge will not constrain habitat restoration, but instead will add additional considerations to the design process in order to protect the facilities. Design considerations will be discussed with the owners of the facilities before initiating the next phase of the design process.

Bonners Ferry maintains a water supply intake on the southern edge of the river near the downstream end of the Braided Reach. Additionally, the town maintains a sewage treatment plant discharge on the northern edge of the river near the downstream end of the Straight Reach. Riprap bank revetment protects both locations. The intake and discharge are two examples of stream-side developments along the urbanized segment of the river that limit establishment of a riparian buffer and development of bank cover for aquatic habitat through the Bonners Ferry portion of the project area. Design considerations related to the intake include evaluating the effects of restoration treatments on water quality, the facility's ability to intake water at the present location, and bank stability at the intake. The sewage treatment plant discharge will require similar design considerations.

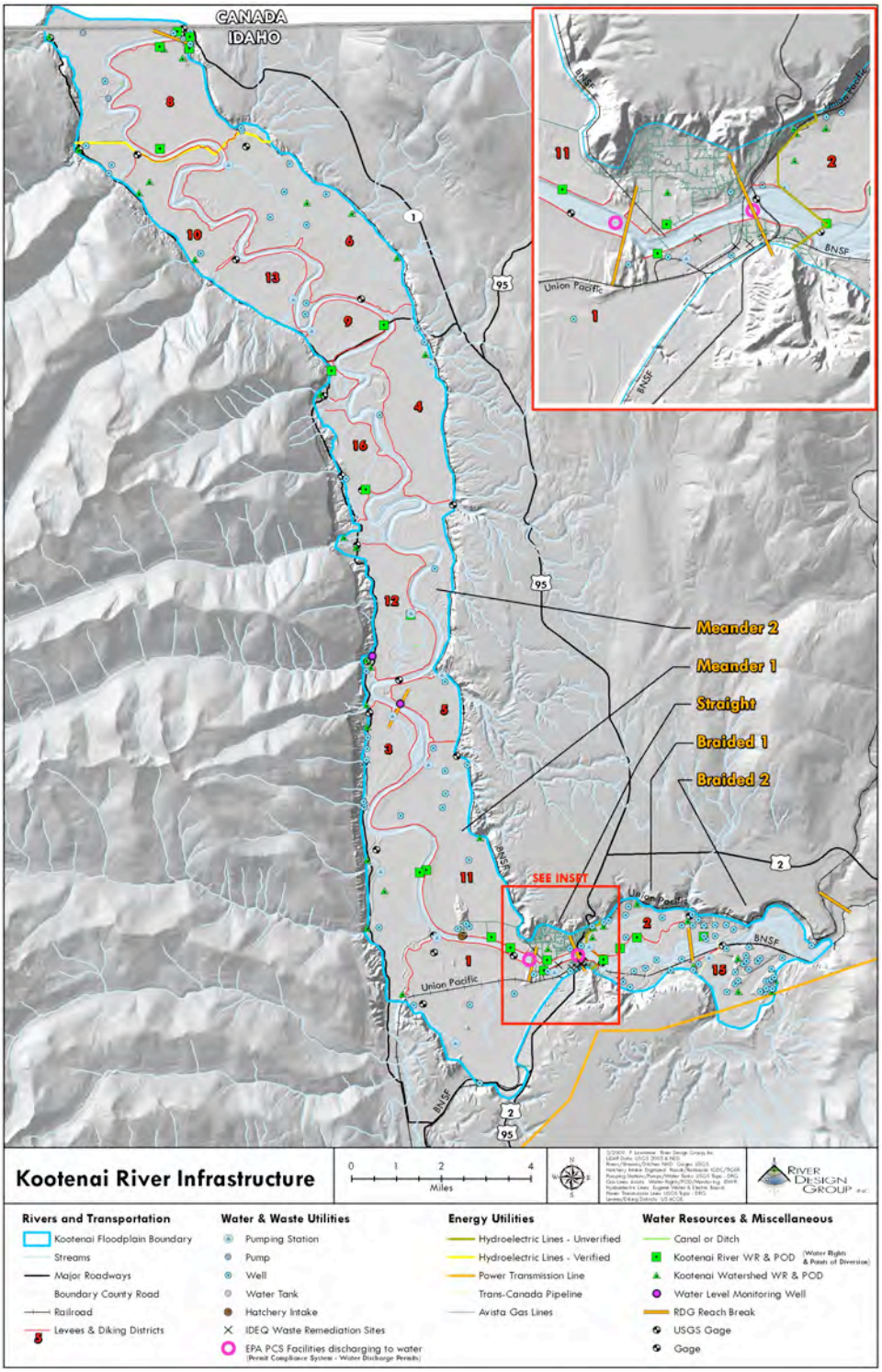


Figure 2-4. Infrastructure in the Kootenai River project area.

The Kootenai Tribe currently operates a water intake for the Kootenai Tribal Sturgeon Hatchery near the upstream end of the Meander Reach. The surface water intake is operated for most of the year except when high turbidity events and temperatures degrade water quality. Similar to

the Bonners Ferry municipal water facilities, the hatchery intake poses a constraint to habitat restoration by potentially limiting implementation of restoration treatments that could adversely affect water quality, influence the ability to intake water at the present location, or jeopardize bank stability at the intake. Space limitations and the absence of a high quality groundwater source have prevented the expansion of the Kootenai Tribal Sturgeon Hatchery at Bonners Ferry (KTOI 2008, draft Aquaculture Master Plan). The Tribe is currently proposing construction of a new Tribal hatchery facility (through the NPCC three-step planning process) near the Moyie River confluence with the Kootenai River. This new hatchery would provide expanded rearing capacity for Kootenai sturgeon and space for the Tribe's proposed burbot conservation aquaculture program. River water from both the Kootenai River and the Moyie River, in addition to groundwater, will be used for the proposed facility. Sturgeon will be reared on the surface water supply that has been filtered and disinfected to control pathogens in order to imprint them on waters closer to existing suitable habitat upstream from the current Tribal Sturgeon Hatchery (KTOI 2008).

Utilities

Avista Corporation maintains a network of power transmission and natural gas lines within Bonners Ferry. A cable-suspended gas line crosses the Kootenai River near the downstream end of the Straight Reach. An overhead power transmission line crosses the Kootenai River near the downstream end of the Braided Reaches. Neither crossing appears to pose a significant constraint to habitat restoration efforts.

River Gages

The USGS operates two river gages in the project area, one at the upstream end of the Meander Reaches, and another near the border at Porthill, Idaho. In addition, several other, smaller gages are maintained throughout the project area to support ongoing river studies. Similar to other instream constraints, the USGS gages pose a constraint to habitat restoration by potentially limiting implementation of restoration treatments that could adversely affect operation of the gages. Modification of the river in the vicinity of the river gages could require recalibration of the gages to the altered river conditions and result in temporary losses of gage operation. Nonetheless, it is feasible to mitigate for impacts to USGS gages in the design process, and efforts will be coordinated with USGS.

Levees and Diking Districts

Levees and dikes, combined with other aspects of river and floodplain stewardship (particularly flow management), have resulted in loss of connection between the river and floodplain within the project area. In addition, levees and dikes function to confine high water within a narrow band near the river channel, artificially causing vegetation to be submerged at times during the growing season. Certain aspects of habitat restoration may require working near levees, and levee management in the project area is complicated for several reasons. Responsibility for dike maintenance was transferred to landowners within diking districts years ago, leaving maintenance to each individual. Some diking districts have followed U.S. Army Corps of Engineers (USACE) suggested maintenance standards, while others have not. These standards include removal of woody vegetation, so any restoration actions that include revegetation on levees will need to be coordinated with landowners and the USACE. Although the levees and dikes pose some constraints on habitat restoration, they also function to control floods and support agriculture and other land uses in the historical floodplain. Therefore, restoration

designs that may affect levees and dikes will be developed through a collaborative process that includes landowners and other entities that have a stake in how levees and dikes are maintained.

2.3.5 Dam Operations

The 55-mile Kootenai River Master Plan project area is unique in that both the hydraulic and sediment regimes are significantly influenced by the operation of multiple dams, including Libby Dam, Corra Linn Dam, and Duncan Dam, which controls the Duncan River inflow to Kootenay Lake. Figure 2-5 includes dam and river gage locations.

Since the completion of Libby Dam in 1972 (which became fully operational in 1974), notable changes to the primary hydraulic and sediment regimes have been observed, including: a shift in the annual hydrograph to an "inverted" regime characterized by a 50% reduction in spring peak flows, a 300% increase in winter flows, a dampening of natural flood pulses, and trapping of the sediment contribution from nearly half (8,985 square miles) of the 19,300 square mile Kootenai subbasin (Tetra Tech 2004).

Figure 2-6 presents the mean daily discharge recorded at the USGS Porthill, Idaho stream gage. The USFWS has issued three opinions on Libby Dam (1995, 2000, and 2006). Discharge for the pre-dam and post-dam periods is presented in Figure 2-6; post-dam discharge is split into the period prior to the first opinion was issued in 1995 and after the 1995 opinion. In 2006, the USFWS issued the Biological Opinion regarding the effects of Libby Dam Operations on the Kootenai River White Sturgeon, Bull Trout and Critical Habitat (Libby Dam BiOp), which was further clarified in 2008.

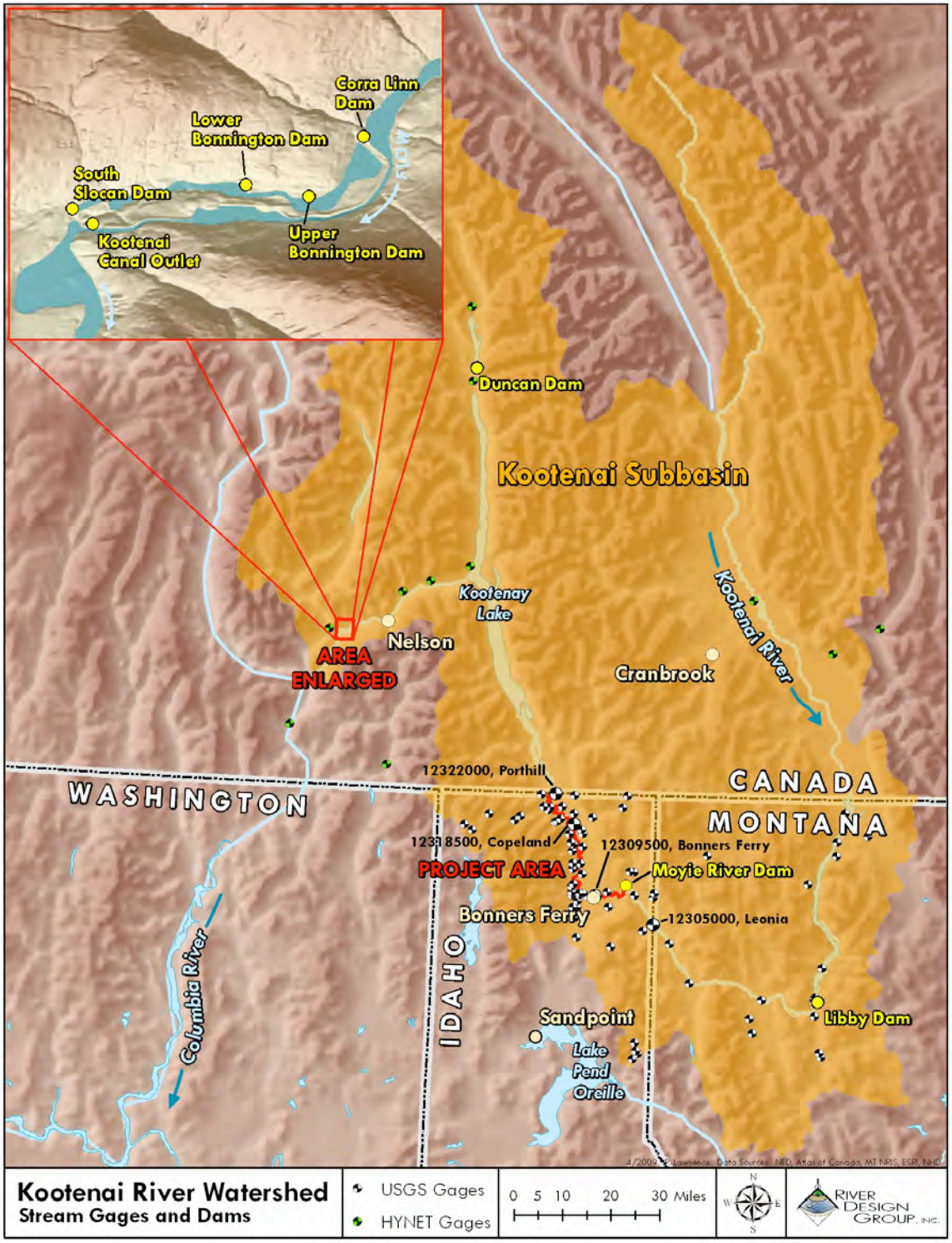


Figure 2-5. Dam and stream gage locations in the project area. USGS gages that are referred to in the Master Plan are highlighted

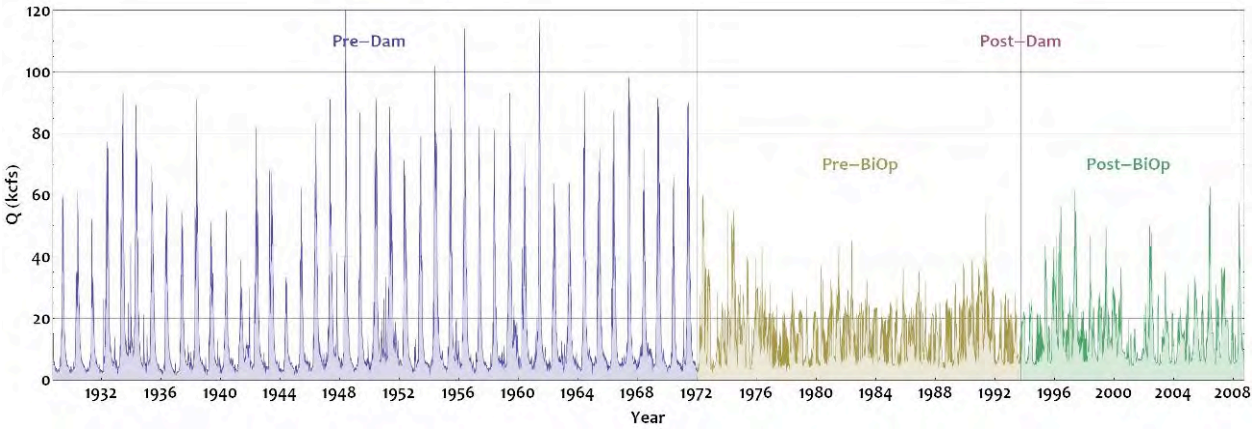


Figure 2-6. The historical mean daily discharge of the Kootenai River measured at Porthill, Idaho (USGS Sta # 12322000). The post-BiOp period includes three opinions from USFWS: 1995, 2000 and 2006. The 2006 Libby Dam BiOp was clarified in 2008.

Historically, the minimum water-surface elevation of Kootenay Lake was naturally controlled by the Grohman Narrows, a bedrock sill in the west arm of Kootenay Lake upstream of the Corra Linn Dam. This combined with the extremely flat valley slopes of the Purcell Trench historically created a backwater effect that extended upstream of Bonners Ferry, Idaho. Following excavation of the Grohman Narrows in 1939 to reduce hydraulic losses in the forebay of Corra Linn Dam, the dam was operated such that the mean maximum elevations of Kootenay Lake were lowered approximately 6 feet from historical levels, which helped in reducing the upstream backwater effects during peak events. Conversely, beginning in the fall through the spring peak (October through May), Kootenay Lake regulation has increased the median lake levels by approximately three feet (Figure 2-7).

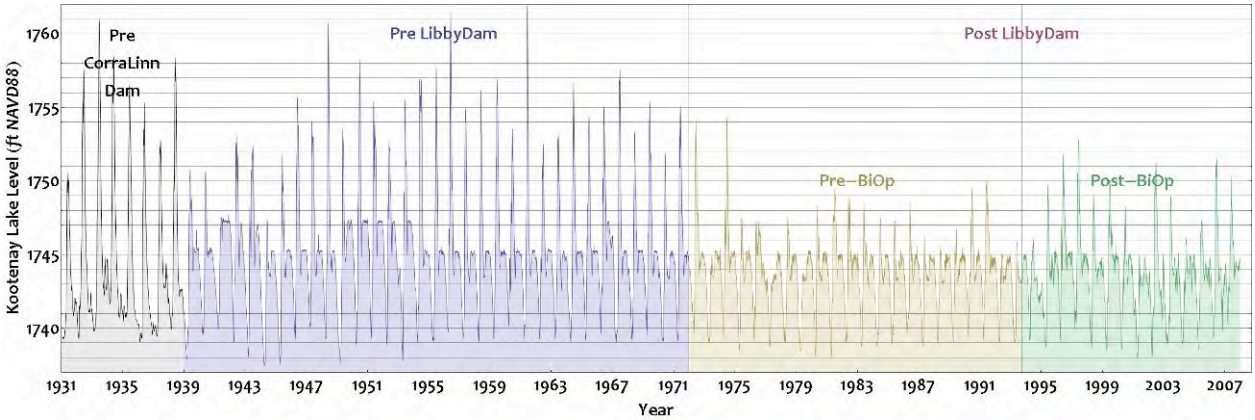


Figure 2-7. Historical water-surface elevations for Kootenay Lake at Queens Bay, British Columbia.

Despite their distance from the project area, the combined effect of Libby and Corra Linn dams resulted in a departure of the primary hydraulic and sediment boundary conditions of the Kootenai River from pre-dam conditions. This departure from pre-dam consitions has subsequently affected the geomorphic response and ecological function of the Kootenai River between the two dams, with the most notable departure in the area subjected to the backwater influence (Tetra Tech 2004; Burke 2006). In general, the upstream transition between the

backwater and free-flowing water within the project area varies as a function of both Libby Dam discharge and Kootenay Lake level. The location of the backwater transition point changes within and between years with changing boundary conditions (i.e., upstream discharge and downstream lake level), and in the post-dam era has generally migrated over a distance of about 6 river miles (Figure 2-8). At the downstream end, this transition point is typically limited to RM 152 near the downstream end of the Straight Reach. Downstream from this location, the river is influenced by the Kootenay Lake backwater year-round. At the upstream end, the location of the transition point varies through the Straight and Braided reaches, and generally does not extend higher than RM 158 midway through Braided Reach 1.

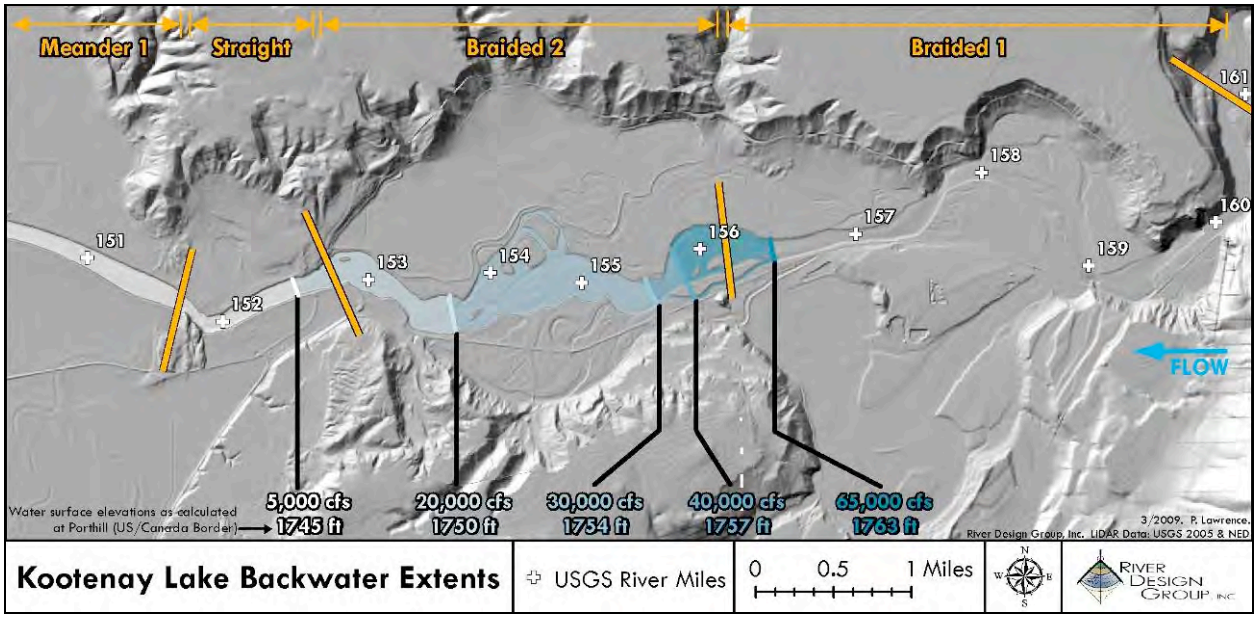


Figure 2-8. Backwater extents on the Kootenai River in the Bonners Ferry area based on hydraulic modeling results and varied boundary conditions (discharge and Kootenay Lake elevation which is represented in the figure by water-surface elevations measured at the Porthill gage). Datum is NAVD88.

The thermal regime of the Kootenai River has also been affected by Libby Dam operations. A selective withdrawal system was implemented in 1977 to better control the temperature of water released from Libby Dam. In the post-dam era, Libby Dam operations have generally increased median Kootenai River temperatures by more than 5°F (2.8°C) during the winter months, increased by about 2°F (1°C) on the rising limb of the spring freshet, and reduced the summer median temperatures by about 2°F (1°C) until the fall. Figure 2-9 compares water temperatures before and after Libby Dam became operational based on Days of the Water Year (DWY) summarizes DWY relative to calendar months.[1]

[1] The Libby Dam selective withdrawal system became operational in 1977; however, implementation of selective withdrawal management actions to specifically benefit sturgeon has only occurred in recent years. Figure 2-8 above simply compares water temperatures before and after Libby Dam became operational.

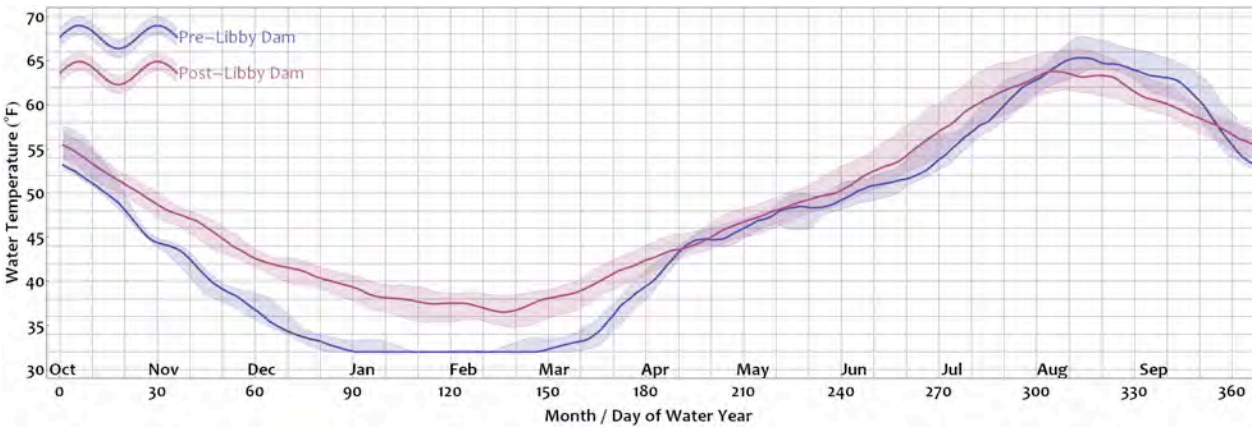


Figure 2-9. Pre and post dam water temperatures for the Kootenai River at Porthill (USGS Sta # 12322000).

Table 2-2. Relationship between calendar year and water year.

Month	DWY Range	Month	DWY Range
January	93 – 123	July	274 – 304
February	124 – 151	August	305 – 335
March	151 – 182	September	336 – 365
April	183 – 212	October	1 – 31
May	213 – 243	November	32 – 61
June	244 – 273	December	62 – 92

2.3.6 Operational Constraints

Both Libby and Duncan dams are operated in concert with other Columbia River Dams under the final objective of not exceeding the Initial Controlled Flow (ICF) downstream at the City of Dalles, Oregon, the site of the Dalles Dam. Corra Linn operations are influenced by system flood control operations but the dam does not provide system flood control (E. Lewis, USACE, personal communication, 2009). Operation of Libby and Corra Linn dams are influenced by a number of competing objectives with additional transnational constraints posed by the Boundary Water Treaty of 1909, the International Joint Commission (IJC) 1938 Order on Kootenay Lake, and the Columbia River Treaty (CRT) of 1961 (the CRT re-evaluation period begins in 2014 with the potential for re-negotiation or termination of the treaty by 2024). The CRT affects Libby and Duncan dams, but not Corra Linn Dam.

Historically, the primary objective of the Canadian dams (aside from Corra Linn Dam) was system flood control as well as power generation and supplemental water storage for downstream power generating dams in the West Kootenay region. Corra Linn Dam flood control operations focus on minimizing flood impacts on Kootenay Lake. To date, the maximum operating water-surface elevations on Kootenay Lake has been controlled by the IJC Order for Storage based on gage measurements at Queens Bay, British Columbia. The following excerpt summarizes the seasonal operation of Corra Linn Dam (K. Ketchum, BC Hydro, personal communication, 2009).

> The water discharge out of Kootenay Lake is equal to the sum of discharges at the Corra Linn and Kootenay Canal projects. FortisBC owns, maintains, and operates the Corra Linn project and holds the IJC Order for Kootenay Lake. BC Hydro owns,

maintains, operates, and dispatches the Kootenay Canal project. Under the terms of the Canal Plant Agreement, BC Hydro normally directs the discharges for Corra Linn; however, FortisBC retains the right to override BC Hydro's directions for various reasons, including meeting the IJC Order.

The Kootenay Lake IJC Order states that the Corra Linn project must be operated, to the extent possible, to keep the Kootenay Lake level at or below specified lake elevations. This IJC Order curve has variable (inflow dependent) maximum lake levels during the spring freshet and fixed maximum lake levels at other times (Table 2-3 on following page).

Normally, the lake is drafted down into the range 1738 ft to 1739 ft in late March and early April, just prior to the spring freshet. In March-April, under some low inflow conditions, it may be possible to draft the lake below 1738 ft (Figure 2-10). However, there are potential stakeholder impacts, including those related to ferry operations on the lake, at lake levels near and below 1738 ft. These impacts are considered when planning the operation of Kootenay Lake.

Typically, in order to improve flood control for Kootenay Lake stakeholders (i.e., to reduce maximum lake levels later in the year), the lake discharge is maximized (restricted only by the hydraulic control at Grohman Narrows) from late March or April until:

1) The lake level has peaked and receded to below 1749.5 ft, or,
2) BC Hydro and FortisBC agree that the lake level is expected to remain below 1749.5 ft.

BC Hydro and FortisBC consider the 1749.5 ft level the "onset of flood damage concern". Current practice is to pass maximum discharge from Kootenay Lake to avoid exceeding this level or to minimize the time above this level. After the threat of flood damage abates, discharges from Kootenay Lake are reduced. Both FortisBC and BC Hydro are careful to ensure that the lake level remains below the IJC curve, which falls during the receding limb of the freshet until the level at Nelson reaches 1743.32 ft.

If Grohman Narrows were excavated further, then there would be additional operating flexibility to draft Kootenay Lake prior to the freshet, including the option to draft below 1738 ft (subject to stakeholder issues) and/or to discharge more during the ascending limb of the hydrograph. This would reduce the likelihood of the lake level exceeding 1749.5 ft (or any other specified flood level). In addition, such excavation would allow lake discharges to be reduced earlier in the freshet, since the risk of exceeding 1749.5 ft would be reduced.

Table 2-3. The IJC Order rule curve for managing the Kootenay Lake level.			
Start Date	**End Date**	**DWY Range**	**Lake Elevation at Queens Bay**
September	January 7	336 to 123	Fall Refill Period Maximum Elevation of 1745.32 ft
January 7	February 1	93 to 124	Drafting Period Straight-line rule from 1745.32 ft to 1744.0 ft
February 1	March 1	124 to 152	Drafting Period Straight-line rule from 1744.00 ft to 1742.4 ft
March 1	April 1	152 to ~183	Drafting Period Straight-line rule from 1742.4 ft to 1739.32 ft
April 1	Declaration of the Start of Spring Freshet	~183 to ~218	Spring Refill Period Endeavor to maintain elevation at or below 1739.32 ft
During Spring Freshet		~165 to ~218	Variable Depending on Inflows
Post-Freshet	September 1	~218 to 336	Post Peak Period Elevation gradually declines to at or below 1743.32 ft at Nelson.
** Water-surface elevations referenced to NAVD 1988 vertical datum.*			

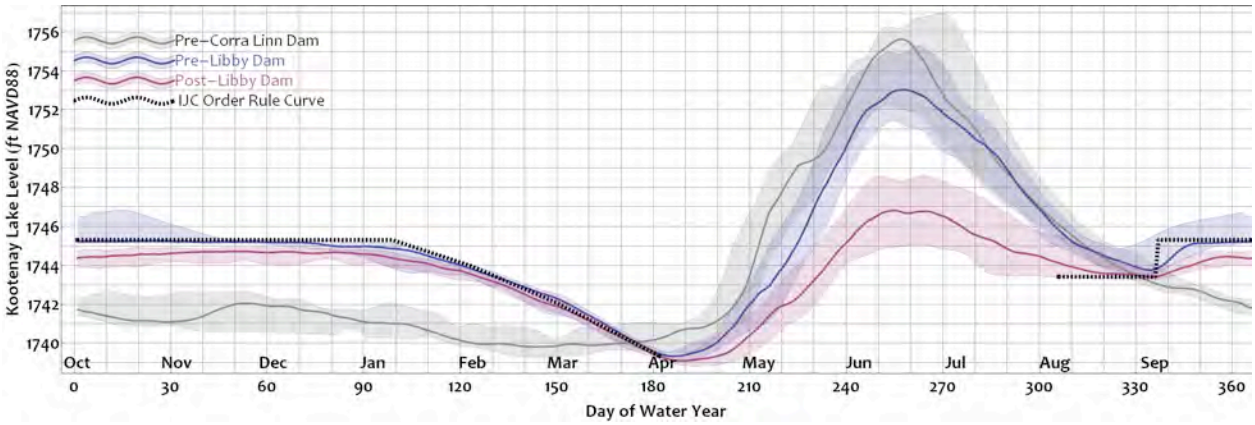


Figure 2-10. Operational regime comparison for Kootenay Lake at Queens Bay, British Columbia (08NH064).

In 2003, the USACE began to implement a variable flow flood control strategy (VarQ) in order to improve the multipurpose operation of Libby Dam while not reducing flood protection in the downstream Kootenai subbasin as outlined in Table 2-4 below. A variable end-of-December draft strategy began in 2005.

Table 2-4. Libby Dam Annual Operational Modes.			
Month	**DWY**	**Operational Period**	**Operational Constraints**
October	1	Fall Operations	▪ Operation governed by power (not flood control)
November	32		
December	62	Drafting Period under VarQ Flood Control	▪ Begin variable December draft based on water supply forecasts (WSP) ▪ Continue drafting until spring refill which typically begins in April ▪ Begin spring refill period 10 days before unregulated flow is expected to exceed the initial controlled flow (ICF) at the Dalles
January	93		
February	124		
March	152		
April	183		
May	213	Refill Period under VarQ Flood Control Additional biological requirements.	▪ Commencement of the spring rise/freshet ▪ Sturgeon pulse flow (May-June) ▪ Refill Period; variable outflow in accordance with VarQ procedures ▪ Final refill period typically by July ▪ Draft to 2439 ft by end of summer in most years for salmon flow augmentation
June	244		
July	274		
August	305	Biological	▪ Bull trout flows
September	336	Return to Fall Operations	▪ Return to power governed operations

In 2008, the USFWS issued a clarification of the 2006 Libby Dam BiOp Reasonable and Prudent Alternatives (RPAs) as listed in Table 2-5 on the following page.[2]

The Libby Dam BiOp seeks to address habitat attributes associated with Kootenai sturgeon and bull trout recovery that have been negatively impacted by operation of Libby Dam. Towards this end, the Libby Dam BiOp identifies a number of specific measures and objectives to address each identified habitat attribute.

In the context of this Master Plan, this information has been considered in relationship to the overarching goals and objectives of the Kootenai River Habitat Restoration Project, which seeks to address a broad range of interrelated limiting factors, in order to recovery naturally self-sustaining populations of Kootenai sturgeon and other native aquatic focal species. As previously noted, the Kootenai River Habitat Restoration Project is intended to address a broad range of interrelated limiting factors through implementation of an ecosystem-based restoration project.

[2] The Libby Dam BiOp, is located online at http://www.fws.gov/easternwashington/documents/Final%20Libby%20Dam%20BiOp%202-18-06lr3.pdf. At the time this document was being finalized the 2008 clarification of the 2006 Libby Dam BiOp was not available online.

Table 2-5. Libby Dam BiOp RPA for Critical Habitat Reach (RM 141.4 to RM 159.7).		
Attribute	**Measure**	**Objective**
Timing of Augmentation Flows	▪ May into July (triggered by sturgeon spawning condition), in all years except for Tier 1.[3]	▪ Provide conditions for normal sturgeon migration and spawning behavior. ▪ Between May 15 and Sept 30, minimum bull trout discharge is 6kcfs.
Duration of Peak Augmentation Flows for Adult Migration and Spawning	▪ Maximize peak augmentation flows with available water for as many days as possible, up to 14 days during the peak of the spawning period with pulses1, in all years except for Tier 1	▪ Through in-season management, provide peak augmentation flows that lead to a biological benefit for sturgeon to maximize migration and spawning behavior via a normalized hydrograph.
Duration of Post-Peak Augmentation Flows for Incubation and Rearing	▪ Maximize post-peak augmentation flows with available water for as many days as possible, up to 21 days, in all years except for Tier 1.	▪ Through in-season management, provide post-peak augmentation flows that lead to a biological benefit for sturgeon to maximize embryo/free-embryo incubation and rearing via descending limb of a normalized hydrograph.
Minimum Flow Velocity	▪ 3.3 ft/s and greater in approximately 60% of the area of rocky substrate in the area of RM 152 to RM 157 during post-peak augmentation flows.	▪ Provide conditions for spawning and embryo/free-embryo incubation and rearing.
Temperature Fluctuation	▪ Optimize temperature releases at Libby Dam to maintain 50° F with no more than a 3.6° F drop.	▪ Provide conditions for normal migration and spawning behavior via a normalized thermograph.
Depth at Spawning Sites	▪ Intermittent depths of 23 ft or greater in 60% of the area of rocky substrate from RM 152 to RM 157 during peak augmentation flows.	▪ Provide conditions for normal migration and spawning behavior.
Substrate Extent/Spawning Structures	▪ Approximately 5 miles of continuous rocky substrate; create conditions/features that improve the likelihood of recruitment success.	▪ Provide habitat for embryo/free-embryo incubation and rearing.
Minimum Frequency of Occurrence	▪ To facilitate meeting the attributes via: powerhouse plus up to 10 kcfs flow test: a flow test will occur 2010 through 2012 (or until the Kootenai River Habitat Restoration Project is implemented) if the Service determines in 2008 and 2009 that the success criteria described in Action 1.3(b) have not been met. ▪ Habitat improvement projects and other options: through adaptive management, as noted in RPA Components 2 and 5.	

2.4 Morphological Limiting Factors

Human activities have changed the channel morphology and channel-floodplain connectivity along the lower Kootenai River since the early 1900s. The most serious impacts resulted from

[3] Per the 2006 Libby Dam BiOp, the sturgeon pulse volume is determined from a tiered flow structure based upon the USFWS May Final Water Supply Forecast for the period of April-August.

water impoundment and diversion, river diking, stream channel straightening, wetland draining, urban and residential development, land clearing for agriculture, and road development. This degradation impaired key geomorphic processes, altering hydraulic conditions, sediment filtering, channel plan form and profile, streambank stability, water storage, aquifer recharge, dissipation of stream energy, and fish and wildlife habitat.

Within the lower Kootenai subbasin, the specific anthropogenic activities that have had the most direct effects on channel morphology include:

- River diking, flood control and channelization;
- Dam construction and operation;
- Water diversion for irrigation;
- Land clearing for agriculture;
- Suburban and urban development; and
- Road building and other transportation corridors.

The primary effects of these activities on channel morphology include the following:

- Altered hydraulics resulting in reduced velocity, depth and shear stress in the project area;
- Altered sediment-transport resulting in reduced supply of coarse bedload from the watershed, reduced sediment transport competence (particle mobility for given size class), reduced sediment transport capacity (volume of sediment moved), and increased embeddedness of coarse substrate;
- Altered channel plan form, profile and dimension including over-sized channel cross-sections, higher width to depth ratios, loss of floodplain connection and decreased lateral channel migration zone; and
- Bank erosion resulting in sediment loading and channel migration.

The above effects have led to the following primary factors limiting restoration of channel morphology in the Kootenai subbasin:

- River and floodplain response to altered flow regime and altered hydraulics;
- River and floodplain response to altered sediment supply and sediment sediment-transport;
- Loss of channel and floodplain connection; and
- Bank erosion and reduced channel boundary roughness.

These effects and factors are described in greater detail in the following sections.

2.4.1 Altered Hydraulics

The long-term effects of both upstream and downstream regulation of the governing hydrologic boundary conditions (i.e., Libby Dam discharge and Kootenay Lake stage) have resulted in a departure from the historical hydraulic conditions and geomorphic response under which the

Kootenai River developed. Within the project area, the geomorphic response corresponding to water and sediment conveyance is generally controlled by the available energy, which is consumed as water and sediment are routed downstream.

The morphology within the project area reflects a state of dynamic equilibrium between any remaining energy and the erodible materials in the channel boundary. The magnitude of the potential energy available for water conveyance and sediment-transport is characterized by the reach energy grade slope, which is generally a function of valley slope, discharge, and local flow resistance created by sediment, vegetation, or other obstructions to flow. The Kootenay Lake backwater also dampens stream energy. The departure of hydraulic response to changes in energy grade can be further evaluated by considering select hydraulic parameters such as shear stress, which represents the force per unit area of the river bed available to entrain and transport sediment.

Additionally, water velocity may also be evaluated to determine hydraulic conditions as hydraulics are correlated with geomorphic processes and ecological function. For the analysis of the Kootenai River conducted as part of this Master Plan, select hydraulic parameters were synthesized for the dominant historical hydrologic regime periods (e.g., pre-dam, pre-BiOp, and post-BiOp) using existing conditions geometry (the rationale for, and limitations of, this exercise are described in Appendix A). Comparing hydraulic conditions for these hydrologic regime periods allowed an approximate comparison of the magnitude and variability of hydraulic departure.

Figure 2-11 illustrates the seasonal departure in upstream and downstream boundary conditions affecting the project area annually for a multi-year hydrologic regime. The seasonal degree of variability around the median is shown as the shaded inner quartile range of the 25th and 75th percentiles.

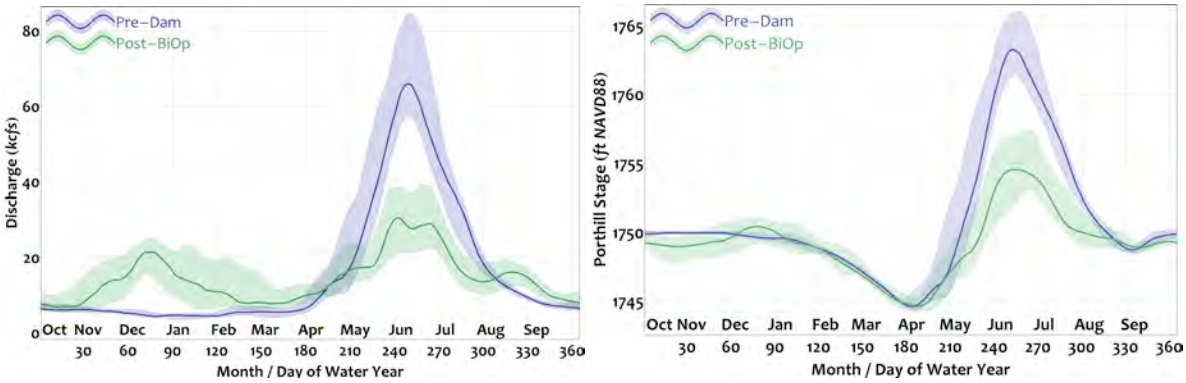


Figure 2-11. Governing boundary conditions by DWY for pre-dam, post-BiOp at the Porthill USGS Station #12322000.

These figures illustrate a reduction in median annual peak flows of approximately 50%, which also corresponds to lower peak Kootenay Lake elevations as represented by a nearly 10 foot reduction in river stage at Porthill, ID in the June to July time period. Also notable are higher flows and corresponding lake levels during the fall drafting period when dam operations are traditionally governed by power generation. The combination of additional Libby Dam flow and regulated Kootenay Lake levels during this period has resulted in departure of the channel hydraulics and corresponding geomorphic response. An increase in variability around the median values for both discharge and stage is observed for post-dam conditions. Pre-dam variability

generally only occurred on the rising and falling limbs of the annual peak and can be attributed to pre-dam subbasin processes, whereas the post-dam variability is fairly consistent for the entire water year and can be attributed to operational modes and constraints of Libby Dam and Kootenay Lake. Model simulations were used to compare pre-dam and post-BiOp hydraulic regimes. For the modeling work for this project, median seasonal peak discharges of 65kcfs and 30kcfs were selected as bankfull channel discharge surrogates representing the historical and contemporary conditions, respectively. Downstream median peak backwater elevations of 1763 feet (for the 65kcfs event) and 1754 feet (for the 30kcfs event) were selected to coincide with the surrogate bankfull discharge values.

The valley slope flattens abruptly by over an order of magnitude between the Braided Reaches and the Straight Reach. The slope transitions from 0.0005 ft/ft near RM 158 in the middle of the Braided Reach 1, to 0.00005 ft/ft at RM 152 in the Straight Reach (Figure 2-12).

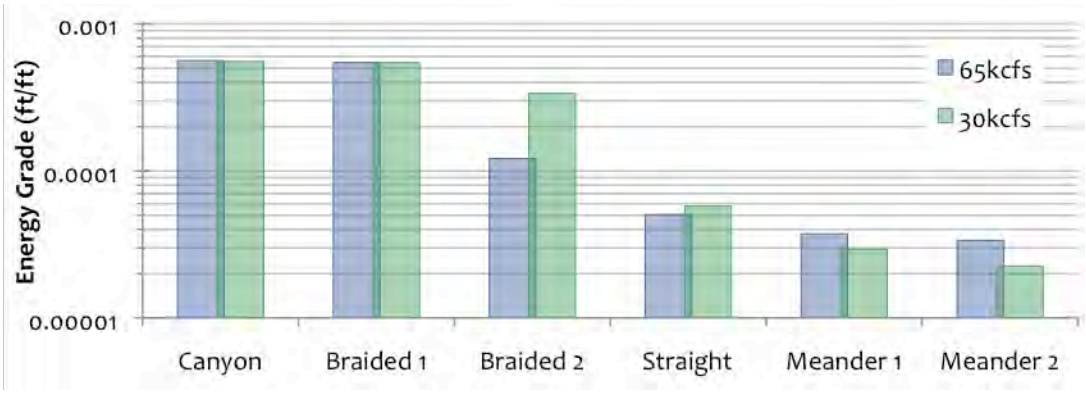


Figure 2-12. Departure in bankfull energy grade by reach for pre-dam (65 kcfs) versus post-BiOp (30 kcfs).

As a result of such mild slopes through the project reaches, the upstream extent of the Kootenay Lake backwater effect can extend over 50 miles upstream from Porthill, seasonally fluctuating over a range of six river miles between the Straight Reach and Braided Reach 1. The surrogate bankfull energy grade for median lake levels at 30kcfs exceeds that of 65kcfs in Braided Reach 2 and the Straight Reach, and as such influences channel hydraulics. A summary of mean bankfull hydraulic departure by reach for the pre-dam and post-BiOp hydrologic regimes is shown in Table 2-6. Post-BiOp hydraulic variables (depth, velocity and shear stress) generally have lower values relative to the pre-dam period.

Table 2-6. Summary of mean bankfull hydraulic departure for pre-dam and post-BiOp regimes.									
Reach/Param	Hydraulic Depth *(ft)*			Velocity *(ft/sec)*			Shear Stress *(lbf/ft²)*		
	65kcfs	30kcfs	% Change	65kcfs	30kcfs	% Change	65kcfs	30kcfs	% Change
Canyon	20.9	5.8	-24%	7.0	4.9	-30%	0.63	0.44	-31%
Braided 1	16.8	12.0	-29%	6.5	4.5	-31%	0.55	0.38	-31%
Braided 2	20.5	10.8	-47%	2.9	2.9	-1.5%	0.13	0.19	40%
Straight	31.1	23.6	-24%	3.4	2.5	25%	0.09	0.06	-29%
Meander 1	31.4	23.9	-24%	3.1	2.2	-29%	0.07	0.04	-41%
Meander 2	35.2	27.6	-22%	3.0	2.0	-35%	0.07	0.04	-48%
** Assumes Water-surface elevation at Porthill (USGS Sta#12322000) of 1763 for 65kcfs and 1754 for 30kcfs*									

The departure in bankfull hydraulic depth by reach is shown in Figure 2-13. Both hydrologic regimes are characterized by the general trend of increasing mean depth in the downstream direction, partially as a result of the backwater influence, and also due to the transition from a braided channel type in the upstream Braided Reaches to entrenched channel conditions in the Meander Reaches. The largest estimated change in mean hydraulic depth occurred in the Braided 1 and 2 reaches with nearly 30% and 50% reductions in depth between the pre-dam and post-BiOp conditions. There has also been a 25% reduction in mean hydraulic depth between the two periods in the Straight and Meander reaches.

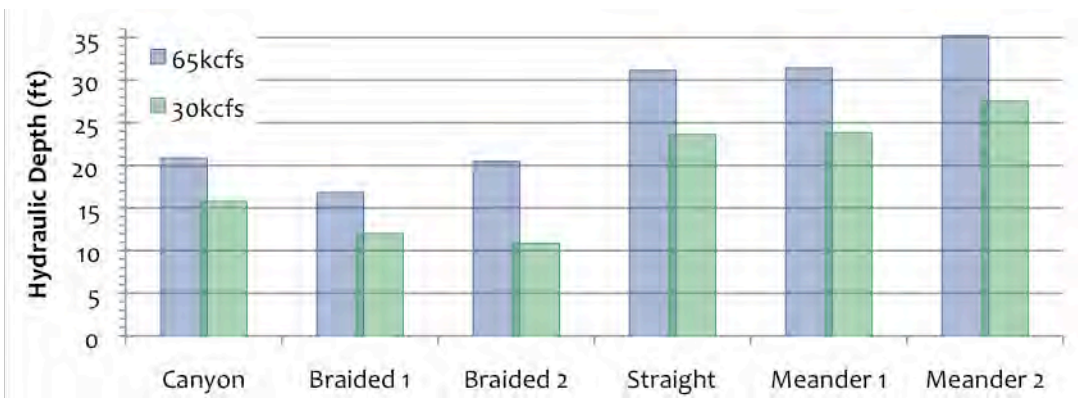


Figure 2-13. Departure in bankfull hydraulic depth by reach for pre-dam (65 kcfs) versus post-BiOp (30 kcfs) regimes.

The temporal response of hydraulic depth to departure in discharge and backwater boundary conditions in the Braided Reaches is plotted in Figure 2-14 below. In the Braided Reaches, pre-dam mean annual peaks for hydraulic depth generally correlate with pre-dam discharge around mid-June indicating a diminished influence from Kootenay Lake backwater which is not present year-round and does not extend upstream of Braided Reach 2. Under the post-BiOp hydraulic regime, median values for hydraulic depth have been reduced by one-third in Braided Reach 1, and one-half in the Braided Reach 2. Between RM 152 and RM 157, the Libby Dam BiOp recommends intermittent depths of 16.5 ft to 23.0 ft or greater during peak augmentation flows for Kootenai sturgeon migration and spawning habitat.

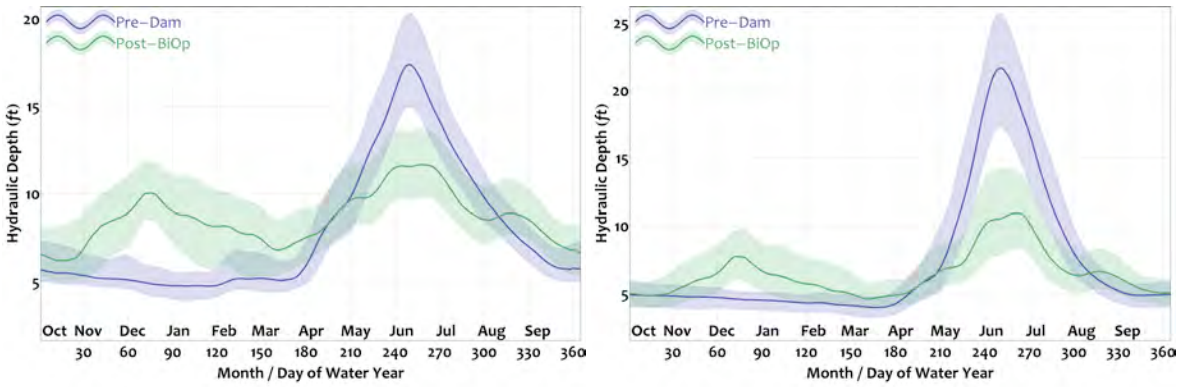


Figure 2-14. Hydraulic depth by DWY for pre-dam versus post-BiOp in the Braided Reaches 1 and 2.

Analysis completed for this project suggests a 30% reduction in bankfull channel velocity from the pre-dam to post-BiOp condition in all reaches except the Braided Reach 2, where pre-dam and post-BiOp velocities were nearly equal, averaging less than 3 ft/sec as shown in Figure 2-15. In the Canyon Reach and Braided Reach 1, post-BiOp bankfull discharge velocities were estimated between 4 ft/sec and 5 ft/sec, while downstream in the Meander Reach, bankfull velocities averaged just over 2 ft/sec. Libby Dam BiOp (USFWS 2006) recommends that water velocities during the spawning period should exceed 3.3 ft/sec in over 60% of the reach characterized by rock substrate between RM 152 and RM 157 to provide habitat conditions believed to be important for Kootenai sturgeon spawning and egg survival.

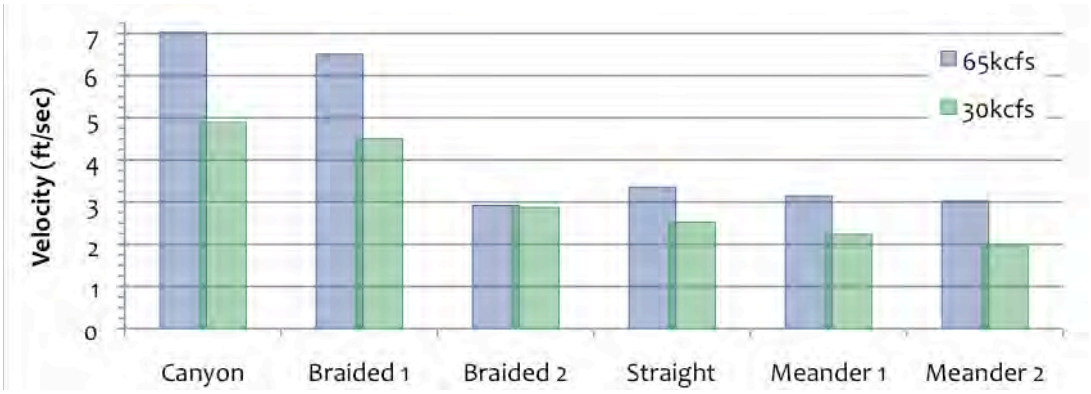


Figure 2-15. Departure in bankfull discharge velocity by reach for pre-dam (65 kcfs) versus post-BiOp (30 kcfs) regimes.

Boundary shear stress departure between the pre-dam and post-BiOp hydraulic regimes was less than 50% for all reaches. In Braided Reach 2, the greater than 100% increase in post-BiOp energy grade slope resulted in a 40% increase in shear stress (Figure 2-16). The increase in shear stress in Braided Reach 2 is due to the less extensive Kootenay Lake backwater associated with the post-BiOp period. Regardless of this significant increase, the general trend of decreasing energy with decreasing river mile still dominates. This shear stress trend contributed to the depositional channel regime under both pre-dam and post-BiOp hydraulic regimes.

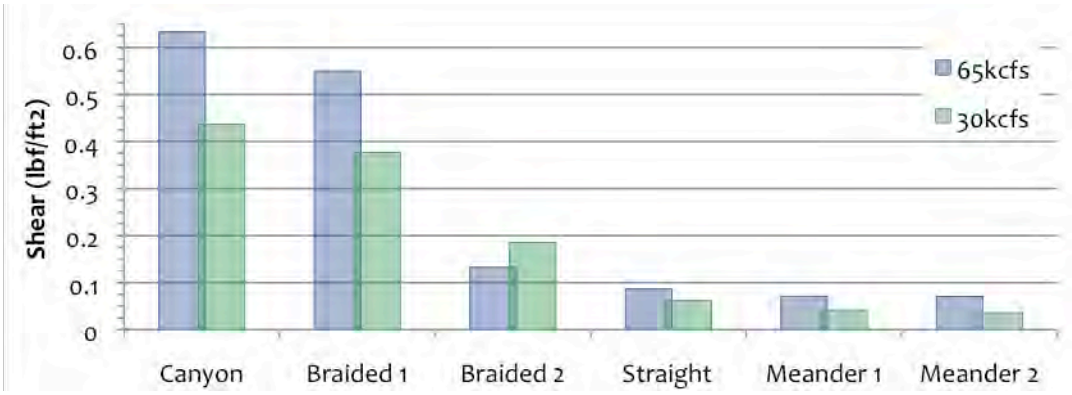


Figure 2-16. Departure in bankfull boundary shear stress by reach for pre-dam (65 kcfs) versus post-BiOp (30 kcfs) regimes.

This abrupt transition in available shear and corresponding depositional response is also illustrated by comparing the temporal plots between the Braided 1 and 2 reaches. In Braided Reach 1, both pre-dam and post-BiOp hydraulic responses suggest that shear stress generally correlates with discharge. This result indicates there is a higher correlation of hydraulic response with Kootenai River discharge versus the Kootenay Lake backwater influence as the backwater effect is not present year-round in Braided Reach 1 (Figure 2-17, left figure).

Conversely, in the downstream Braided Reach 2, less separation between the pre-dam and post-BiOp median shear stress is evident throughout the entire water year (Figure 2-17, right figure). Additionally, there is a dampening of hydraulic effects around the spring peak for both pre-dam and post-BiOp regimes. The overall similarity of median shear values in the Braided Reach 2 for both regimes (just above 0.2 lbf/ft^2) indicates the hydraulic response is more strongly tied to the channel geometry and Kootenay Lake backwater than the Kootenai River discharge.

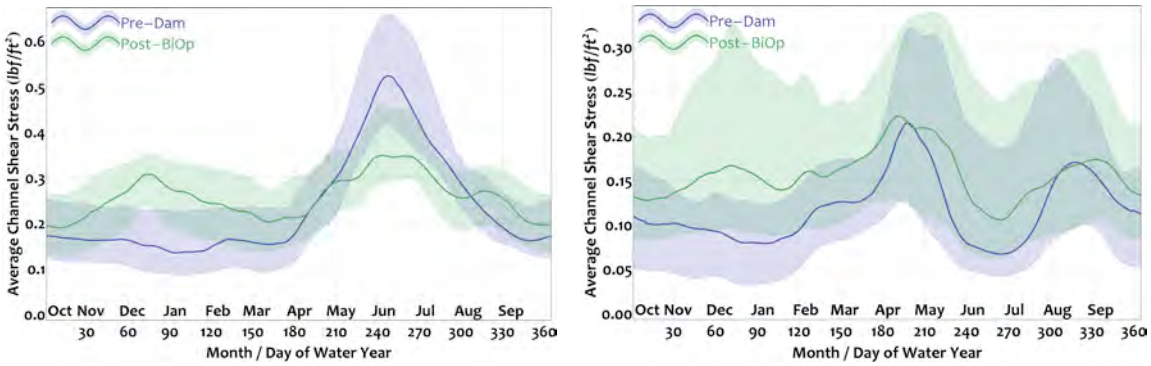


Figure 2-17. Boundary shear stress by DWY for pre-dam versus post-BiOp regimes in the Braided Reach 1 (left) and Braided Reach 2 (right).

In Braided Reach 2, on the rising limb of the spring peak in late April (approximately DWY 200) a less frequent peak in hydraulic response occurred during both pre-dam and post-dam regimes. This effect is generally on a declining trend by the June peak (approximately DWY 250) due to the combined effects of the over-widened braided geometry and backwater as Kootenay Lake refills.

Downstream from RM 151 in the Meander Reaches, the pre-dam regime was characterized by a seasonal peak in both velocity and shear in June in response to seasonal peak flows (Figure 2-18). In the post-BiOp era, this seasonal peak in hydraulic response was essentially dampened to just above 2.0 ft/sec within a consistent range of variability throughout the entire water year.

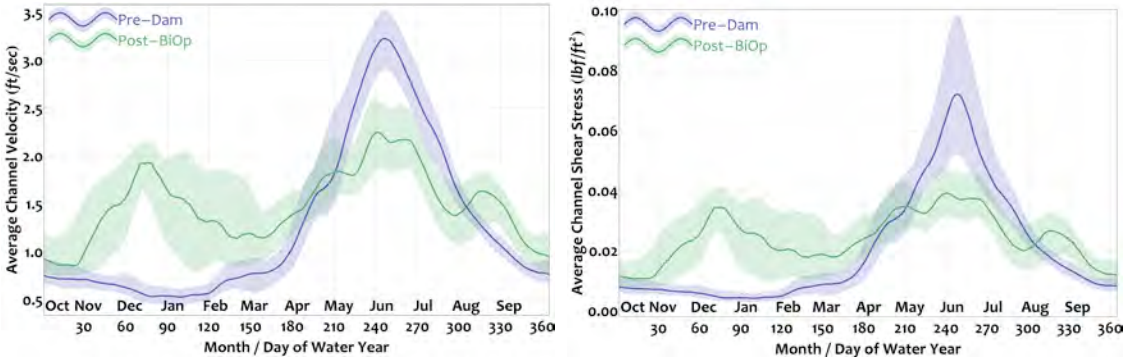


Figure 2-18. Annual trends of velocity (left) and shear stress (right) for pre-dam versus post-BiOp regimes in Meander Reach 1.

In contrast to the Straight and Braided reaches, the Meander Reaches are not characterized by the short-term peaks in hydraulic response coincident with the rising limb between April and June (DWY 200-250). This condition may suggest that for the Meander Reaches during the post-dam period, any potential increases in hydraulic response on the rising limb were sufficiently dampened by the more persistent backwater effects of Kootenay Lake. Post-BiOp hydraulic response in the Meander Reaches is characterized by higher velocity and shear during the fall and early spring drafting period (October - March) similar to other upstream reaches.

In summary, the general change in hydraulic response within the project area resulting from the dam-altered regime is dependent upon the combined effect of both Libby Dam discharge and Kootenay Lake level. The altered hydraulics are characterized by reduced median spring peak flows and increased median flows for the remainder of the year. In essence, spring runoff peaks are lower and base flows are higher in the post-BiOp period compared to the pre-dam period. In the Braided Reaches, where the hydraulic response is seasonally influenced by the Kootenay Lake backwater effect, the combination of larger flows with high lake levels can actually dampen the hydraulic response (i.e., velocity and shear stress) as compared to moderate flows and lake levels. Below RM 151, the Straight and Meander reaches are influenced by the Kootenay Lake backwater effect year round and follow a general trend of decreasing magnitude of hydraulic response with river mile. Additional examples of alteration in hydraulic response are presented in Appendix A, including rating tables and evaluation of frequency duration departure for select hydraulic parameters. Because of departure in channel hydraulics and the resulting changes in channel morphology, we have identified ***river response to altered hydraulics as a limiting factor for morphology***.

2.4.2 Altered Sediment Transport

Since its completion in 1972, and full operation beginning in 1974, Libby Dam (upstream of the project area) has altered both the supply and transport characteristics of the pre-dam sediment regime in the project area. Lake Koocanusa, the reservoir formed by Libby Dam, has a surface

area over 70 square miles with a length extending over 90 miles. Lake Koocanusa effectively traps virtually all of the sediment originating from the upper 46% of the 19,300 square mile subbasin (Tetra Tech 2004). During the design of the Libby Dam Project, the USACE estimated the catchment upstream of Libby Dam would generate an annual suspended-sediment load of 1.48 million tons per year, over 90% of which would be trapped in Lake Koocanusa under average flow conditions. The USACE estimates that during peak spring flows, roughly 12% of this suspended sediment load passes through the dam (USACE 1971). Due to the extensive length and depth of Lake Koocanusa, 100% of coarse-grained sediment (> 2 mm) generated by the upper Kootenai subbasin is likely trapped by the reservoir (Barton 2004; Burke 2006).

This disruption in downstream sediment delivery is reflected in measurements of suspended-sediment load collected between 1966 and 1984 in Meander Reach 2 near Copeland, ID (Sta#12318500, RM 124) as shown in Figure 2-19 on the following page. Calibrated estimates of mean daily suspended-sediment load reveal that median suspended sediment loads coincident with spring runoff between May and August (DWY 210-340) were reduced by an order of magnitude from over 10,000 tons per day to under 1,000 tons per day in the post-dam era. Conversely, median suspended sediment loads for the first half of the water year (October - May) are thought to be about six times higher under the post-dam regime, an increase of around 50 tons per day to 300 tons per day. This increase in suspended sediment loads is due to fall hydropeaking operations, which increase shear stress 300% in the upstream Braided Reach. Hydropeaking provides sufficient energy to selectively transport fine material smaller than 2 mm that is present in depositional features and poorly vegetated banks upstream of the Meander Reaches.

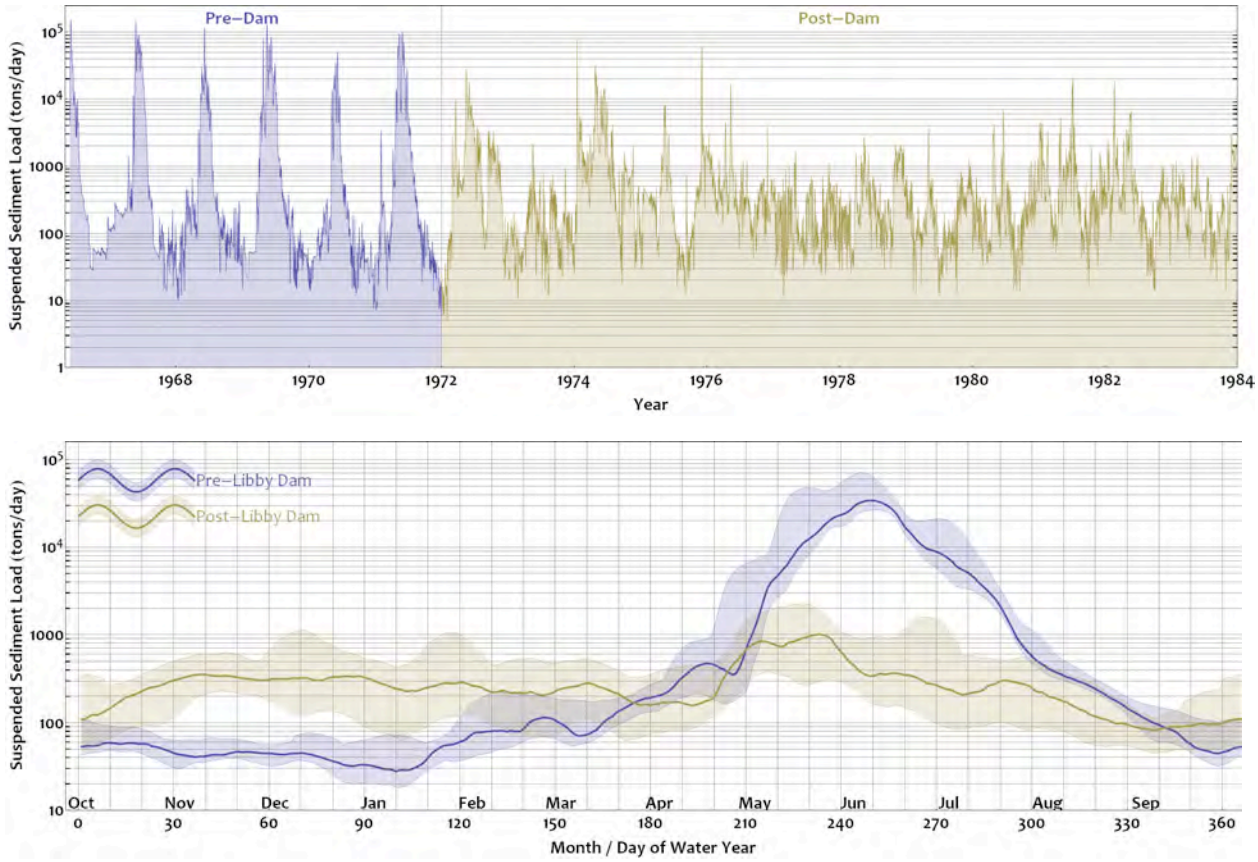


Figure 2-19. Historical suspended-sediment load: Kootenai River near Copeland, ID (Sta #12318500) in Meander Reach 2 from 1968 through 1984.

The project area is also affected by the abrupt decrease in valley slope as the Kootenai River enters the Purcell Trench at the top of the Braided Reach 1 and the backwater effect from Kootenay Lake below RM 158 (Berenbrock 2005; Burke 2006; Wildland Hydrology 2008). As described in Section 2.3, the backwater typically extends through the Straight Reach and into the lower Braided Reaches during spring runoff when Kootenay Lake is elevated. The backwater decreases the energy gradient through the affected reaches, reducing stream power and limiting the ability of the river to transport coarse bedload from upstream reaches.

Figure 2-20 displays the maximum particle size that can be transported using a standard incipient motion Shield's criterion for the pre-dam and post-BiOp regimes. For both regimes, the overall reduction in available transport competence is reflected as the mobile particle size decreases from coarse gravels (coarse grain 16mm - 32mm) in Braided Reach 1 to medium gravels (medium grain 8mm - 16mm) in Braided Reach 2 to very fine gravels (very fine grain 2mm - 4mm) in the Straight Reach and very coarse sands (very coarse grain 1mm - 2mm) in Meander Reach 1. Of particular importance is the observed difference in sediment transport competency between regimes. In general, the post-BiOp regime mobilizes smaller particles during the spring and summer (DWY 180-300) and larger particles during the fall and winter (DWY 1-180) as a result of hydropeaking operations at Libby Dam. This additional transport competence results in the

mobilization of select finer fractions during times of the year when sediment transport may not have occurred historically.

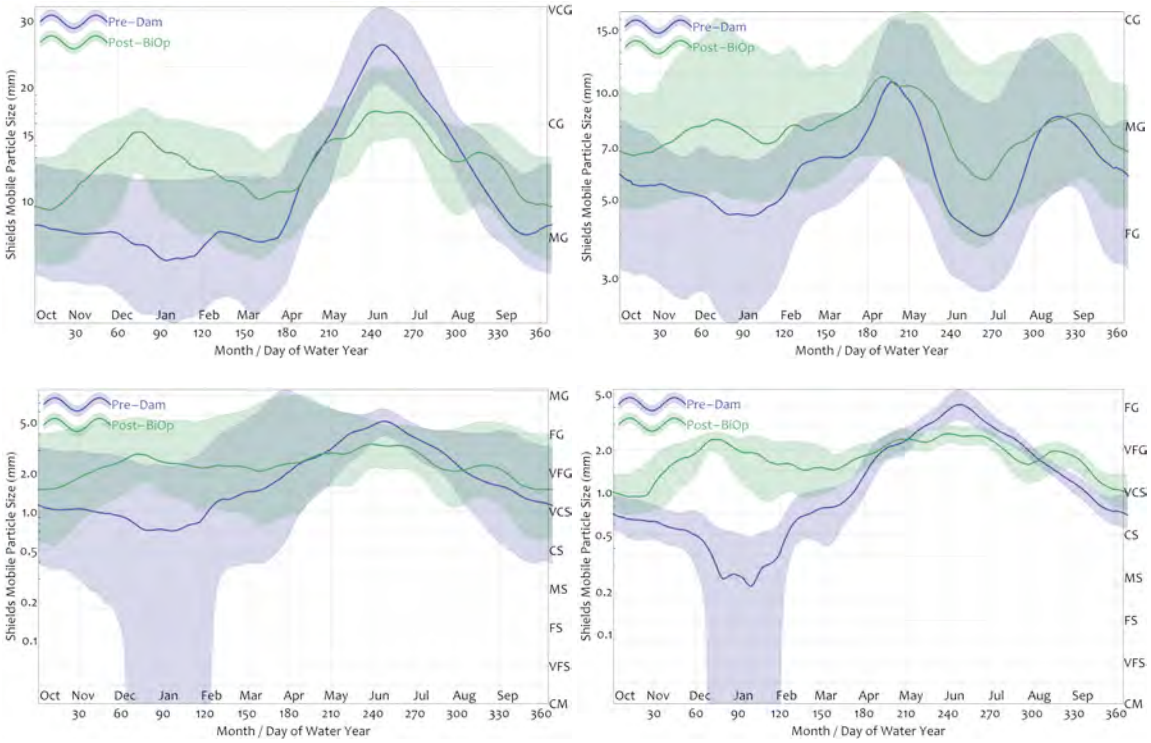


Figure 2-20. Maximum mobile particle size and inner quartile range for the pre-dam and post-BiOp regimes for the Braided 1 reach (top left), Braided 2 reach (top right), Straight reach (bottom left), Meander 1 reach (bottom right) for median hydraulic conditions.

Compared to pre-dam conditions, spring runoff transport competency under the post-dam regime was reduced by approximately two-thirds or one grain size class. In Braided Reach 1, spring transport competency was reduced from coarse gravel to medium gravel, while in Meander Reach 1 it was reduced from very fine gravel to very coarse sand. One notable exception to this trend is in Braided Reach 2, where the mobile particle size is nearly equal between pre-dam and post-BiOp regimes as a result of the reduced backwater influence during spring runoff. Nonetheless, this decrease in transport competency for larger size classes under the post-dam regime is thought to have sustained a slight bias for the selective transport of fines, which propagates in the downstream direction as overall available slope and energy decrease. This shift is also reflected in the gradation of the channel bed material between the project reaches as illustrated in Figure 2-21.

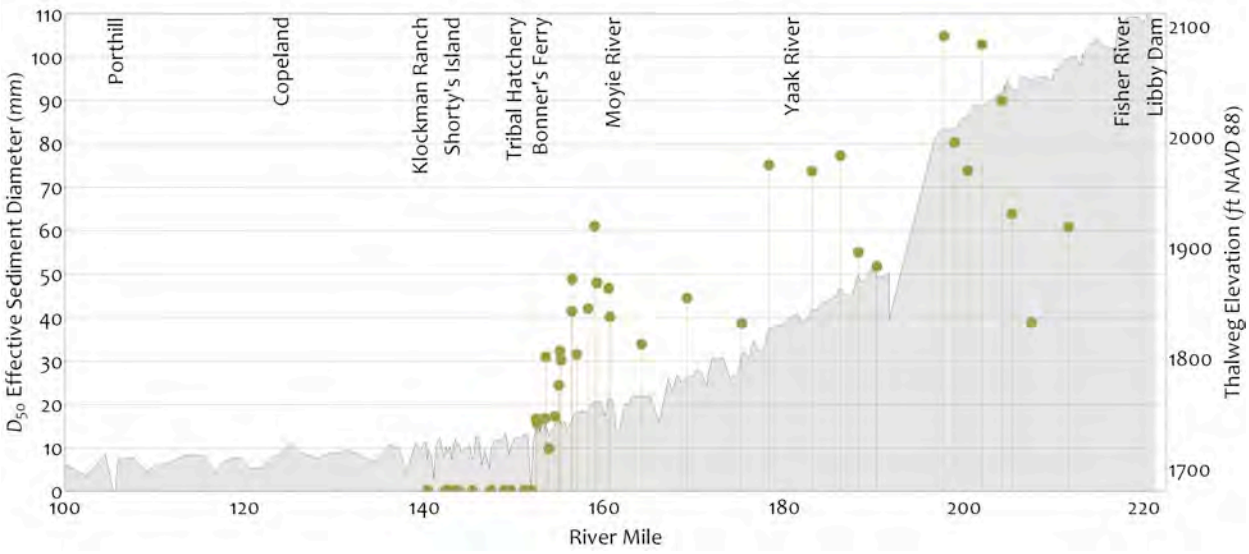


Figure 2-21. D50 particle size of bed sediment by river mile (after Burke 2006).

Upstream of RM 162 in the Canyon Reach, the Kootenai River is characterized by alternating confined and semi-confined sub-reaches with channel slopes exceeding 0.05%. The channel surface is generally made up of coarse gravel and cobbles (D_{50} less than 32 mm) with a moderate degree of armoring, supporting both pool-riffle and armored plane-bed morphology (Burke 2006). Downstream from RM 158, the Kootenai River exits the confined planform of the Canyon Reach, with a significant increase in width-to-depth ratio and the formation of multiple low-flow channels in response to an abrupt loss of slope as the river enters Braided Reach 1. Under both pre-dam and post-dam regimes this slope transition created a depositional environment, especially for larger size classes of sediment. The streambed through Braided Reach 1 is composed primarily of gravel and cobble bars coarser than 2 mm, which are generally thought to provide a suitable substrate for Kootenai sturgeon spawning, incubation, and early life stages. The coarse fraction of the channel bed continues to decrease through Braided Reach 2 which is seasonally influenced by the Kootenay Lake backwater, transitioning from very coarse gravel to very fine gravel as shown in Figure 2-22 and Figure 2-23.

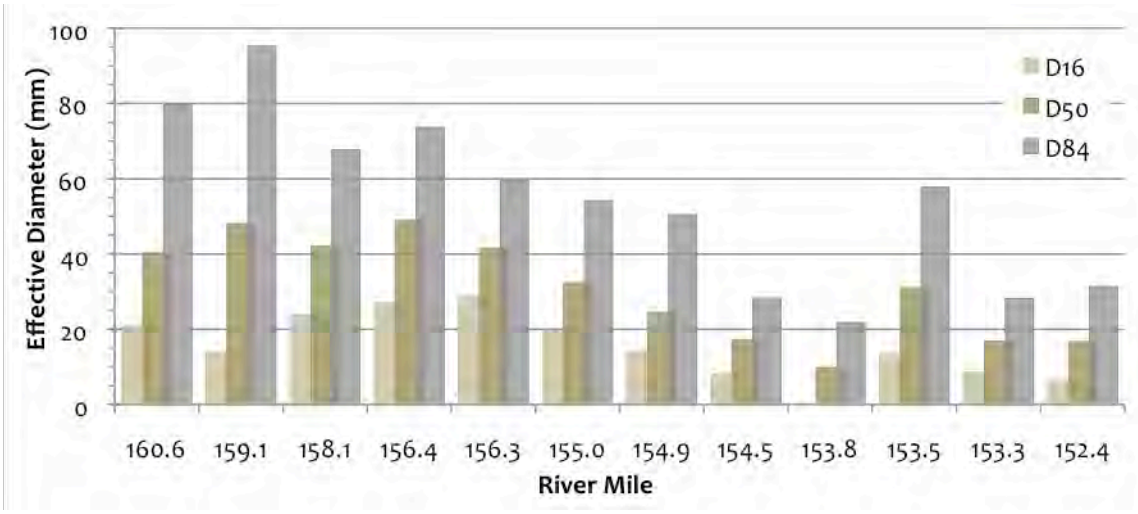


Figure 2-22. Effective diameters of surface layer sediment through the Braided Reaches, from USGS Pebble Count and Shovel Data collected from 2002-2008.

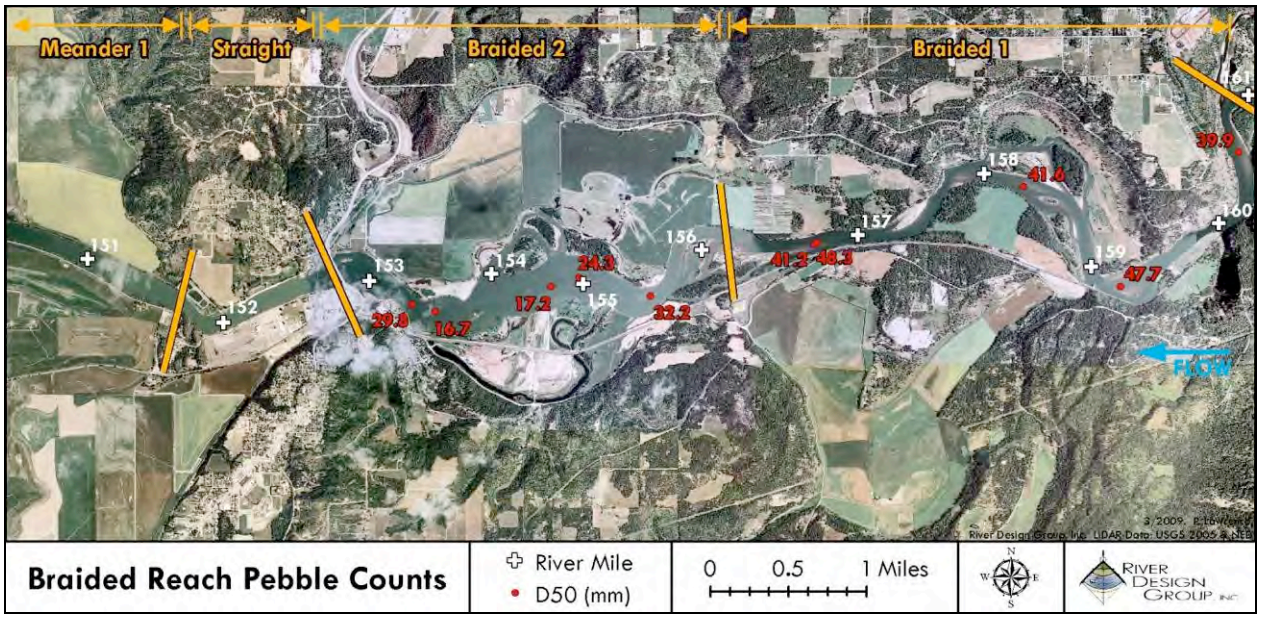


Figure 2-23. D50 Surface Pebble Counts in the Braided Reaches.

At the top of the Straight Reach, core samples collected by the USGS near the channel center at the HWY 95 bridge crossing, indicated that there are gravel deposits extending over 100 feet below the riverbed. Upstream of Ambush Rock, core samples were found to consist primarily of gravels and cobbles with increasing sands near the banks. Less than one river mile downstream, core samples collected near Ambush Rock indicate the presence of a geologic contact where the deep gravel and cobble is replaced by a thick lacustrine clay and silt layer about 15 feet below the streambed overlain by a discontinuous gravel cobble and sand layers (Barton 2004). Through the Straight Reach (below RM 152), the Kootenai River continues the trend of downstream fining, transitioning to a sand veneer over coarser patches of gravel and cobble. It is thought that under

the pre-dam regime, coarser patches in the Straight Reach were annually washed clean of the overlying sand prior to the descending limb of the hydrograph.

Further downstream in the Meander Reaches where the backwater influence is present year-round and the energy grade slope averages less than 0.00003 ft/ft, the Kootenai River channel bed is composed primarily of medium to fine sand, which is thought to be unsuitable bed material for spawning. Coring samples reveal that the geologic conditions downstream from the Straight Reach are dominated by lacustrine clay-silt deposits overlain by sand varying in thickness between 3 feet and 36 feet. Fine sediment, particularly in the Meander Reaches has accumulated to the extent that seasonal dunes with heights that cyclically fluctuate three to six feet per year (Barton 2004) are formed. As shown in Figure 2-24, channel substrates in Meander Reach 1 are composed of medium sands (<0.5 mm) and finer material. However, underwater videography taken during the 2006 high-flow season indicated that a few lenses of coarse material exist throughout the reach (Figure 2-50 in Section 2.6).

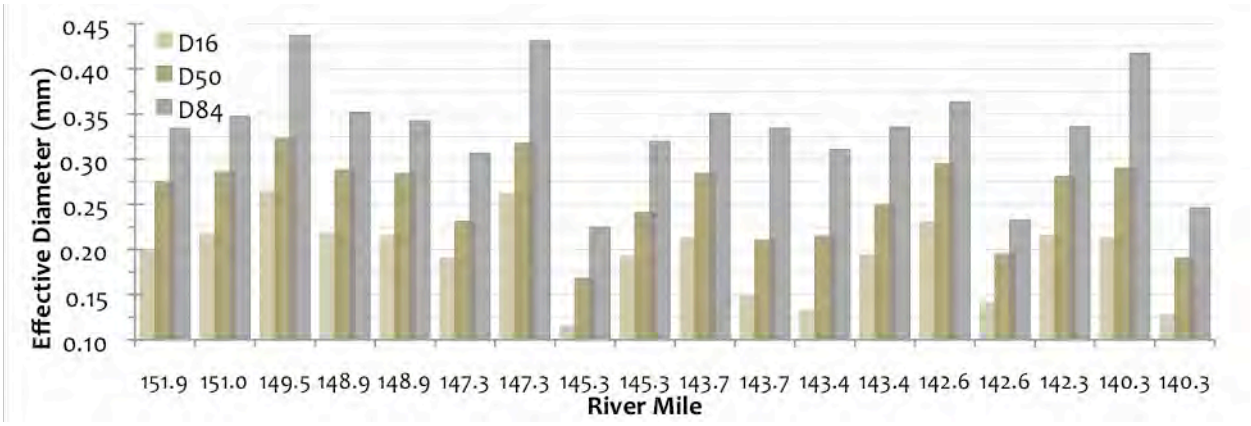


Figure 2-24. Effective diameters for subsurface Dredge Samples in Meander Reach 1 (Berenbrock 2005).

Despite the reduction in sediment supply caused by the trapping of sediment at Libby Dam, fine sediment delivery from the remainder of the catchment and tributaries is thought to have changed in the post-dam era as a result of watershed disturbances from river and floodplain management. To clarify the extent of this impact and address the potential implications on habitat restoration actions, efforts are underway to estimate the sediment supply derived from the watershed upstream of the project area as well as the sediment supply derived from within the project area. These efforts will be used to inform future decisions about the feasibility of habitat restoration, however the results of this analysis were not available for inclusion in this Master Plan.

In support of the development of limiting factors, approximately 500 sediment load measurements in the project area were assembled from historical and recent datasets for the post-dam era. Of these measurements, over 80% were suspended load, with the remainder made up of bedload samples. In general, the most reliable samples were those collected by the USGS over 16 days during water year 2008 at three stations (Figure 2-25). These samples were collected from a boat at discharges up to 47 kcfs. Related efforts are currently underway to estimate the annual supply of sediment derived from tributaries located between the dam and the project area, and from bank erosion in the project area (Section 2.4.5).

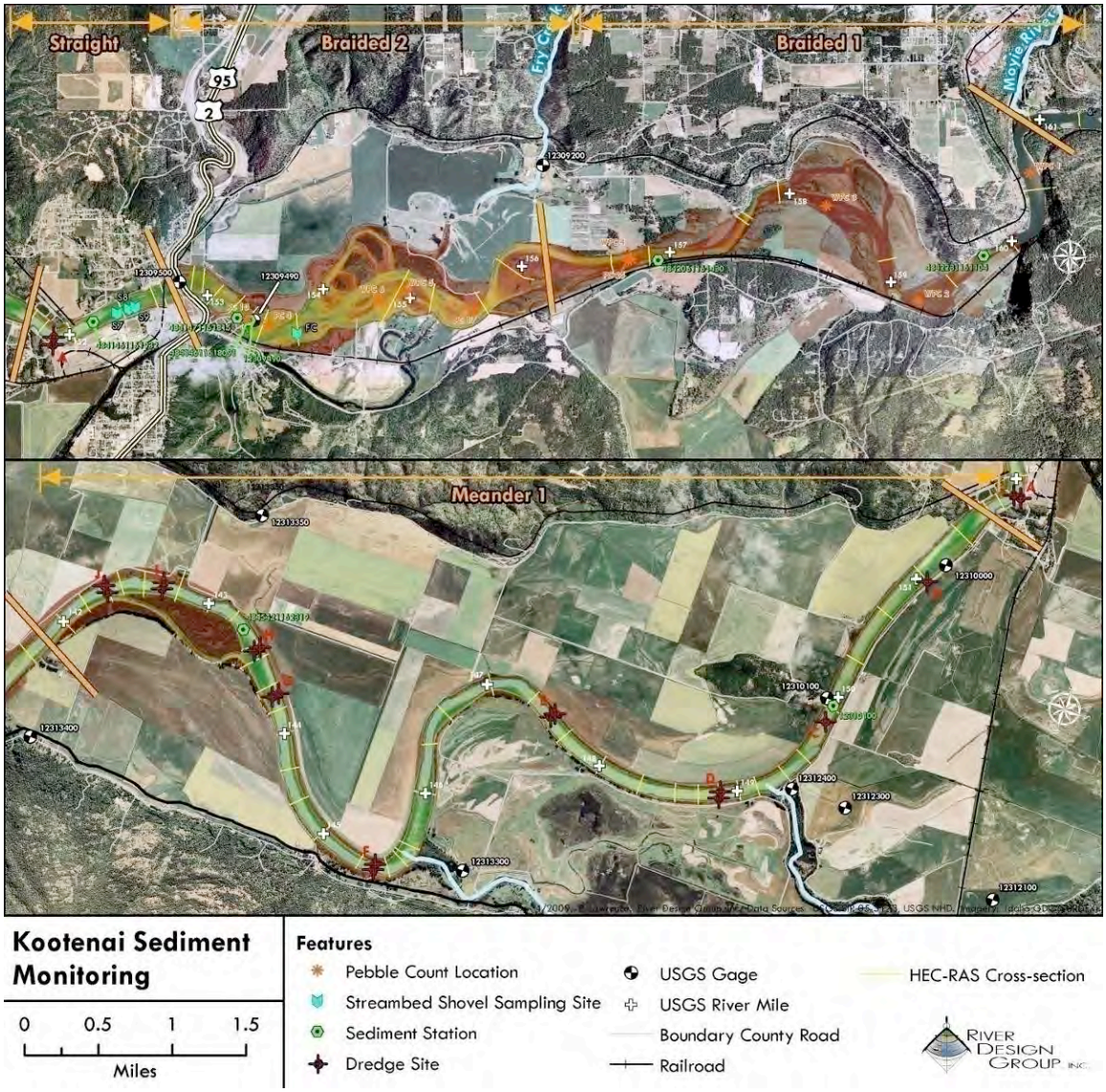


Figure 2-25. Sediment sampling stations in the study reach.

The 2008 bedload and suspended sediment measurements were used to complete a preliminary estimate of sediment transport and supply in project area. The purpose of the preliminary analysis was to support the development of limiting factors. Additional data collection and analysis will be necessary during the design phases in order to inform future decisions related to project feasibility and development of specific designs. Measurements were taken at three locations in the project area. For the purposes of this Master Plan, measurements from the upstream sampling site (RM 159) are assumed to represent the sediment supply entering the project area from the watershed. Measurements from the middle sampling site (RM 153) are assumed to represent the sediment supply near the downstream end of the Braided Reaches and within the backwater influence of Kootenay Lake. Measurements from the downstream sampling site (RM 143) are assumed to represent the sediment supply at the downstream end of

Meander Reach 1. Figure 2-26 shows the 2008 sampling events overlain on the 2008 water year hydrograph.

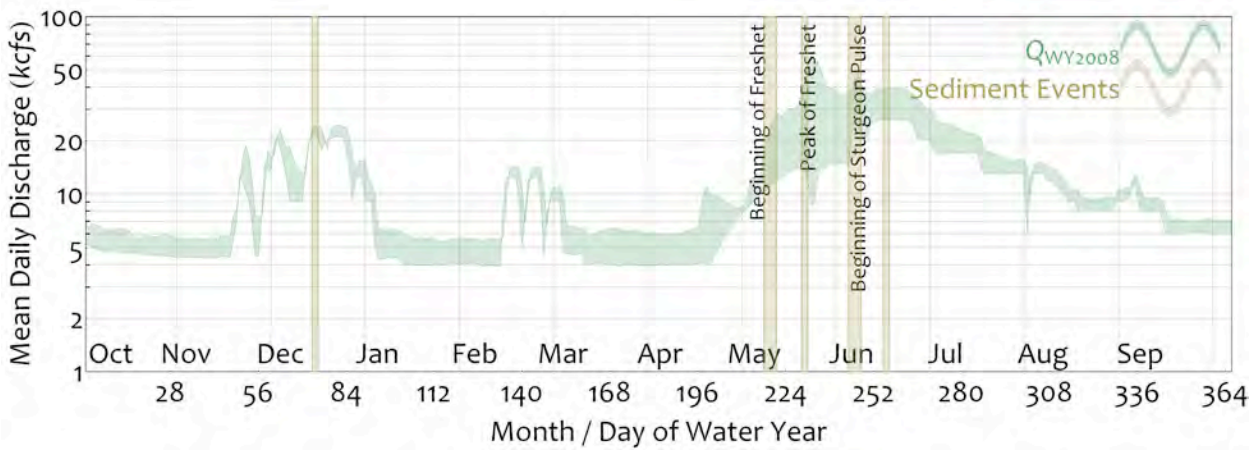


Figure 2-26. Hydrograph at Porthill (USGS #12322000) and Libby Dam (USGS #12301933) with sediment sampling events for water year 2008.

Preliminary results for estimates of the bed material load (Figure 2-27), which includes bedload and the sand fraction (> 0.0625mm) of the suspended load, indicate that bed material load increases through the Braided Reaches and decreases through Meander Reach 1. Under equilibrium transport conditions, sediment load and sediment supply are equal, suggesting that sediment is recruited from within the Braided Reaches and deposited in the Meander Reaches. There are no major tributaries in the Braided Reaches, therefore, the supply is presumed to come from the channel banks and bed. Because of the loss of floodplain connection in the Meander Reaches, the only place for sediment to deposit is on the channel bed or the infrequent, small bars.

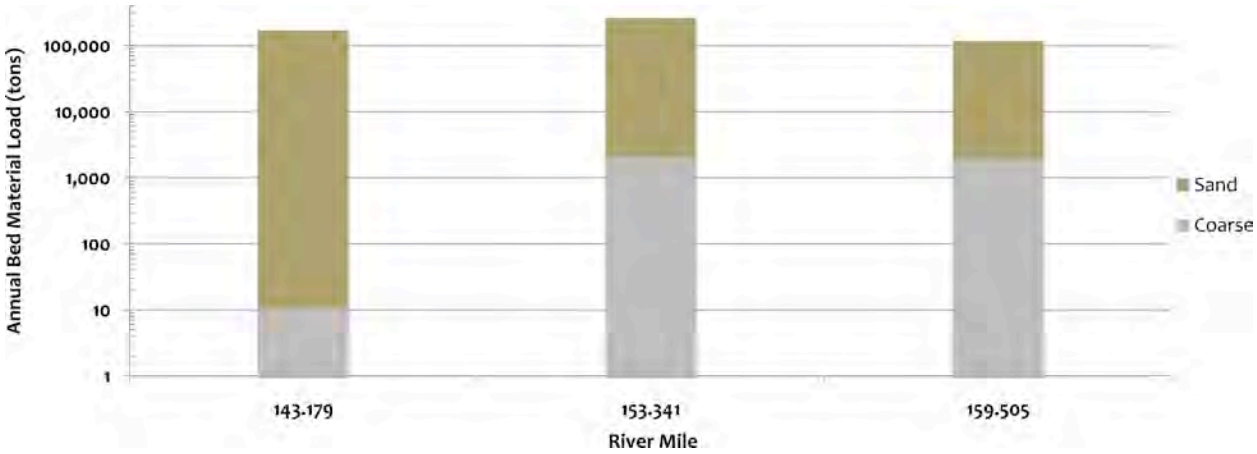


Figure 2-27. Estimated annual bed material load for water year 2008.

Another observation gleaned from the preliminary sediment sampling results is the low proportion of coarse bedload (gravel and cobble) measured. On average, coarse bedload accounted for less than 2% of the total sediment load measured at the upstream sampling site. Measured transport rates for coarse bed material load were roughly an order of magnitude less

than the transport rate of the bed material load sand fraction, falling by another order of magnitude near the Shorty's Island sampling site. Two possible explanations are offered to explain the low proportion of coarse bedload in the measured sediment samples.

The first explanation is that coarse bedload could have been under-sampled due the inherent difficulty of sampling from the boat in higher flow conditions. To help characterize the upstream sediment contributions from the catchment, the USGS sampled five tributaries of the Kootenai River comprising about two-thirds of drainage basin between Libby Dam and the Idaho/Montana Border during Spring 2008 (Holnbeck et al. 2008). Preliminary suspended sediment results indicate that these five streams alone may contribute over 10,000 tons/day of bedload to the Kootenai River during the spring peak flow. Zelch (2003) concluded that tributary deltas downstream of Libby Dam have increased in size due to storage of tributary bedload. Whether tributary sediments are stored in the tributary deltas or transported downstream to the project area is unknown and will be investigated further in subsequent phases of this project.

The second explanation for the low proportion of bedload sampled is that measurements are representative of supply and the Kootenai River upstream of the project area is unable to mobilize sources of coarse bedload. In natural gravel bed systems, bedload is typically mobilized at flows approaching mean annual peak flow, which in the Kootenai River would have historically been 65kcfs. If the Kootenai River is not capable of breaking up the existing bed armor and mobilizing large quantities of coarse bedload at flows of less than 65kcfs, it could be concluded that delivery of coarse bedload to the project area is low for all flow levels except for very large flood events in the post-dam era. Future data collection and analysis will be completed during design phases in order to refine the understanding of coarse bedload supply to the project area. Additional information regarding historical and current sediment sampling efforts is presented in Appendix B.

In summary, sediment transport in the project area is affected by a reduction in sediment supply from the watershed due to sediment trapping at Libby Dam and changes in sediment transport compentence and capacity due to altered hydraulics. The effects of altered sediment tranport have implications for aquatic habitat including: 1) reduced supply of suitable spawning substrate delivered to the project area, and 2) increased embeddedness of coarse substrate with sand and finer sediment. The implications for aquatic habitat are discussed in more detail in Section 2.6, Aquatic Habitat Limiting Factors. Not only does altered sediment transport affect aquatic habitat, but it also affects channel morphology and vegetation processes. Because variations in sediment-transport regimes have a profound effect on river behavior, we have identified ***river response to altered sediment-transport as a limiting factor for morphology*** in the Kootenai River. The Kootenai River's response to altered sediment transport, altered hydaulics and river management constraints is described in more detail in the following section.

2.4.3 Altered Morphology

Altered flow and sediment regimes have influenced the morphology of the Kootenai River. The following sections discuss the changes in the river morphology within the project area. Table 2-7 presents a summary of valley type, historical stream type, and existing stream type by reach (Wildland Hydrology 2008). Valley and stream type descriptions are summarized in Appendix E. Figure 2-28 presents a graphic of the existing stream types by reach.

Table 2-7. A summary of valley type, historical stream type, and existing stream type by reach.			
Reach Name	**Valley Type**	**Historical Stream Type**	**Existing Stream Type**
Braided 1	Terraced Alluvial Valley	Meandering/Braided	Meandering/Braided
Braided 2	Terraced Alluvial Valley	Braided	Braided
Straight	Structurally-Controlled Valley	Entrenched	Entrenched
Meander 1	Glacio-lacustrine Valley	Meandering	Entrenched
Meander 2	Glacio-lacustrine Valley	Meandering	Entrenched
Tributaries	Structurally-controlled Glaciated Valleys and Alluvial Fans	Entrenched/Confined	Entrenched/Confined

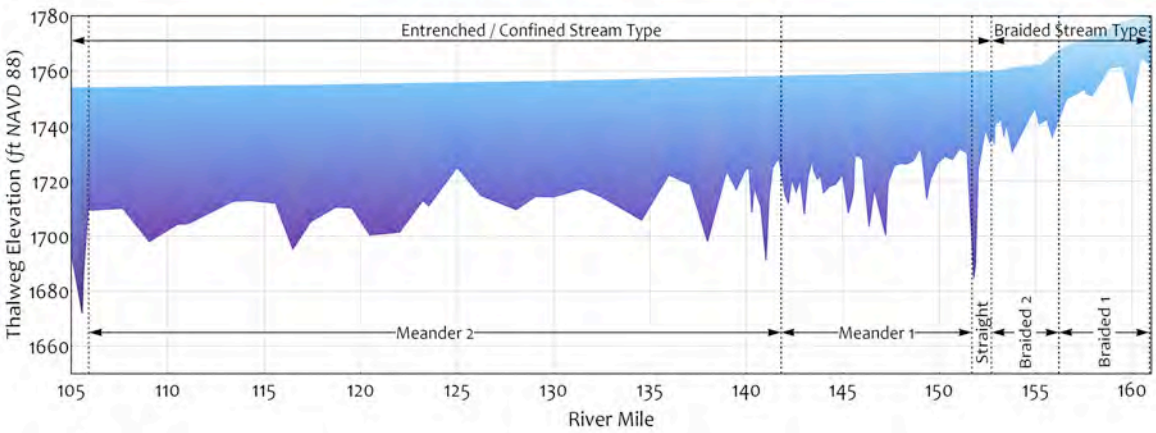


Figure 2-28. The distribution of existing condition stream types by reach. The graph also illustrates the 30 kcfs water-surface elevation through the project area.

2.4.3.1 Historical Aerial Photograph Interpretation and Planform Departure

An historical aerial photograph analysis was conducted to evaluate morphological trends from 1862 through 2006 in the majority of the project area reaches. While the Kootenai River's planform has varied over time by reach, post-dam changes have been within the range of adjustments that occurred in the pre-dam period (Tetra Tech 2004). It should be noted, however, that natural systems have wide ranges of variability and the causes of the adjustments may be attributed to different factors as discussed in later sections. The channel has been most dynamic in Braided Reach 2 upstream of Bonners Ferry. Overall, observed adjustments in planform are related to direct land use impacts, floodplain modifications, and changes in the hydraulic and sediment-transport characteristics of the project area. Table 2-8 summarizes percent change in channel plan form metrics for the project area from the 1862-1865 (General Land Office) maps, 1934 and 2006 aerial photos. The analysis was not performed for the Straight Reach due to its confined and stable configuration over the analysis period.

Table 2-8. Percent change in channel planform indices for the Kootenai River Project Area using the Government Land Office (GLO) maps, 1934 and 2006 air photos. The percent change compares 2006 values relative to the GLO values.

Parameter[1]	1862-1865 GLO Value	1934 Value	2006 Value	Percent Change
Braided 1				
Meander Length (ft)	5,642	6,143	5,668	0.5
Belt Width (ft)	1,729	1,259	1,597	-7.6
Radius of Curvature (ft)	1,660	1,466	1,581	-5.0
Bankfull Width (ft)	669	600	547	-22.3
Braided 2				
Meander Length (ft)	6,721	6,962	6,593	-1.9
Belt Width (ft)	4,445	3,024	2,985	-32.8
Radius of Curvature (ft)	2,713	1,508	1,578	-71.9
Bankfull Width (ft)	875	1,414	1,021	14.3
Meander 1				
Meander Length (ft)	13,868	13,728	13,686	-1.3
Belt Width (ft)	6,695	910[2]	910[2]	-86.4
Radius of Curvature (ft)	3,551	3,727	3,804	6.7
Bankfull Width (ft)	544	630	660	17.6
Meander 2				
Meander Length (ft)	6,199	6,402	6,429	3.6
Belt Width (ft)	4,070	2,256[2]	2,256[2]	-44.6
Radius of Curvature (ft)	1,551	1,585	1,591	2.5
Bankfull Width (ft)	584	586	636	8.2

1. An illustration of planform parameters is provided in Appendix E.
2. 1934 and 2006 meander belt width is defined as the distance between the levees.

Braided Reaches

The Kootenai River downstream from the Moyie River confluence enters a wide valley with decreasing gradient. The river is characterized by sediment deposition and lateral migration. These factors, with the corresponding changes in valley type and decreasing slope, have induced a braided river morphology that likely represents the historical form since the Holocene period (Wildland Hydrology 2008). Channel morphology in Braided Reach 2 has been and continues to be influenced by the Kootenay Lake backwater. Several studies have evaluated channel change over time including the Kootenai Flats Erosion Study (USACE 1983) and the USGS study by Barton et al. (2005). Both of these studies confirmed that the channel in the Braided Reaches has shifted its position over time (Wildland Hydrology 2008). As shown in Figure 2-29, the Braided Reaches are characterized by a dominant channel with secondary channels, extensive sediment deposition, and a meandering channel pattern.

Figure 2-29. The existing morphology of Braided Reach 1 (left) and Braided Reach 2 (right) is characterized by a dominant channel, active secondary channels, sediment deposition, and lateral migration.

Several major channel adjustments are noted in aerial photo series. The USGS study by Barton et al. (2005) indicated that the river in Braided Reach 2 shifted approximately 1,968 ft (600 m) between 1928 and 1958. Between 1934 to 1992, the dominant channel avulsed in response to meander migration and sediment deposition. This gradual process of sediment accretion, outer band erosion and meander cutoff development was likely exacerbated by vegetation removal that reduced bank strength and resistance to erosion. The geomorphic process described above is demonstrated in the drawing and photos presented in Figure 2-30, which compare the 1862-1865, and 1934 channel alignments and planforms to the 1992 and 2004 river positions. Presently, the relict channel scrolls maintain some degree of hydrologic connectivity with the main channel and provide flood relief and backwater habitat, particularly during high flows and periods when the Braided Reach is subject to backwater from Kootenay Lake. This example of a channel succession scenario appears to be a common geomorphic process in the Braided Reaches.

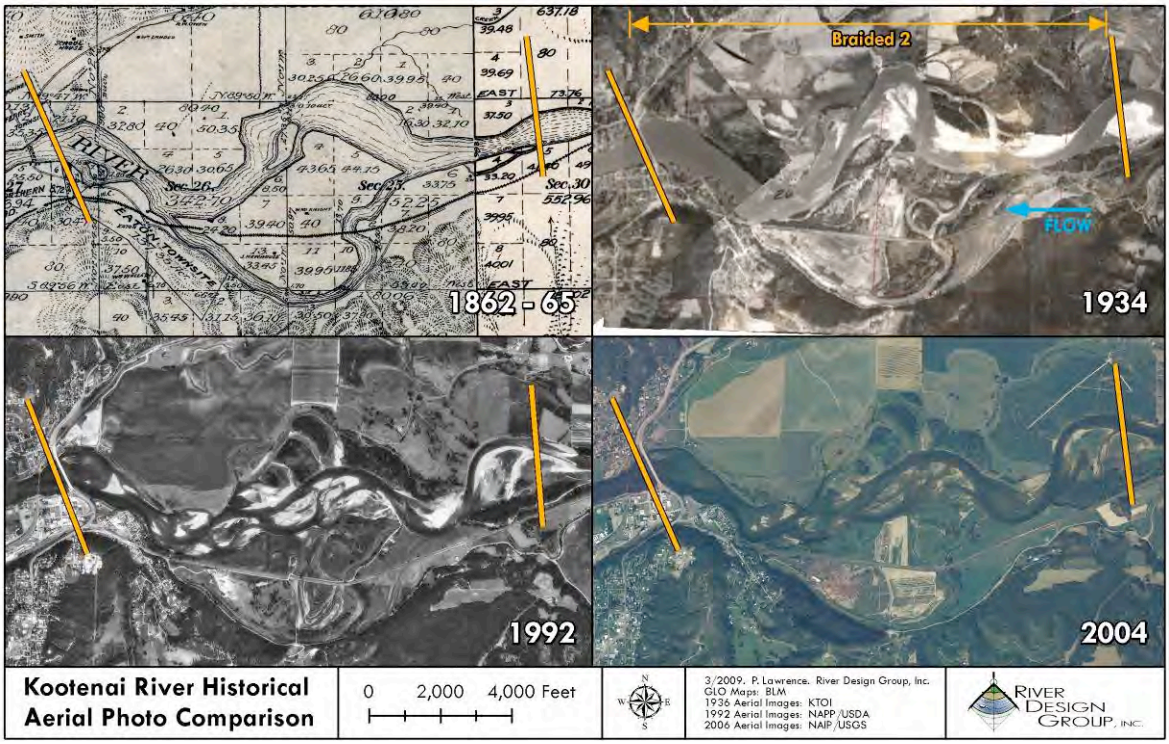


Figure 2-30. Comparison of channel migration trends from 1862-2004 in Braided Reach 2. A major channel avulsion occurred between 1934 and 1992. A pronounced side channel has been gradually disconnected from the system over time due to hydrologic changes and construction of the BNSF railway.

Meander Reaches

The Meander Reaches are generally a sand-bed stream type that is confined by levees. The Kootenai Flats Erosion Study (USACE 1983) evaluated rates of channel migration at 32 bends in the Meander Reaches. Two periods were evaluated including 1928–1968, and 1968–1992. The USACE study concluded that only two meander bends had major changes and the rest had experienced minor lateral channel migration (as presented in Tetra Tech 2004). This same USACE study suggested that in Meander Reach 1, about 100 to 200 feet of lateral bend migration occurred between 1928 and 1968 (pre-dam period), whereas between 1968 and 1983 (post-dam period after 1972), only minor rates of bend migration were observed (Tetra Tech 2008). Similarly, in Meander Reach 2, from 1928 to 1968 most bends reflected up to 100 to 300 feet of lateral adjustment, compared to only three bends with approximately 200 feet of adjustment from 1968-1992. A neck cutoff also occurred between 1968 and 1992 in Meander Reach 2 resulting from over 400 feet of lateral down-valley channel migration (Tetra Tech 2008) (Figure 2-31).

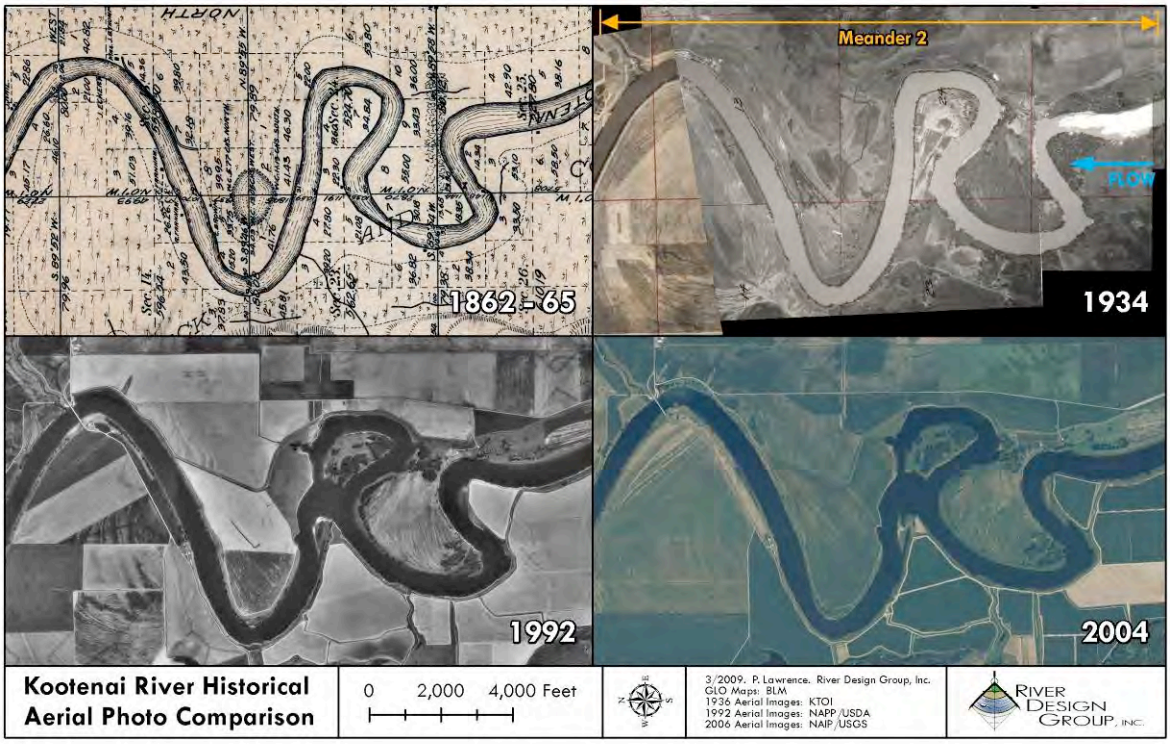


Figure 2-31. Comparison of channel migration trends from 1862-2004 in Meander Reach 2. An active neck cutoff is visible as the channel erodes the lower one-third of the bend in the center of the photo. The oxbow maintains hydrologic connectivity with the dominant channel.

While rates of meander bend migration appear to have moderated since Libby Dam closure, the most significant alteration to the channel planform has been the reduction in meander belt width due to the lateral constraints imposed by levees on the Meander Reaches. In Meander Reach 1, the meander belt width decreased from an average of 6,695 ft in 1862-1865 to 910 feet in 1934, a reduction of 86.4%. Similarly, values in Meander Reach 2 decreased from 4,070 feet in 1862-1865 to 2,256 feet in 1934, a 44.5% reduction. Since the locations of the levees have remained relatively unchanged through the air photo record, existing meander belt width values are assumed to be very similar to 1934 values, although minor increases have resulted from levee erosion and subsequent channel migration (Figure 2-31). Loss of boundary roughness provided by woody riparian vegetation and confinement of flood flows to the active, entrenched channel (Figure 2-32) contribute to levee erosion and bank migration.

Figure 2-32. Existing levees in Meander Reach 1. The levees are subject to erosion due to loss of boundary roughness and lack of resistance to flow (left photo). Stabilization efforts are ongoing in the Meander Reach and typically include rock armoring and placement of tree revetments (right photo). Levee erosion is a source of sediment to the Kootenai River in the Meander Reach.

As shown in Figure 2-33, reach-averaged meander belt width has decreased in all four of the primary reaches. The greatest reduction has occurred in Meander Reach 1 and Meander Reach 2, with a corresponding 86.4% and 44.6% change from 1862 to 2006.

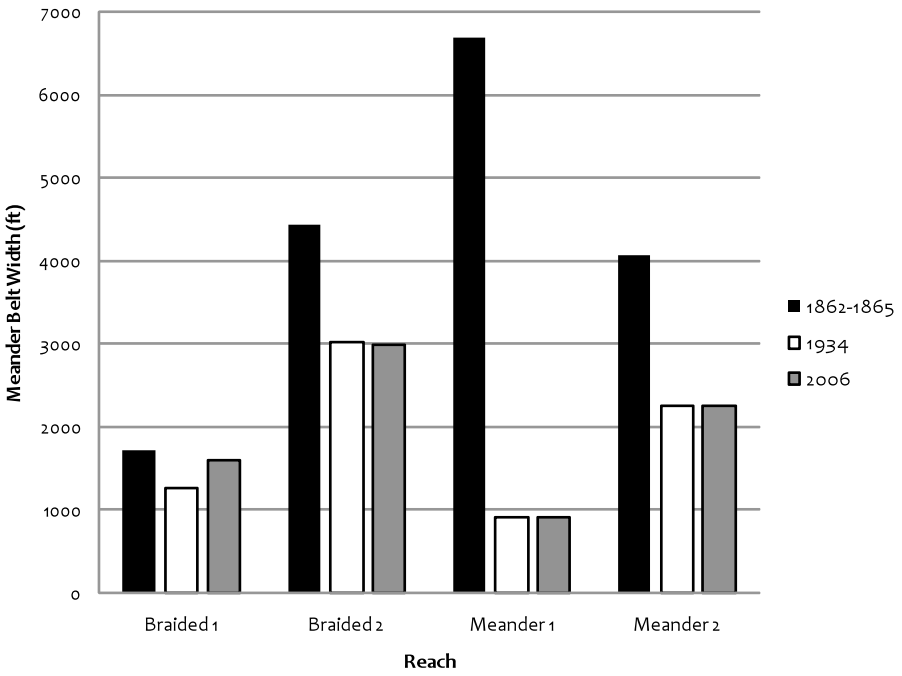


Figure 2-33. Comparison of reach-averaged meander belt width values from 1862-1865, 1934 and 2006. Floodplain constraints and infrastructure have decreased the channel belt width in the four primary reaches of the project area.

Summary of Historical Aerial Photo Analysis

Analysis of historical narrative, maps and aerial photographs confirms that the Kootenai River from the Moyie River downstream to Canada has undergone widespread change since the valley was first settled. Vegetation clearing, construction of transportation corridors and levee systems, agriculture and other subbasin development activities have altered the landscape within which the Kootenai River interacts. A temporal pattern of channel planform adjustment was observed in response to anthropogenic and natural disturbances through the period of record studied. To understand the Kootenai River's response to disturbance more clearly, additional investigations were completed to evaluate the morphological departure from historical conditions.

2.4.3.2 Channel Cross-section and Longitudinal Profile Departure

This section provides a summary of changes in channel morphology in the project area, in terms of cross-section and longitudinal profile. Limited data is available to fully evaluate reach-scale changes in the longitudinal profile and cross-section dimensions over time. Tetra Tech (2004) compared channel cross-sections from 1929 (USGS), 1956 (USACE) and 2002 (USACE Seattle District office) and overlaid these with historical thalweg profile data from 1929 (USGS 1937), 1950 (USACE), and 2002 (USGS 2004) to evaluate if cross-sections indicated that significant sediment deposition had occurred. In general, the studies found that the mean channel bed elevations through the project area have not changed significantly suggesting that neither aggradation nor degradation of the bed profile has occurred. In addition, recent underwater videography taken by USGS indicates that deep pools on outer bends in the Meander Reaches have thalwegs that are scoured deep into lacustrine clay layers and remain relatively free of sand and fine sediment (G. Barton, USGS, personal communication, 2009).

Results from hydraulic modeling were used to evaluate departure in cross-section hydraulics for pre-dam and post-BiOp flow regimes. For the modeling, mean annual peak discharges of 65kcfs and 30kcfs were selected as bankfull channel discharge surrogates representing the pre-dam and post-BiOp flow conditions, respectively. Downstream mean annual peak backwater elevations of 1763 ft (for the 65kcfs event) and 1754 ft (for the 30kcfs event) were selected to coincide with the surrogate bankfull discharge values. Due to a lack of historical topographic data, existing channel topography was used for all modeling scenarios in order to gain a conceptual understanding of the magnitude of the changes.

As shown in Table 2-9, hydraulic radius, flow area and width-to-depth ratio have changed significantly when comparing pre-dam and post-BiOp hydraulic regimes. Channel width-to-depth ratio has changed most significantly in Braided Reach 2, increasing by 85% from the pre-dam to post-dam period (Figure 2-34). A consequence of this departure is the loss of channel and floodplain connection at mean annual peak flow in all reaches. Figure 2-35 and Figure 2-36 illustrate the loss of floodplain connection by reach in a longitudinal profile and cross-sections. Loss of floodplain connection has widespread implications for ecological and biological processes as described in subsequent sections in this chapter. From a morphological perspective, loss of floodplain connection results in a lack of semi-permanent over-bank storage areas for water and fine sediment. As such, a greater proportion of sediment is stored more temporarily within the active channel. Because of these effects, ***loss of channel and floodplain connection is identified as a limiting factor for morphology***.

Table 2-9. Summary of mean bankfull hydraulic departure for pre-dam and post-dam regimes.									
Reach	Hydraulic Radius (*ft*)			Flow Area (ft^2)			W/D Ratio		
	65kcfs	30kcfs	% Change	65kcfs	30kcfs	% Change	65kcfs	30kcfs	% Change
Canyon	19.8	15.0	-24%	9,523	6,546	-31%	24.00	30.56	27%
Braided 1	16.5	11.8	-28%	10,097	6,755	-33%	37.55	50.04	33%
Braided 2	20.1	10.7	-47%	24,747	11,828	-52%	63.83	118.34	85%
Straight	29.7	22.5	-24%	19,632	12,523	-36%	22.25	28.32	27%
Meander 1	30.3	23.1	-24%	20,475	13,329	-35%	21.71	24.62	13%
Meander 2	33.7	26.6	-21%	21,556	15,388	-29%	18.10	21.41	18%
** Assumes Water-surface Elevation at Porthill (USGS Sta#12322000) of 1763 for 65kcfs and 1754 for 30kcfs*									

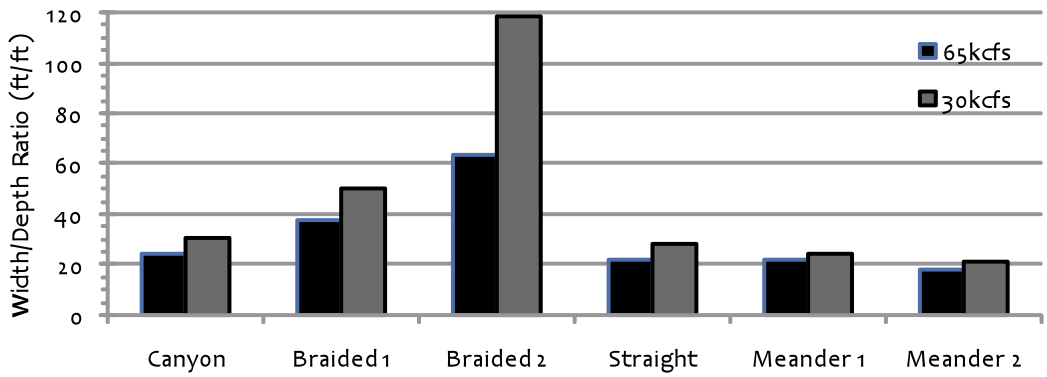


Figure 2-34. Comparison of channel width-to-depth ratios in the project reaches based on pre-dam and post-BiOp hydraulic regimes. Reach averaged width-to-depth ratios have increased in all reaches, most notably by 85% in Braided Reach 2 in the post-BiOp era.

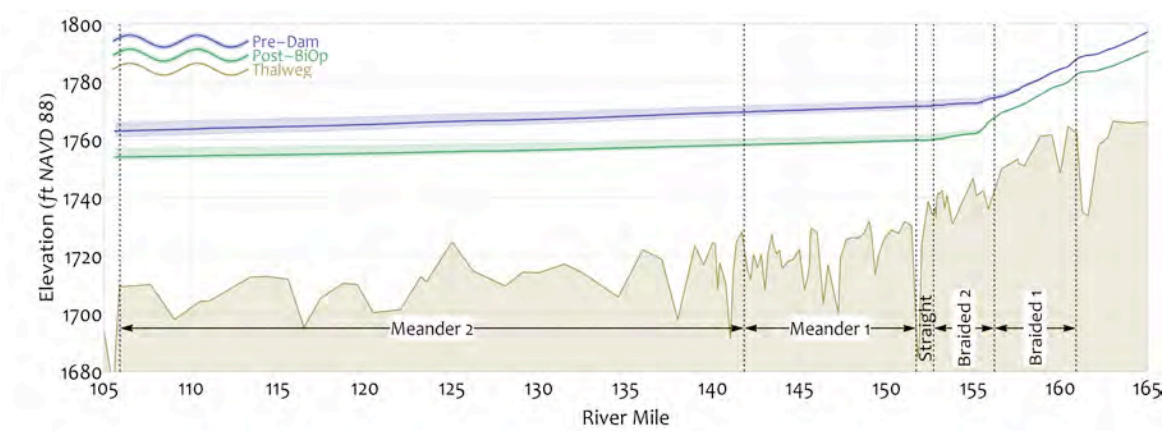


Figure 2-35. Comparison of mean annual peak water surface elevations for pre-dam (65kcfs) and post-BiOp (30kcfs) flow regimes. The difference between the two water surfaces is approximately seven to ten feet.

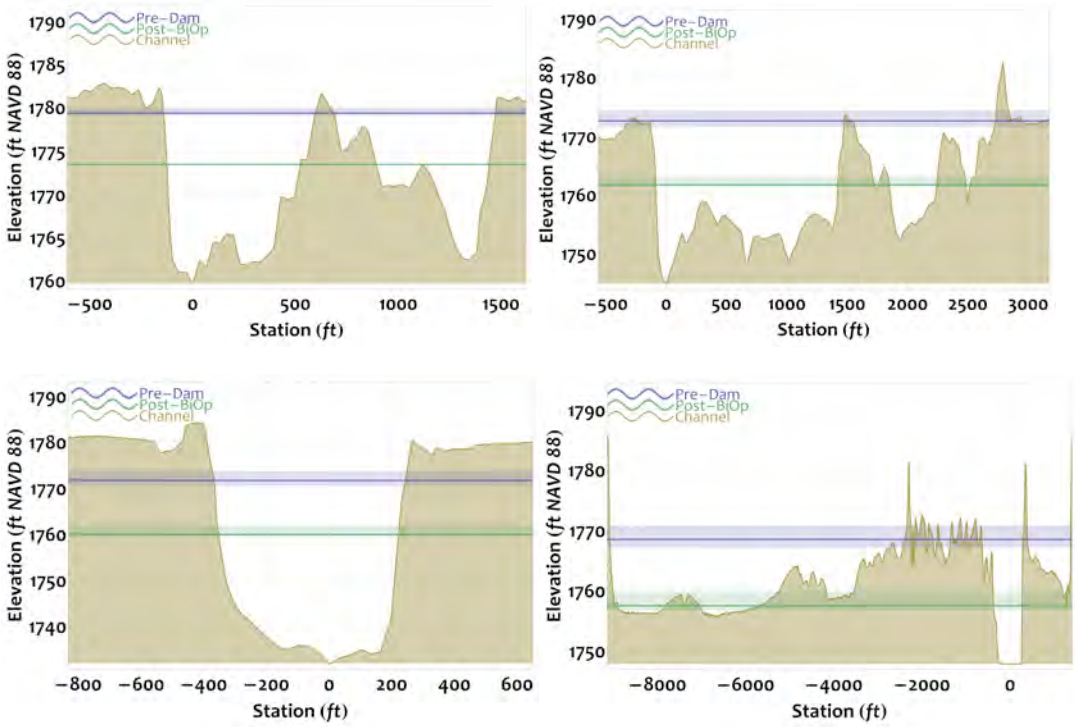


Figure 2-36. Select cross-sections with pre-dam (65kcfs) and post-BiOp (30kcfs) mean annual peak discharge water surface elevations for Braided Reach 1 RM 158.2 (top left), Braided Reach 2 RM 154.2 (top right), Straight Reach RM 152.3 (bottom left), Meander Reach 1 RM 136.5 (bottom right). Lower water surface elevations in the post-dam era combined with levees have resulted in a loss of floodplain connection in all reaches.

2.4.3.3 Bank Erosion

Streambank stability in the Kootenai River has been impacted by river and floodplain management, the loss of native bank vegetation, and the river's response to altered hydraulics and sediment transport. The net effect of these impacts is land loss and sediment loading. Annual streambank erosion rates for the Kootenai River were predicted and validated using the Bank Assessment for Non-point source Consequences of Sediment (BANCS) model (Wildland Hydrology 2006). The BANCS model uses two bank erosion estimation tools including the Bank Erosion Hazard Index (BEHI) and near-bank stress (NBS) ratings. The combination of the BEHI and NBS ratings were used to derive annual streambank erosion rate estimates in the project area. Erosion rates were predicted based on these two estimation tools, and validated through repeated surveys of bank study sites established in the project area. Appendix E includes additional information on the BANCS model.

Historically, in the Meander Reaches, streambank heights, which were naturally upwards of 25 ft higher than the base flow water-surface, were built up over millennia by annual floods that deposited fine sediment. Constructed dikes and levees have further increased bank heights relative to the river and adjacent floodplain. Combined with altered hydraulics and the effects of the Kootenay Lake backwater, these high streambanks do not the support dense, woody riparian vegetation that historically would have helped maintain streambank integrity. Throughout much of the Meander Reaches, native cottonwoods, willows and other native shrubs are absent, and fluctuating water depths, combined with few available areas for substrate deposition, present

very limited opportunities for these species to colonize naturally. Because of this, most streambanks in the Meander Reaches are vegetated with herbaceous plant species that contribute little rooting strength to banks. Appendix C includes a more detailed description of vegetation conditions along the Kootenai River's streambanks.

Ramping rates associated with fall hydropeaking at Libby Dam (Figure 2-11) combined with the variable downstream backwater effect from Kootenay Lake, are thought to have contributed to bank erosion. Cyclical bank saturation and de-saturation following rapid drawdowns causes poorly drained saturated banks to exhibit increased pore water pressure, which decreases bank strength and can exacerbate bank erosion.

2.4.3.4 Bank Erosion by River Reach

As part of the development of this Master Plan, bank erosion rates and streambank sediment yields were predicted for each project reach of the project area (Table 2-10, Figure 2-37 and Figure 2-38). On a reach-specific basis, bank erosion rates differ from the Braided Reaches to the Meander Reaches. Sediment yield predictions were based on bank erosion and sediment yield data collected on streams in Colorado (Wildland Hydrology 2008) and from data collected at discrete bank erosion modeling sites on the Kootenai River within the project area.

Table 2-10. Comparison of predicted (Colorado) and measured (Kootenai) bank erosion rates for Kootenai River reaches.					
Reach	Colorado		Kootenai		% Difference (tons/yr)
	tons/yr	tons/ft/yr	tons/yr	tons/ft/yr	
Braided 1	20,719	0.35	19,438	0.33	-6.2
Braided 2	57,429	1.29	46,785	1.05	-18.5
Straight	3,126	0.27	3,625	0.31	-15.9
Meander 1	55,863	0.54	61,256	0.59	9.6
Meander 2	237,228	0.61	309,225	0.80	-30.3

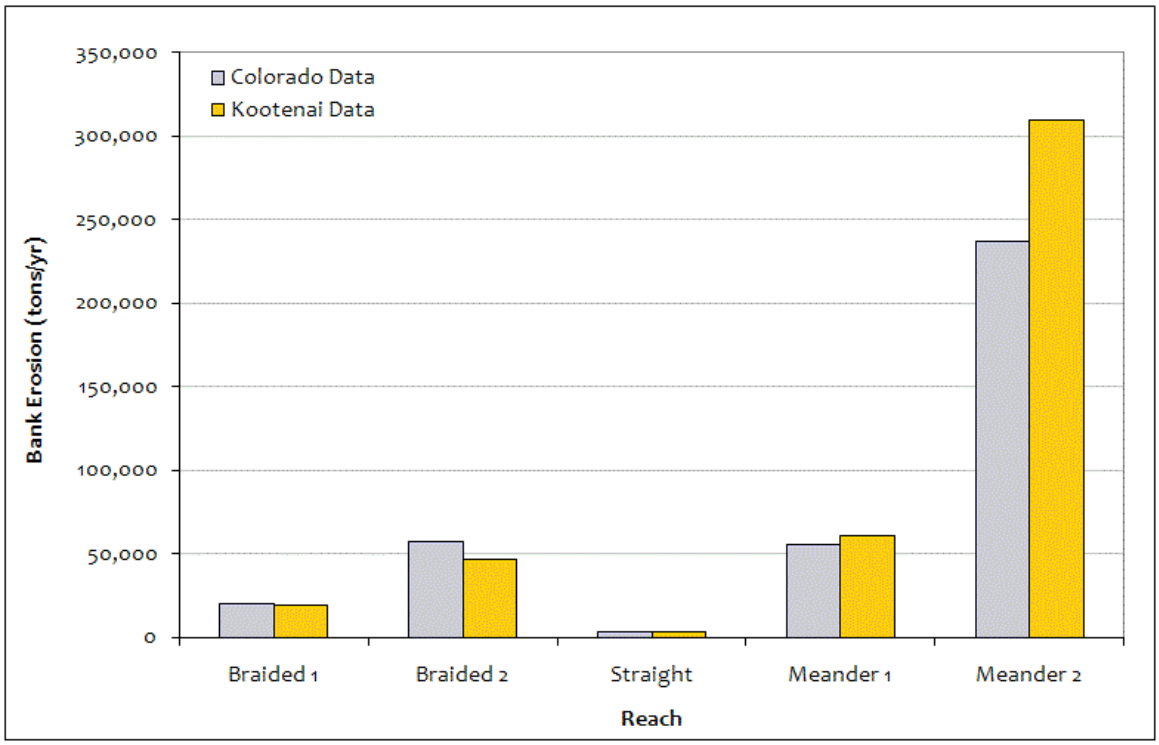


Figure 2-37. Comparison of predicted and measured bank erosion rates for the Kootenai River project area by reach (Wildland Hydrology 2008).

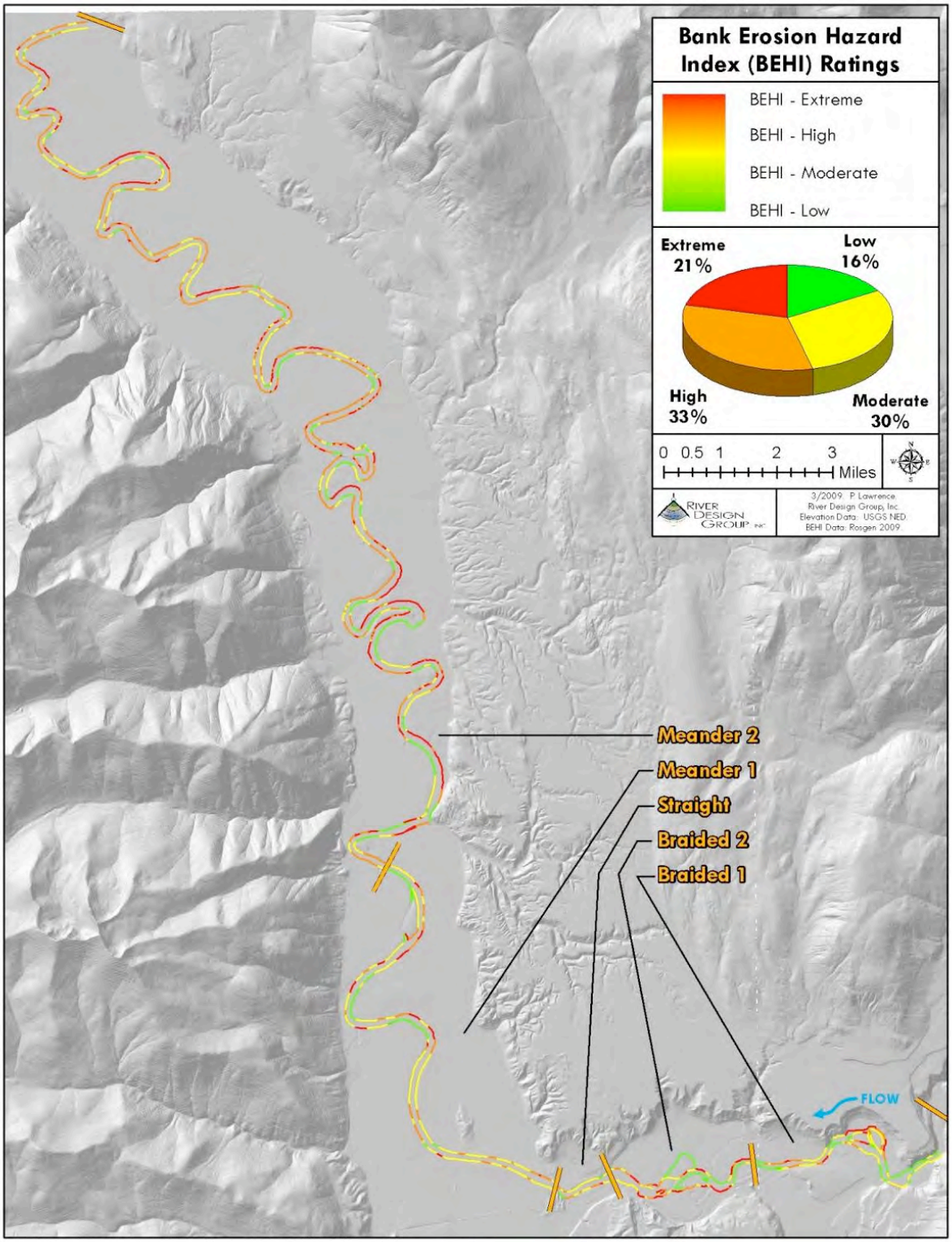


Figure 2-38. Existing condition bank erodibility hazard indices (BEHI) in the project area. The map categorizes streambanks by BEHI rating including low, moderate, high and extreme.

Braided Reaches

Bank erosion measurements completed in 2008 by USGS and Wildland Hydrology suggest the greatest bank erosion rates occur in Braided Reach 2 (Table 2-10). Prediction level bank erosion models (Wildland Hydrology 2008) suggest that 103,153 ft (total bank length) of streambank in the Braided Reach contribute 78,148 tons/yr, or 0.76 tons/ft/yr. Measured data indicate approximately 66,223 tons/yr, or 1.38 tons/ft/yr, a difference of approximately 15.3%. On a per linear foot basis, sediment generated from streambank erosion is three times higher in Braided Reach 2 than Braided Reach 1. BEHI predicted data suggest Braided Reach 2 contributes approximately 5,536 tons of sediment per mile per year compared to an estimated measured value of 6,336 tons.

Straight Reach

Streambank erosion rates in the Straight Reach are the lowest of the three reaches due to bedrock outcrops and extensive bank stabilization for scour and flood protection (Wildland Hydrology 2008). Based on measured data, the Straight Reach through Bonners Ferry produces approximately 3,625 tons/yr for 11,670 ft of streambank, or 0.31 tons/ft/yr, the lowest values of the project reaches (Table 2-10). Both streambanks in the Straight Reach are diked to prevent flooding in Bonners Ferry. Infrastructure protection measures and bedrock outcrops prevent lateral channel migration in the reach.

Meander Reaches

The Meander Reaches are characterized by considerable streambank erosion with estimated erosion rates of 0.59 tons/ft/year in Meander Reach 1 and 0.80 tons/ft/year in Meander Reach 2 (Table 2-10). Based on bank erosion data in Meander Reach 1 and Meander Reach 2, approximately 370,481 tons/yr from 489,953 ft of streambank is contributed to the system (Wildland Hydrology 2008).

In summary, bank erosion and sediment loading have always played a role in the morphology of the Kootenai River. However, observed disturbances in the project area including river and floodplain management, loss of bank vegetation, altered hydraulics, and altered sediment transport are thought to have changed the rates at which these processes occur relative to undisturbed conditions. Measured data suggest that bank erosion in the project area is a significant source of sediment to the Kootenai River. When compared with the estimated annual bedload supply (Figure 2-27), bank erosion accounts for approximately 15 to 30% of the total bedload supply. Data indicate that the highest bank erosion rates occur in Braided Reach 2, and correspond with the highest measured rates of sediment supply at RM153.3. As discussed previously, fine sediment loading has implications for aquatic habitat such as increasing the embeddedness of coarse spawning substrate with sand and finer sediment. In addition, bank erosion and associated rates of channel migration, if accelerated, could cause excessive disturbance and have negative effects on aquatic habitat and ecological processes. Moreover, bank erosion and land loss is a costly problem that affects river stewardship as well as river and floodplain management. For these reasons, ***reduced channel boundary roughness*** and ***bank erosion are identified as limiting factors for morphology***.

2.5 Vegetation Limiting Factors

Human activities have caused significant losses in riparian and wetland areas or substantially impaired riparian, wetland and overall floodplain functions along the lower Kootenai River since

the early 1900s (USEPA 2004). Some of the most serious impacts have come from the following anthropogenic activities: water impoundment and diversion; river diking, flood control and channelization; dam construction and operation; wetland draining and associated reduction of native species dependent on wetlands (including beavers); livestock grazing; urban and suburban development; clearing of land for agriculture; road building; and recreation.

This degradation impaired key riparian and floodplain wetland ecological functions, including sediment filtering, streambank building, water storage, aquifer recharge, dissipation of stream energy, nutrient retention, and fish and wildlife habitat.

The primary effects of these activities to riparian and wetland communities and overall floodplain ecosystem function include:

- Direct loss of riparian vegetation resulting in reduced floodplain and streambank stability;
- Loss of habitat and habitat connectivity both along the river and between the river and tributary systems and the river and uplands;
- Loss of natural sources of river and floodplain nutrient, organic matter and large woody debris inputs; and altered temperature regimes;
- Alterations to hydrologic and sediment regime resulting in interrupted patterns of vegetation succession;
- Loss of floodplain connectivity resulting in elimination of low velocity back water and side channel habitat;
- Loss of wetland acres and corresponding wetland function including primary production, potential sturgeon rearing habitat, wildlife and waterfowl habitat;
- Increased competition and species diversity due to the introduction and spread of non-native and invasive plant species.

The above effects have led to the following primary factors limiting restoration of riparian vegetation in the Kootenai subbasin:

- Lack of surfaces that support riparian vegetation recruitment;
- Lack of vegetation on outer banks;
- Frequent scour or deposition of alluvial surfaces;
- Altered hydroperiod;
- Invasive weeds;
- Lack of native plant diversity and seed sources; and
- Lack of nutrient sources for primary productivity and limited carbon storage.

These effects and limiting factors are described in more detail in the following sections.

2.5.1 Altered Riparian Vegetation

Riparian and wetland plant communities within the Kootenai subbasin historically would have been formed, maintained and distributed according to a variety of naturally occurring controls.

At the broadest scale, these controls would have included geology, valley geomorphology and soils. The most influential of these controls were likely related to fluvial processes that resulted in highly variable surface water/groundwater interactions, frequent flood disturbance cycles, creation and erosion of streambanks and floodplain surfaces, and significant biological feedback loops such as beaver influences, seed dispersal mechanisms, and a high frequency exchange of nutrients and organic matter.

Early photographs and artistic renderings show a multi-storied riparian system with shrubs, cottonwoods, and several conifer species (Jamieson and Braatne 2001). Very tall, large diameter white pine (*Pinus monticola*) appear to be present in many of the old photos and paintings available in Kootenai Tribe's archives, indicating that much larger wood than is currently present may have been a part of this system. General Land Office notes from between 1894 and 1898 indicate abundant marshy land, rich alluvial soils, three- to four-foot diameter cottonwoods, shrubs and several types of emergent wetlands (KTOI and MFWP 2004).

The following general structural groups of plant communities were likely present along the lower Kootenai River and within the Kootenai River floodplain prior to European settlement (interpreted from Egger et al. 2007 and Hansen et al. 1995):

- Early successional phases of cottonwood and willow would have occurred on point bar features and deposition/scour areas within the broader floodplain.
- Later successional phases of cottonwood and willow would have occurred further from the channel and along abandoned meander scrolls. Mature cottonwood stands also likely occupied extensive areas of the floodplain outside of natural levees.
- Herbaceous emergent wetlands dominated by various sedge, rush, grass and forb species would have been present in floodplain depressions, and along backwater or other open water features such as abandoned oxbows or floodplain depressions.
- Riparian areas dominated by alders (*Alnus* species), birch (*Betula* species), hawthorne (*Crataegus* species) and other hydrophytic species would have occurred along side channels, tributary streams, and in transitional areas between low floodplain surfaces and low terrace features.
- Early successional stages of pine (*Pinus* species) and cedar (*Thuja* species) would have been present in higher elevation areas of the floodplain not subject to frequent flooding, scour, or high water. These plant communities typically would occur as an understory component in pole or mature cottonwood stands.
- Later successional phases of various conifer species would develop over time on terrace features or drier microsites in the floodplain. Understory species would consist of a mix of shrubs, grasses and forbs.
- Drier grassland and shrub communities may have occupied portions of sand levees adjacent to the river.

Historical and current land uses within the Kootenai subbasin have altered the native plant communities. Riparian vegetation has been reduced by livestock grazing, clearing for agriculture and development or logging; interruption or alteration of natural flood processes; and diking. Nearly complete elimination of the deciduous riparian forest has occurred in the lower reaches of the Kootenai River below Bonners Ferry through diking and conversion to agriculture.

Approximately 50,000 acres of lowland floodplain and 23,000 acres of ephemeral and perennial wetlands have been converted into agricultural row crop and pastureland (Richards 1997). Jamieson and Braatne (2001) found that human impacts to the floodplain were much more extensive below Libby Dam where much of the river is diked and most of the floodplain is now farmland.

The loss of riparian and floodplain vegetation has reduced streambank protection and flood water filtering and retention. These functions support formation of new habitats and surfaces that are necessary for early successional plant species to establish, store flood waters and maintain late season flows. Loss of riparian vegetation has also significantly affected plant and wildlife diversity in the lower Kootenai subbasin.

Grassland and Farmland are the primary cover types in the project area, illustrating the extensive conversion of floodplain areas to drier sites. A vegetation study associated with evaluating ecosystem losses from Libby Dam operations (Egger et al. 2008) included collection of detailed plant community data for select reaches of the lower Kootenai River, regional reference stream reaches and reference reaches upstream of Libby Dam. These data show the predominance of grassland vegetation types and also distinct differences in riparian and floodplain plant community diversity and distribution between the Meander and Braided reaches (Figure 2-39). The primary differences are the lack of cottonwood and willow communities in the Meander Reaches and the predominance of Great Plains cottonwood (*Populus deltoides*) in the Meander Reaches compared with black cottonwood (*Populus trichocarpa*) being dominant in the Braided Reaches. The Braided Reaches generally supports a more diverse assemblage of riparian plant communities due to a larger overall floodplain area that is still subject to annual overbank flows. Some mature cottonwood forests within the Braided Reaches were probably established before the construction of Libby Dam. While these areas are no longer connected with the current river channel, they do support diverse, multi-storied plant communities with a native shrub understory. Within the Meander Reaches, riparian vegetation consists of cottonwood forests and shrub-dominated communities that are currently restricted to small linear bands on or within the levees and on mid-channel islands.

Table 2-11. Existing vegetation communities and other cover types within select reaches of the Kootenai River in the project area, reference reaches on the Kootenai River upstream of Libby Dam, and on other regional streams (Egger et al. 2008).

Vegetation and other Cover Types used by Egger	Lower Kootenai-Meandering	Lower Kootenai Braided	NF Reference Site	Elk River	Upper Kootenai Reference-Wasa	Upper Kootenai Reference--Fenwick
Vegetation community/cover type percent cover by reach						
River	21.44	12.52	11.07	15.77	20.77	34.8
Creek	0	0	0.34	0	0.31	0
Still water	0.43	0.75	1.57	0.90	0	0
Gravel bar or sandbar without vegetation	0.44	0	4.99	5.74	2.08	4.33
Pioneer vegetation –gravel bar	0	0.74	2.61	1.44	0.25	0
Pioneer vegetation-sand bar	0.46	0.14	0	0.29	0.88	0.22
Sandbar willow	0	0.49	0.50	0.18	1.14	2.72
Black cottonwood shrub	0	0.59	0.29	8.34	0	0
Black cottonwood-willow shrub	0	0.22	7.49	1.88	0	0
Hawthorn shrub	0.56	1.11	0	0	0	0
Grassland/willow shrub	0.0	0.25	0	0	0.91	0
Snowberry shrub/grassland	3.01	0	0	1.66	0	1.8
Mountain alder/willow shrub	0	0	0.13	1.82+1	0	1.24
Drummond willow/reed grass	0	0	1.32	0	0	0
Water birch/shrub	0	0	0	0	0.95	3.35
Yellow willow shrub	0	0	0	0	0	2.28
Sedge reed	0	0.21	0	0	0	0
Reed canarygrass	0.13	1.11	0	1.49	0	0
Cattail reed	18.15	0	0	0	0	0
Spike rush reed	0	0	0	0	1.77	0
Black cottonwood/dogwood	0	0.31	14.74	0	2.31	2.51
Black cottonwood/snowberry	0	2.77	1.38	12.52	0.72	0
Black cottonwood-spruce	0	2.82	0	3.92	4.87	0
Black cottonwood-grassland	0.33	1.23	2.16	12.41	0	0
Great plains cottonwood/snowberry	5.94	2.12	0		0	0
Great plains cottonwood/shrub	0.45	0	0		0	0
Aspen forest/dogwood	0	0.29	0		23.49	25.68
Black cottonwood/reed canarygrass	1.55	0.42	0			0
Aspen forest/snowberry	0	0.38	0			4.74
Spruce forest	0	1.58	15.81	6.41	16.42	0
Spruce forest/aspen	0	0	1.59	0	1.94	3.12
Spruce forest/black cottonwood	0	0	5.35	1.52	0.78	0
Red cedar/Black cottonwood forest	0.77	0.78+0.99	1.13	12.92	0	0
Lodgepole pine	0		22.08	0	0	0
Ponderosa pine	0		0	0	0.6	8.49
Grassland, dry	14.04	7.93	2.65	1.64	7.97	0
Grassland, fresh	13.17	16.13	1.26	7.34	11.84	1.21
Farmland	19.13	43.14	0	0	0	
Street railway	19.13	0.96	1.53	0		3.52
Bank protection	0	0	0	0.79		

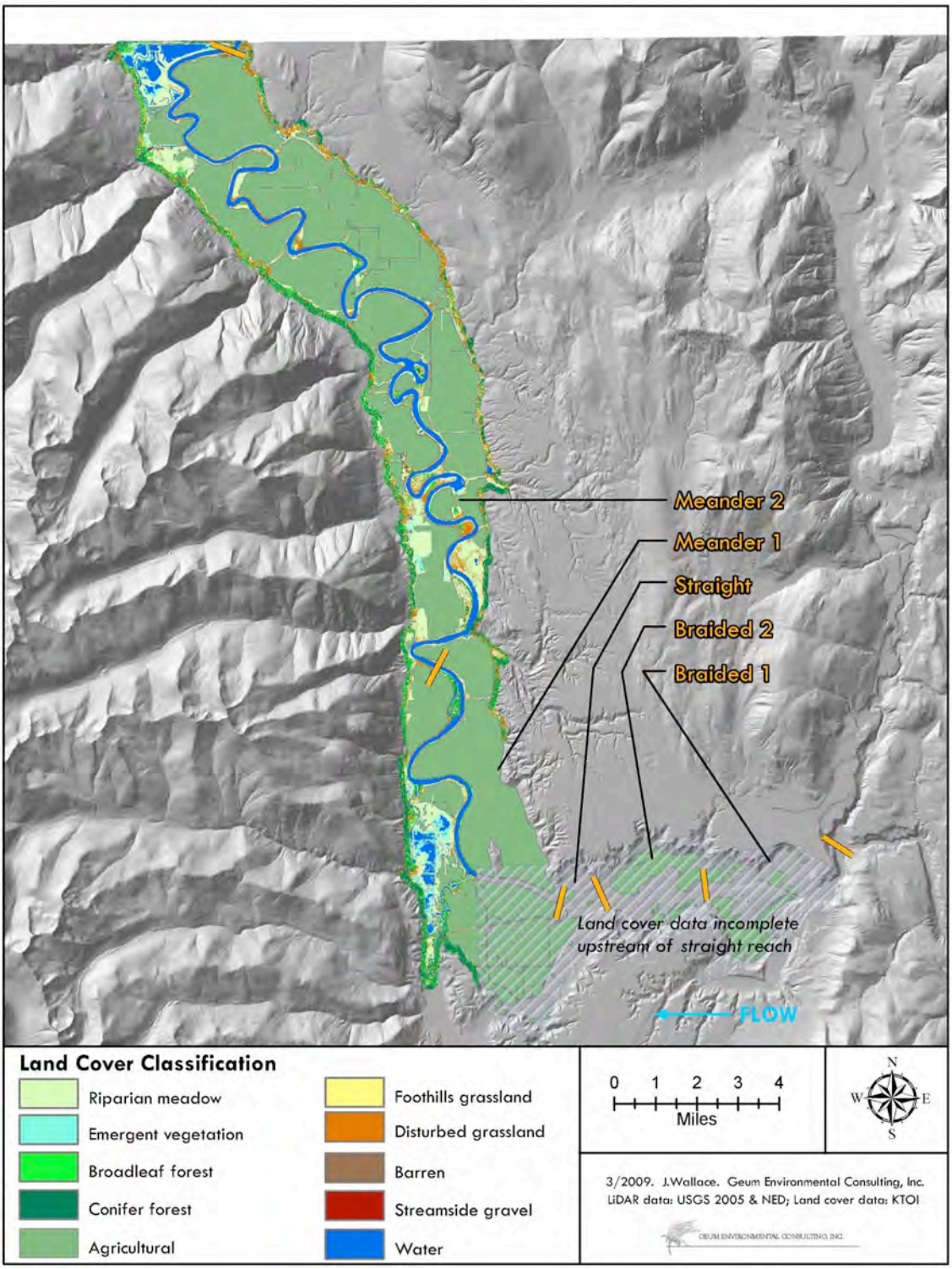


Figure 2-39. Vegetation and land cover types in the Kootenai River project reach (KTOI 2009).

The loss of riparian and floodplain vegetation contributes to reduction of the overall productivity of the lower Kootenai River system by reducing the amount of organic inputs reaching the river

and being deposited in floodplain environments where they decompose and fuel primary and secondary production. The loss of riparian vegetation has also led to a decline in the amount of large, instream woody debris, which directly impacts trout populations in the Kootenai River (USFWS 2002). Riparian vegetation loss can contribute to increased summer water temperatures by reducing overhanging cover, although this effect is more significant in smaller channels.

Succession within existing mature cottonwood stands, evidenced by the lack of a shrub understory and younger age classes or tree species, is also limited in the project area. Plant community succession appears to be hindered by a number of factors including lack of seed sources and land management including grazing and extensive agricultural operations. In general, early successional pioneer vegetation, such as willows and cottonwoods, is lacking in the project area. The lack of these plant communities is an indication of altered hydrologic and sediment-transport regimes resulting from the presence and operation of Libby Dam. Various studies have surveyed young cottonwood stands in the Kootenai River downstream from Libby Dam (Jamieson and Braatne 2001; Egger et al. 2007). These studies have found that seed germination is occurring, and young cottonwood are present, but location, species composition and age class structure differ significantly between the Braided and Meander Reaches. Various studies have identified areas in the Braided Reaches with extensive floodplains supporting a range of young aged-class black cottonwoods (Jamieson and Braatne 2001; Egger et al. 2007; Geum Environmental Consulting 2008) (Figure 2-40 and Figure 2-41). The age classes of these stands may indicate that they became established after initiation of increased spring flow releases from Libby Dam or as a result of more gradual ramping of tiered sturgeon flows that has occurred in the last decade. Young cottonwood stands are very rare in the Meander Reaches and consist almost entirely of Great Plains cottonwood (*Populus deltoides*). Additional observations of cottonwood recruitment are summarized in Appendix C.

Figure 2-40. Typical distribution of cottonwood stands on levees in the Meander Reaches (left photo). The right photo shows colonization of Great Plains cottonwood on sandbar surfaces in distinct linear banks likely tied to Libby Dam reservoir flow releases.

Figure 2-41. Young age classes of black cottonwood (left photo) and sandbar willow (right photo).

As described above, the altered riparian plant community has affected the ecosystem's ability to stabilize soils and streambanks and recolonize floodplain areas, therefore ***lack of vegetation on outer banks*** and ***lack of native plant diversity and seed sources are identified as limiting factors for riparian plant communities***.

2.5.2 Altered Hydrologic and Sediment Regime

The physical effects of the construction and operation of Libby Dam include alterations to the flow of water and sediment-transport downstream, which have resulted in significant changes to floodplain processes dependent upon natural variations in the hydrologic and sediment-transport regimes. Modifications to the timing, periodicity and magnitude of the hydrograph directly affect the processes that form and maintain floodplain plant communities. These alterations have affected riparian and wetland plant community composition throughout the project area.

Several ecological processes depend upon natural flood events, including nutrient transport, deposition and scour, seed dispersal, and ground water recharge. The altered hydrologic and sediment-transport regime has mostly eliminated nutrient and sediment exchange between the river and the floodplain. Polzin (1998), Marotz et al. (2000), and Burke et al. (2008) have documented the loss of cottonwood recruitment due to flood manipulation. Many existing riparian forests lack seedlings, saplings and pole-sized trees because the floodplain surfaces required for colonization of new plants are no longer deposited due to the reduction in peak annual flood events. The Burke et al. (2008) investigation of the Kootenai River's pre-Libby Dam hydrograph found that the historical hydrograph showed a pattern consistent with seasonal mobilization of sediment. The cottonwood and willow recruitment period coincided with sediment mobilization, providing fresh fine sediment deposition on bars (Burke et al. 2008).

As described by Burke et al. (2008), the annual pattern of sediment mobility and vegetation colonization was disrupted by the regulation of the Kootenai River by Libby Dam. Regulated flows are maintained at higher levels throughout the year, though the mobility is limited to fewer sites due to lower magnitude flood events relative to the pre-dam era. Elevated flows that are sustained through fall and winter may scour successfully recruited seedlings from the preceding recruitment period (Burke et al. 2008). Moreover, the fact that sediment mobility is less evenly distributed over the project area, but for longer periods, suggests that while the locations with

larger grain sizes are not being scoured, the finer grained locations are being scoured more frequently (Barton 2004; Burke 2006).

Jamieson and Braatne (2001) made similar conclusions in their study of the impacts of flow regulation on Kootenai River riparian cottonwood forests. Jamieson and Braatne report that in relatively unaltered sections of the Kootenai River, regular flood events are resulting in cottonwood and willow recruitment. The Braided Reaches have dikes, but the river is able to migrate between them. In these reaches, Jamieson and Braatne (2001) found large stands of mature cottonwood and recruitment of new cottonwood stands that had occurred in recent years as a result of spring flow releases from Libby Dam. In the Meander Reaches, the Kootenai river is restricted by dikes for most of its length, and Jamieson and Braatne (2001) found little evidence that cottonwood and willow recruitment had occurred since construction of Libby Dam except on point bars forming below dikes where the dikes cut across the neck of meander loops. Although the study concludes that diking for agricultural use has severely restricted the hydrologic connectivity between the river and the floodplain, Jamieson and Braatne (2001) proposed that the operation of Libby Dam is the major factor affecting cottonwood recruitment. The survival of cottonwood recruits is unknown and is likely tied to subsequent years' flows and erosion processes. Snyder (2002) reported in her assessment that dikes were constantly being eroded and reshaped, which may affect cottonwood survival. Appendix C provides additional details about cottonwood and willow recruitment in the Meander Reaches.

Based on these studies and field observations documented in Appendix C, ***lack of surfaces that support riparian recruitment*** and ***frequent scour and deposition of floodplain surfaces were identified as limiting factors for riparian plant communities.***

2.5.3 Altered Floodplain Connectivity

Channelization, diking and altered flood regimes have all contributed to a large-scale reduction in available, connected floodplain for the Kootenai River to access within the project area. In addition, most of this floodplain area has been converted from native riparian and wetland complexes to agricultural cropland or pastureland (Figure 2-42). Natural levees were present in most of the project area due to the backwater effect created by Kootenay Lake and seasonal flooding of the Kootenai River. Despite the height of the natural levees, the Kootenai River regularly inundated the adjacent floodplain. Reduced floodplain connectivity is mainly due to the regulation of flows by Libby Dam and construction of levees.

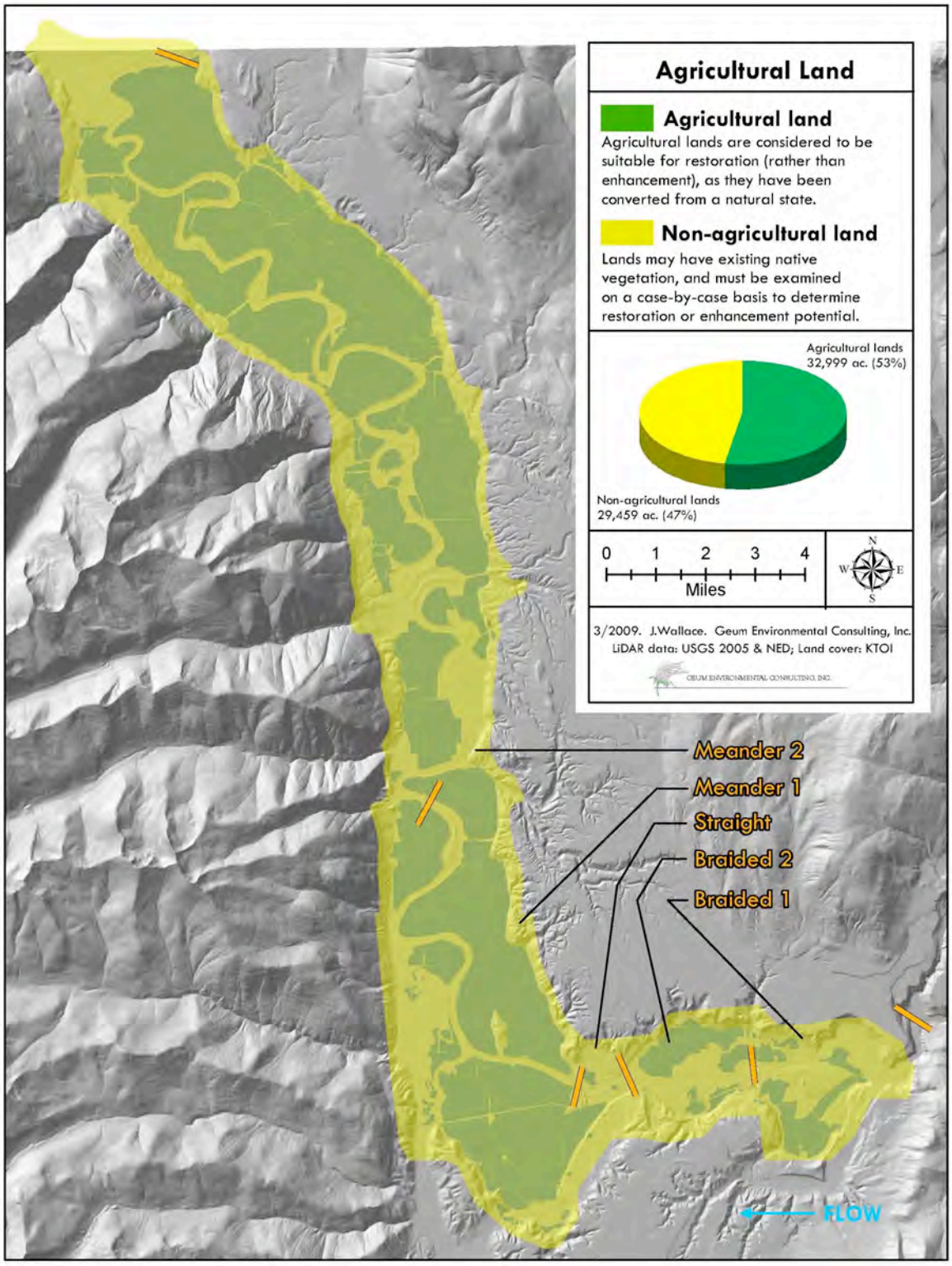


Figure 2-42. Distribution of agricultural and non-agricultural land in the Kootenai River project area.

Historically, plant communities were adapted to and dependent upon the free-flowing flood disturbance patterns of the Kootenai River and the connection between the river and floodplain. Over time, and under the pressure of the various anthropogenic disturbances, native plant communities have shifted from diverse, in both species and structure, to simple and ecologically static communities adapted to a steady environment resulting from fewer large disturbance events. Reduced floodplain connectivity, combined with a lower water table and reduced stream flows, has resulted in a shift from extensive, complex riparian and wetland communities to a predominance of agricultural fields and drier, flood intolerant plant communities along streambanks and many portions of the floodplain.

Based on these changes, ***altered hydroperiod was identified as a limiting factor for riparian plant communities.***

2.5.4 Altered Wetland Function

Before European settlement, the lower Kootenai subbasin experienced frequent floods, which formed approximately 22,000 acres of wetlands and associated riparian habitats (KTOI 2004). The alterations described in the previous sections affected wetland acres and function within the Kootenai River floodplain. In the lower Kootenai subbasin, approximately 50,000 acres of lowland floodplain and 23,000 acres of ephemeral and perennial wetlands in the U.S. portion of the Kootenai subbasin (Figure 2-43) have been converted to agricultural crop and pastureland (EPA 2004). Before European settlement, the lower Kootenai subbasin experienced frequent floods, which formed approximately 22,000 acres of wetlands and associated riparian habitats (KTOI 2004).

Table 2-12 lists the estimated wetland acres remaining by elevation above sea level in the lower Kootenai subbasin (McPhail and Baxter 1996). Some land in the project area was converted back to wetlands by the early 1990s in an area that is now managed as a wildlife refuge with managed wetland areas behind the dikes (Jamieson and Braatne 2001).

Table 2-12. National Wetlands Inventory (NWI) acres of wetlands in the lower Kootenai subbasin.

Lentic Environments	Total Acres	0-2,500 ft elevation	2,500-4,500 ft elevation	4,500+ft elevation
NWI-Palustrine	6,002.9	3,199.0	2,257.6	546.3
NWI-Lacustrine	1,044.0	635.1	303.8	105.9
Total	7,046.9	3,834.1	2,561.4	652.2
Riverine	5,040.1	4,755.2	2,846.3	0.0
Lotic Environments	Total Miles of Streams	Total Miles of Streams in 500-Year Floodplain	Total Miles of Streams in Upland Areas	
	1,897.9	164.2		1,733.7

Source: NWI as reported in KTOI 2004. Lentic and lotic inventories in Boundary County, Idaho.

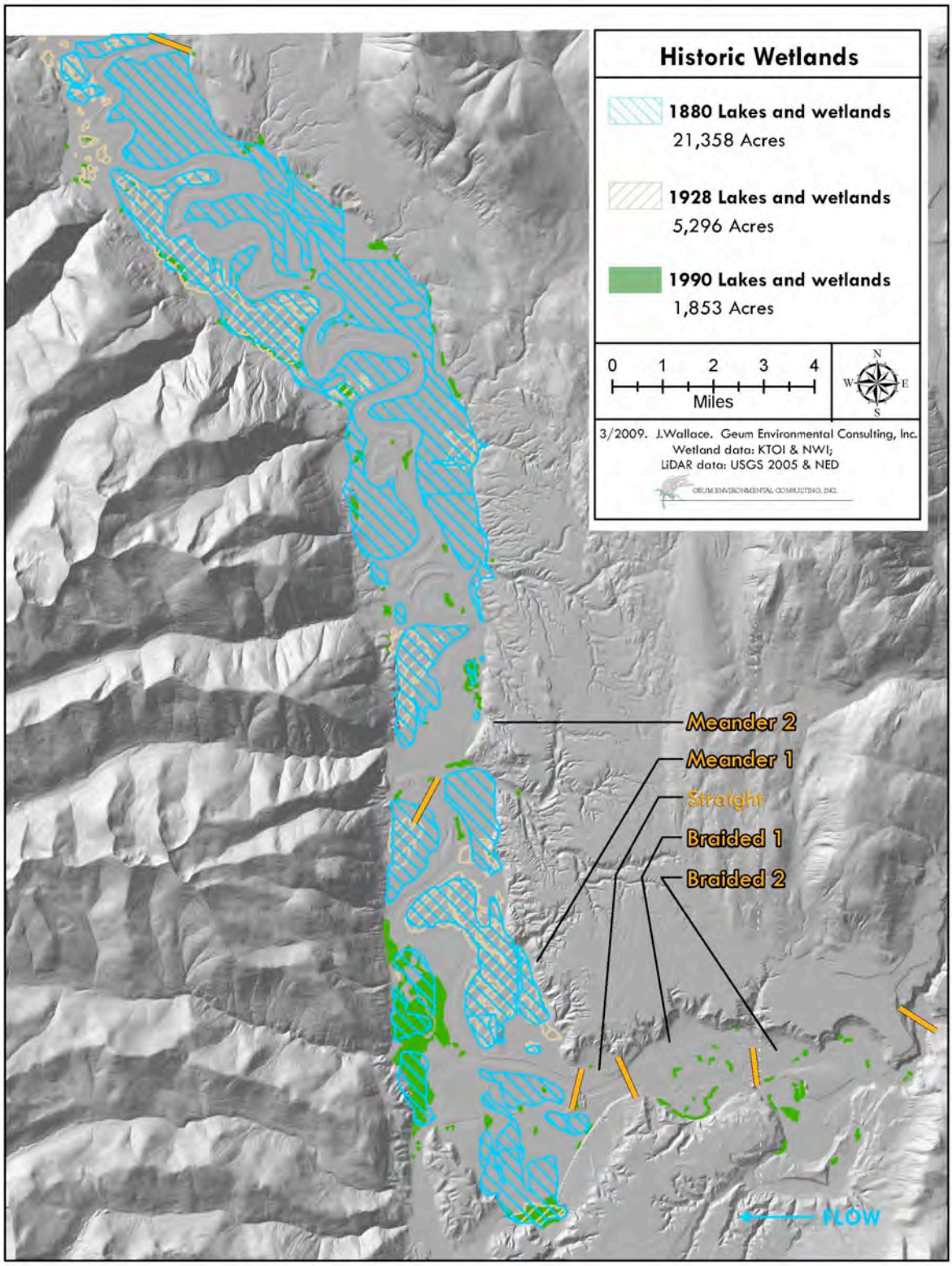


Figure 2-43. Time-series analysis of wetland change, 1890-1990 (Modified from USEPA 2004).

A study completed by Sieracki (2002) mapped approximately 265 miles of streams and ditches present in the 500-year Kootenai River floodplain within Boundary County, Idaho. Based on the 1928 USGS maps there were 182 miles of streams and ditches in the floodplain. Relative to the 1928 map, there has been an 83 mile increase in the length of floodplain channels over the past 75 years. The increase in channel length is due to a higher density of ditches that support agriculture; therefore, this increase does not represent an increase in functioning stream channel length within the floodplain. The more expansive channel and ditch network is used to distribute water to support agriculture, resulting in overall negative impacts on tributary conditions, floodplain function, and floodplain ecology.

Wetland systems in the lower Kootenai subbasin probably contributed substantially to the influx of carbon and nutrients to the Kootenai River. Wetland habitats rely on the nutrients and water recharge provided by high spring flows. Although natural levees and constructed dikes are present along much of the lower Kootenai River, the river often overtopped dikes and flooded agricultural lands. These flood events supplied nutrient inputs and created low velocity, backwater and side channel habitat (PWI 1999). These inputs have been reduced by the construction and operation of Libby Dam. Other wetland functions affected by anthropogenic activities include: reduced area and diversity of habitats for a wide range of species, loss of floodwater storage capacity, aquifer recharge and maintenance of base flows, and filtering of sediments, nutrients and other potential contaminants.

Based on these changes in wetlands, ***altered hydroperiod***, ***lack of nutrients for primary productivity*** and ***altered carbon balance were identified as limiting factors for riparian plant communities.***

2.5.5 Altered Species Composition

Humans have introduced several non-native grass and forb species within the riparian and floodplain areas of the lower Kootenai subbasin. Competition and reduced species diversity due to the introduction and spread of non-native and invasive species is a limiting factor that will need to be addressed to restore diverse, native riparian and wetland plant communities.

Extensive populations of non-native species, particularly reed canarygrass (*Phalaris arundinacea*) and common tansy (*Tanacetum vulgare*) are present along the river (KTOI and MFWP 2004). Other invasive forb species include spotted knapweed (*Centaurea maculosa*), Canada thistle (*Cirsium arvense*), and houndstongue (*Cynoglossum officinale*). Non-native grasses include quackgrass (*Agropyron repens*) and redtop (*Agrostis stolonifera*). A study of the vegetation composition on dikes along the Kootenai River below Bonners Ferry by Snyder (2002), showed out of 100 plant species identified, 61% of those were non-native and 39% were native. These non-native species reduce the value of the areas for wildlife habitat and can displace native plant species. Within the Meander reaches, aggressive grasses such as reed canarygrass appear to be colonizing similar depositional features as cottonwood seedlings (see Appendix C for additional discussion). The ability of reed canarygrass to spread rapidly, form dense root mats, and tolerate fluctuating water levels may be one factor limiting establishment of cottonwoods in these areas.

The abundance of aquatic macrophytes has increased in the post-dam environment. Eurasian watermilfoil (*Myriophyllum spicatum*) is present in the lower Kootenai River. The introduction of Eurasian watermilfoil can drastically alter a water body's ecology. Eurasian watermilfoil forms very dense mats of vegetation on the water-surface which can reduce oxygen levels in the water

and shade out of native aquatic vegetation. However, based on the habitat requirements of Eurasian watermilfoil, it is not expected to cover or colonize most of the river channel, with possible exceptions of near-shore or shallow, low velocity areas.

Based on the presence of non-native and invasive plant species, ***invasive plants have been identified as a limiting factor for riparian plant communities.***

2.6 Aquatic Habitat Limiting Factors

In developing the Kootenai River Habitat Restoration Project Master Plan, six Kootenai River aquatic focal species were considered: Kootenai sturgeon, burbot, bull trout, Columbia River redband trout, westslope cutthroat trout, and kokanee salmon. Each of these six aquatic focal species has been affected by anthropogenic activities within the river corridor and corresponding changes to the aquatic habitat.

This section provides a summary of the historical and current status of each species, an abbreviated overview of the life history of each species, and describes the species' habitat requirements, and the habitat factors thought to limit naturally self-sustaining populations of each species. Finally, this section includes a discussion of how broad ecosystem level changes have resulted in the current aquatic habitat limiting factors that are being addressed by this Master Plan.

Within the Kootenai River project area, the specific anthropogenic activities that have had the most direct effects on aquatic habitat include:

- River diking, flood control and channelization;
- Dam construction and operation;
- Land clearing, side channel and wetland filling for agriculture;
- Suburban and urban development;
- Road and railroad construction;
- Trapping and killing of beaver; and
- Introduction of non-native fish and plant species.

The primary effects of these activities to aquatic habitat include:

- Loss of backwater, side channel, and off-channel habitats resulting from river corridor simplification for flood control and agriculture;
- Disconnected floodplain tributaries due to infrastructure fish passage barriers;
- Floodplain tributary manipulation and land surface draining to facilitate agriculture;
- Altered hydrology influencing river hydraulics including hydraulic depth and water velocity, which influences fish movement and spawning migration timing;
- Dam operations influenced the thermal regime, which influences spawning migration timing and spawning success;

- Nutrient sequestration in Lake Koocanusa, disconnection of the river from the floodplain, and loss of riparian vegetation and wetlands disrupt primary productivity and undermine the basis of the food web;
- Coarse bedload trapping in Lake Koocanusa, lower shear stress and sediment competency in the project area, and fine sediment inputs affect sediment particle size distribution, availability of suitable spawning substrate, and embeddedness of coarse substrate;
- Absence of large wood from the channel and a diminished riparian forest have reduced large wood accumulations and loading to the river;
- Loss of wetland acres and corresponding wetland function including primary production have diminished potential sturgeon rearing habitat, wildlife and waterfowl habitat; and
- Aquatic habitat simplification due to introduced plant species (e.g., water milfoil) and encroachment of aquatic vegetation related to river management changes.

The above effects have led to the following primary factors limiting aquatic habitat in the Kootenai subbasin:

- Insufficient depth for Kootenai sturgeon migration;
- Insufficient velocity for successful Kootenai sturgeon spawning, incubation, and early life stages;
- Lack of coarse substrate for egg attachment;
- Lack of cover for juvenile fish;
- Lack of pool-riffle complexity;
- Simplified food web from lack of nutrients;
- Insufficient pool frequency;
- Lack of fish passage into tributaries;
- Lack of off-channel habitat for rearing; and
- Altered water quality.

These effects and factors are described in more detail in the following two sections, which link focal species to aquatic habitat limiting factors, and with altered ecosystem effects on aquatic habitat.

2.6.1 Overview Aquatic Focal Species

The following sections present information about the historical and current status, life histories, and habitat factors thought to limit naturally self-sustaining populations of the six aquatic focal species that were considered in developing this Master Plan (Kootenai sturgeon, burbot, bull trout, kokanee, Columbia River redband trout, and westslope cutthroat trout).

In addition to the above information, this section includes a summary table for each of the six species, of preferred habitat characteristics thought to meet the physical habitat requirements

and preferences for that species. This information was used to help guide the identification and conceptual development of restoration strategies and restoration treatments described in subsequent chapters of this Master Plan. The information presented in these tables was identified through a collaborative process incorporating expert opinions from regional co-managers and biologists. The process for developing and refining the information presented in these tables and additional information that was identified in the original tables is described in Appendix D along with additional details related to each of the tables.

2.6.1.1 Kootenai River White Sturgeon

The following information is drawn primarily from the Kootenai Subbasin Plan (KTOI and MFWP 2004); recent research papers and peer review publications; Kootenai Tribe publications, reports, and project proposals; and the Critical Habitat Revised Designation for the Kootenai River Population of the White Sturgeon (*Acipenser transmontanus*): Final rule (USFWS 2008).

Historical and Current Status

Relatively little is known about the historical status of Kootenai sturgeon in the Kootenai Subbasin (KTOI and MFWP 2004). Within the Kootenai River Subbasin, white sturgeon historically occupied an approximately 300 km (186.5 mile) reach, from Kootenai Falls (km 380.5) downstream to the north end of Kootenay Lake (km 17), and upstream into what is now Duncan Reservoir, as well all of the lake's West Arm (approx. 50 km or 31 miles) (KTOI and MFWP 2004).

Most white sturgeon populations in western North America are anadromous. Only the Kootenai River supports a naturally landlocked population. Kootenai Falls, Montana, and Bonnington Falls, British Columbia, are thought to have been migration barriers that isolated white sturgeon in a 270 km reach of the Kootenai River in Montana, Idaho, and British Columbia after recolonization following the most recent Pleistocene glacial period (Wisconsin), approximately 12,000 years BP (Alden 1953; Northcote 1973; Partridge 1983). During this glacial period, the outlet of the West Arm of Kootenay Lake was blocked by ice. This blockage formed glacial Lake Kootenay, which extended south into the area currently occupied by the Lake Pend Oreille system. It is believed that this connection with the large glacial lakes to the south permitted recolonization of the Kootenai region by fish species whose subsequent migration was blocked by Kootenai and Bonnington Falls (Alden 1953).

Consequently, this population adapted to specific local conditions in the Kootenai River headwater system. Kootenai sturgeon are active at cooler temperatures (Paragamian and Kruse 2001), spawn in different habitats (Paragamian et al. 2001), and have lower genetic diversity than other populations in western river systems (Bartley et al. 1985; Setter 1989; Setter and Brannon 1992; Anders et al. 2000; Anders 2002; Anders and Powell 2002; Rodzen et al. 2004). The range of this population extends from Kootenay Lake upstream 190 km to Kootenai Falls, but they are primarily found in the low gradient reach downstream from Bonners Ferry and in Kootenay Lake.

The Kootenai sturgeon was listed as endangered on September 6, 1994 (59 FR 45989) under the ESA and a recovery plan was completed in 1999 (UWFWS 1999). Within Canada, white sturgeon occur only in British Columbia and are divided into six populations, based on geography and genetics: the lower, mid and upper Fraser River, Nechako River, Columbia River, and Kootenay River. All populations were listed as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), but only the latter four are legally listed under the Canadian Species at Risk Act (SARA). Kootenay sturgeon are included in this group and are listed as

endangered under SARA. A recovery plan for white sturgeon is currently being developed under SARA and is scheduled for release in late 2009 or early 2010.

A hind-casted recruitment history generated with empirical data indicates that natural recruitment initially plummeting around 1950 to 1960 and has been largely suppressed or absent ever since. A few minor exceptions of limited year class production, but at levels insufficient for population viability and persistence, were observed during the early 1970s (Paragamian et al. 2005). Despite annual monitoring during recent decades, too few wild fish are captured to produce reliable recruitment estimates. The remnant population is currently distributed in a 250 km reach of the Kootenai River from the Bonners Ferry area downstream into and including all of Kootenay Lake.

Current population abundance is estimated to be approximately 500-1,000 adults, with the population decreasing by 50% in roughly 8 years, down from a reconstructed abundance estimate of approximately 8,000 adults in 1980 (Paragamian et al. 2005). The next 10-20 years will be a critical period for the future of sturgeon in the Kootenai River. There will be a significant bottleneck in spawner numbers as the wild population declines but hatchery fish are not yet mature. Kootenai sturgeon begin maturing around 30 years of age and so the first hatchery-reared fish from releases in the early 1990s will begin reaching maturity around the year 2020. In the interim, the wild population will reach critical low levels where normal population processes begin to break down on the final slide into extinction (the "extinction vortex" described by Gilpin and Soule 1986).

The Kootenai Tribe initiated a sturgeon conservation aquaculture program in 1989 as a stopgap measure designed to ensure preservation of an adequate demographic and genetic base for a healthy future population while adequate habitat restoration actions are implemented and have a chance to take effect. This conservation aquaculture program currently provides the only significant source of recruitment for the Kootenai River population.[4] The Tribe submitted a proposal to the NPCC (Kootenai River Native Fish Conservation Aquaculture Programs Master Plan) in July of 2009 proposing vital hatchery upgrades for the existing Tribal Sturgeon Hatchery near Bonners Ferry, and construction of a new hatchery facility near the confluence of the Moyie and Kootenai rivers that will provide additional rearing capacity for sturgeon and help to imprint fish on waters further upstream where suitable habitat currently is thought to exist.

[4] The Libby Dam BiOp specifically acknowledges the essential role of the Tribe's sturgeon aquaculture program in Reasonable and Prudent Action (RPA) Component 4, and directs the action agencies to provide funding to expand adult holding and spawning capability at the Tribal Sturgeon Hatchery (RPA Action 4.2) (USFWS 2006, clarified in 2008).

Life History

The longevity of Kootenai sturgeon (up to 100 years), lengthy maturation period (approximately age 30 in Kootenai females), and spawning periodicity (5 or more years in females) suggests that white sturgeon populations can persist through extended periods of unsuitable spawning conditions. This adaptation is particularly well suited to large, dynamic river systems where suitable combinations of habitat, temperature, and flow may not occur every year (Beamsderfer and Farr 1997).

Many Kootenai sturgeon are thought to spend part of their lives in Kootenay Lake in British Columbia and migrate upstream to spawn in the Kootenai River (USFWS 2008). Kootenai sturgeon have been described as having a unique two-step pre-spawning migration process, migrating first from the lower river and Kootenay Lake during autumn to staging reaches in the Kootenai River, then migrating in spring to the spawning reach near Bonners Ferry, Idaho (Paragamian et al. 2001; Paragamian et al. 2002).

White sturgeon are broadcast spawners and release demersal eggs (eggs that quickly sink to the bottom) that are initially adhesive upon exposure to water (Paragamian et al. 2001; Anders et al. 2002). Successful reproduction appears to depend on Kootenai sturgeon spawning over coarse bed material that supports egg viability, and where the free embryos that emerge from the eggs have appropriate habitat for development and protection from predators (USFWS 2008). Rocky substrates are thought to provide fixed surfaces for the attachment of the adhesive eggs during incubation and also to provide shelter for the "hiding phase" period following hatching in which free embryos seek cover from predators in the inter-gravel spaces (Brannon et al. 1985; Parsley et al. 2002).

Although there is little information specific to spawning substrates for Kootenai sturgeon, in other areas where white sturgeon are reliably reproducing and recruiting, the river bed at spawning sites typically consists of several miles of gravel, cobble, and boulder substrates that provide shelter and cover during this free embryo hiding phase (USFWS 2008).

White sturgeon spawn in fast-flowing water, and water velocity appears to act as a cue for spawning (USFWS 2008). White sturgeon spawning in fast-flowing water greater than or equal to 3.3 ft/s (1.0 m/s) may also experience reduced predation on eggs by limiting access of some predators to spawning and incubation areas (Brannon et al. 1985; Miller and Beckman 1996; Anders et al. 2002; Parsley et al. 2002).

Fast flowing waters also help to maintain the exposed rocky substrate essential for successful egg incubation and the free embryo hiding phase of the Kootenai sturgeon's reproduction cycle (USFWS 2008). Water depth is also thought to be an important factor in spawning site selection for the Kootenai sturgeon. The USFWS (2008) identified a minimum water depth of 23 ft (7 m) as a requisite for successful spawning in their 2008 revised critical habitat designation for Kootenai River white sturgeon.

Kootenai sturgeon appear to spawn within a fairly narrow range of water temperatures, from 47.3 to 53.6°F (8.5 to 12°C) (Paragamian et al. 2002). Paragamian and Wakkinen (2002) identify temperatures between 49.1 and 49.9°F (9.5 and 9.9°C), or roughly 50°F (10°C), as those at which spawning has the highest probability of occurring in the Kootenai River (USFWS 2008). Sudden drops of water temperature greater than 3.6°F (2.0°C) cause males to become reproductively inactive, thereby negatively affecting egg fertilization (Lewandowski 2004).

In the period following construction of Libby Dam, most Kootenai sturgeon appear to spawn over sandy substrates in the meander reach below Bonners Ferry (USFWS 2008). As previously described in this document, the meander reach has a low stream gradient, and substrates are composed primarily of sand and other fine materials overlying lacustrine clay (Barton 2003; Barton et al. 2004; USFWS 2008). Many of the eggs that are located in this reach are found drifting along the river bottom, covered with fine sand particles in sites without rocky substrate (Paragamian et al. 2001), and where mean water column velocities seldom exceeded 3.3 ft/s (1.0 m/s) (Paragamian et al. 2001; Barton et al. 2005; USFWS 2008).

Healthy sturgeon populations are generally characterized by age-frequency distributions that include large percentages of juveniles and sub-adults. Age and length distributions in such populations are stable and are skewed toward young fish. The lower Columbia River white sturgeon population is composed of > 95% sexually immature fish and this population also sustains an annual harvest of 50,000 fish (DeVore et al. 1999). The age and length of the Kootenai population are heavily skewed toward older fish; approximately 90% are age 25 and older (BPA 1997; Paragamian et al. 2005).

Habitat Requirements and Limiting Factors

In addition to demographic and genetic requirements, suitable physical habitat (abiotic) and ecological (biotic) conditions are required for viability and persistence of fish populations (KTOI and MFWP 2004). In particular, key ecological requirements for Kootenai River white sturgeon include, but are not limited to: suitable water quality, suitable hydraulic and thermal conditions, and predation and competition within ranges that collectively allow life cycle completion. Abiotic and biotic factors must be collectively suitable for completion of each specific life stage in the life cycle process, including: spawning, incubation, recruitment, juvenile and subadult rearing, sexual maturation and reproduction (KTOI and MFWP 2004).

Table 2-13 on the following page, presents a snapshot of preferred habitat characteristics based on empirical data, literature, and expert professional judgment (see Appendix D for additional detail). Consideration is given to habitat preference at each life stage and the relevant duration or seasonality for that life stage habitat requirement. Table 2-13 show the river reach used at each life stage, whether water temperature is a consideration, type of substrate preference, cover related factors, hydraulics, flow related considerations, and channel geometry considerations. Variables noted with an "X" in the table below are believed to be important to the specified Kootenai sturgeon life stage.

Table 2-13. Kootenai sturgeon life stage and preferred habitat characteristics based on empirical data, literature, and professional judgment.

Life Stage	Non-Reproductive Adult	Migrating Adult	Spawning Adult	Embryo	Free Embryo	Larva	Age 0+ Juvenile
Duration/ Seasonality	**Year Round**	**Jan to May**	**May to Jul**	**May to Jul**	**Jun to Aug**	**Jun to Aug**	**~ 65 days, Fall**
River Reach Used by Life Stage							
Canyon	X						
Braided Reach 1							
Braided Reach 2		X					
Straight Reach		X	X	X	X		
Meander Reach 1		X	X	X	X		
Meander Reach 2	X	X	X	X	X	X	
Tributaries							
Temperature							
Water Temperature			X		X		
Substrate							
Type of substrate			X	X	X		
Particle size distribution			X	X	X		
Longitudinal extent (length)			X	X	X		
Interstitial spaces				X	X		
Cover							
Depth/incident light					X		
Hydraulic cover			X		X	X	X
Large woody debris					X		
Bedforms				X			
Hydraulics							
Velocity variability	X	X	X	X	X	X	X
Boundary sheer stress				X	X		
Bedload transport				X			
Hydro operations							
Flow duration, frequency, and magnitude		X	X	X	X		
Channel geometry							
Habitat diversity	X			X			X
Depth	X	X			X		X
Channel stability				X	X		X
Floodplain							X
Connection with off-channel habitat						X	X
Connection with tributary habitat						X	X
Slope/gradient	X	X	X		X	X	X
Pool/riffle/run ratio; pool spacing	X	X	X		X	X	X

Self-sustaining natural populations of Kootenai sturgeon may be recruitment habitat limited, stock limited or both (Anders et al. 2002). River regulation and related and unrelated habitat alterations (e.g., changes in river morphology, loss of floodplain connectivity, loss of riparian habitat) have significantly compromised the quantity and quality of available habitat. Demographic stock limits and early life mortality also are limiting factors for Kootenai sturgeon. Early life mortality factors are thought to include: unfertilized eggs, egg suffocation, egg predation, predation of fry and fingerling, food limitations, and first over-winter mortality (Duke et al. 1999; USFWS 1999; Anders et al. 2002).

A number of factors are thought to account for the Kootenai sturgeon population's decline. However, at this time recruitment failure is generally recognized as the first bottleneck to Kootenai sturgeon survival and a range of recruitment failure hypotheses are most commonly cited as the reason for the Kootenai sturgeon's endangered status.

Decades of study have consistently indicated that recruitment failure most likely occurs during the embryo (incubation to early life) stages (Partridge 1983; Duke 1999; USFWS 1999; Paragamian et al. 2001; Anders et al. 2002; Paragamian et al 2005; KTOI 2008). Several hypotheses have been advanced to explain the relationships between river system changes and ongoing recruitment limitation and failure of Kootenai sturgeon.

These hypotheses are aggregated into time periods to delineate potential failure mechanisms prior to, and after, the completion of Libby Dam in 1972. Following is a summary of the major Kootenai sturgeon recruitment failure hypotheses.

Pre-Dam Hypotheses:

- Ecosystem Degradation Hypothesis – Recruitment failure is due to direct and indirect cascading effects of habitat alteration and loss of the natural floodplain (e.g., reduced nutrient and food availability, altered competition and predation, and reduced habitat quality and availability) (Anders et al. 2002).
- Imprinting/Homing Failure Hypothesis – Kootenai sturgeon no longer migrate upstream from Bonners Ferry into what appears to be suitable spawning, incubation, and early rearing habitats, because fish that historically spawned in these reaches (possibly as far upstream as the "sturgeon hole" at the base of Kootenay Falls) no longer exist.
- Riparian Habitat Loss Hypothesis – Widespread collapse of resident white sturgeon populations is due primarily to the loss of flooded riparian vegetation, which might provide critical incubation and early rearing conditions (Coutant 2004).
- Stock Limitation Hypothesis – Insufficient broodstock remain in the population to produce enough early life stages to compensate for total additive mortality in the post-development Kootenai River.

Post-Dam Hypotheses:

- Flow Reduction Hypothesis – Recruitment failure has resulted from the effects of flow regulation on spawning and early rearing conditions (Paragamian et al. 2001).
- Sand Invasion Hypothesis – Post-dam hydraulics and erosion contribute to sand invasion and accumulation in the braided and meander reaches (assumed to be detrimental to spawning, incubation, and possibly survival of free embryos).

- Scour Hypothesis – Spawning historically occurred in present spawning locations, however reduced flood flows and stream power resulting from operations of Libby Dam have generally failed to clean the hard substrates of sediment or sand cover as would have occurred under historical flow conditions.
- Upstream Migration Barrier Hypothesis – Some number of Kootenai sturgeon historically migrated upstream past Bonners Ferry to spawn in the braided and/or canyon reaches but post-dam habitat features now restrict or prohibit that historical upstream migration.
- Shifted Hydraulic Cue Hypothesis – Prior to levee construction and dam operation, hydraulic conditions that served as spawning cues may have existed further upstream (in the braided reach). Today, similar hydraulic conditions may now exist downstream (in the meander reach) in the current spawning reach due to channel constriction from the enhanced levees.
- Olfactory Spawning Location Shift Hypothesis – Pheromones and chemical odorants produced by females (held in captivity to spawn at the Tribal Sturgeon Hatchery near Bonners Ferry) are released into the river via hatchery effluent and may be influencing the location where Kootenai sturgeon currently spawn (i.e., influencing the sturgeon to not migrate further upstream to spawn).

The breadth of the recruitment failure hypotheses suggest the Kootenai sturgeon population is affected by multiple factors rather than a single or relatively small number of conditions. Due to the range of factors that have been linked to the declining population, addressing recruitment failure within the urgent time frame dictated by the population's decline will require an ecosystem-level approach that goes beyond merely modifying how Libby Dam is operated or focusing restoration actions on a single habitat component like depth, flow or spawning substrate.

2.6.1.2 Burbot

Information in this section is drawn primarily from the Kootenai Subbasin Plan (KTOI and MFWP 2004) and the Kootenai River/Kootenay Lake Burbot Conservation Strategy (KVRI 2005).

Historical and Current Status

Although the abundance of the West Arm Kootenay Lake burbot population prior to 1967 was estimated at 200,000 (Ahrens and Korman 2002), historical abundance of Kootenai River and Kootenai Basin burbot populations remains largely unknown (KVRI 2005).

Historically, burbot were distributed throughout the Kootenai subbasin; however, their natural distribution does not appear to have been contiguous. Although burbot existed in numerous adjacent watersheds in British Columbia (e.g., Arrow Lakes, Columbia River, Slocan Lake), burbot in the Kootenai system were historically isolated from those watersheds by the impassable Bonnington Falls, located downstream from Nelson, B.C. and now inundated between dams. This geographic isolation is thought to have occured post-glacially about 10,000-12,000 years ago (Alden 1953; Northcote 1973). Kootenai Falls in Montana was reported to be a natural upstream barrier to burbot passage. However, burbot and burbot fisheries historically existed upstream from Bonnington and Kootenai falls, and burbot can successfully move downstream through this upstream migration barrier. Numerous dams (e.g. Cora Linn, 1931; Duncan, 1967; and Libby, 1972) have further restricted the distribution and movements of Kootenai Subbasin burbot.

The largest burbot concentrations were believed to have inhabited the Balfour area near the inlet to Kootenay Lake's West Arm, and to a lesser extent seasonally inhabited the Kootenai River from Kootenay Lake to Kootenai Falls. Based on empirical reproductive data collected from fisheries, at least two distinct burbot stocks likely existed in Idaho and British Columbia. One was a lacustrine population in Kootenay Lake, the other a fluvial or adfluvial population in the Kootenai River. Temporal and geographic reproductive isolation appears sufficient to infer reproductive isolation (Martin 1976; Hammond and Anders 2003).

The Kootenai River and Kootenay Lake once provided popular and important sport, subsistence, and commercial burbot fisheries, and may have provided one of the most robust burbot fisheries in North America (Paragamian and Hoyle 2004). Tribal elders report that ling (burbot) were extremely abundant in the Kootenai River in Idaho and were a main staple for the Tribe in the late winter/early spring months. The Kootenai Tribe relied heavily upon this important subsistence fishery and tribal members were very adept at using weirs and traps.

In 1993, IDFG in coordination with other partners implemented a program to assess burbot abundance, distribution, size, reproductive success, and movement, and to identify factors limiting burbot in the Kootenai River in Idaho and British Columbia. A total of only 17 burbot were caught in 1993 (CPUE of one burbot/33 net days) and 8 in 1994 (CPUE of one burbot/111 net days). Only one burbot was captured between Bonners Ferry and the Montana border, with no evidence of reproduction in Idaho. Cooperative sampling in the British Columbia river reach suggested that burbot were only slightly more abundant in the lower river. Telemetry studies indicate that the existing population is transboundary (Paragamian 2000).

When it became clear that the burbot fishery was at risk of failing, regional managers took measures to reduce exploitation by reducing creel limits and implementing fishery closures, but none of these measures restored the fishery (Paragamian et al. 2000). Examples of stock rebound in overexploited burbot populations with fishery restrictions or closures have been documented, although habitat was generally intact in such cases (Paragamian et al. 2000). Since they began monitoring the movement, habitat use, and spawning behavior of burbot in 1993, IDFG has not found evidence of successful spawning or recruitment in Idaho.

Kootenai River native burbot were proposed for ESA listing in 2000. However, the USFWS determined that the population was not eligible for listing because it does not comprise a Distinct Population Segment. Rather than listing burbot as threatened or endangered under the ESA, the Kootenai Valley Resource Initiative Burbot Subcommittee[5], in coordination with the USFWS and other stakeholders proposed the Kootenai River drainage as a "pilot project" to develop, implement, and evaluate a Conservation Strategy for Lower Kootenai River Burbot in lieu of an ESA listing.

[5] The Kootenai Valley Resource Initiative (KVRI) was formed under a Joint Powers Agreement (JPA) between the Kootenai Tribe, the City of Bonners Ferry, and Boundary County, dated October 2001. Under the JPA, the KVRI is empowered to foster community involvement and development to restore and enhance the resources of the Kootenai Valley. The KVRI membership and its partners include the Kootenai Tribe, who initiated the process, federal, state, and provincial fisheries and water regulatory agencies, regional city and county governments, private citizens, landowners, environmental advocacy groups, and regional representatives of business and industry. The KVRI Burbot Subcommittee was formed as a subset of the KVRI to pursue coordinated burbot conservation and management.

Currently, most burbot in the Kootenai River Subbasin exist in three separate lake systems: Koocanusa Reservoir in Montana, Duncan Reservoir in B.C., and Trout Lake in B.C. (figure 4.17). Little is known about the distribution of burbot in Koocanusa Reservoir and the upper Kootenai River upstream from the lake. Distribution of burbot in Duncan Reservoir and Trout Lake was addressed in Spence (2000), Neufeld and Spence (2001), Spence and Neufeld (2002), and Baxter et al. (2002a, 2002b). In addition, Bisset and Cope (2002) indicated that a viable burbot population exists in Moyie Lake based on a 2002 creel survey (KTOI and MFWP 2004). Kootenai River burbot are considered functionally extinct, a status that occurs when populations are so small they are unable to recover on their own, even if suitable habitat conditions exist or are restored (Paragamian et al. 2000; KVRI 2005).

Burbot is a culturally significant species to the Kootenai Tribe. As mentioned previously, the Tribe is submitting a proposal to the NPCC in July 2009 (Kootenai River Native Fish Conservation Aquaculture Programs Master Plan), to construct a new hatchery at the confluence of the Moyie and Kootenai rivers (Twin Rivers Hatchery) that in addition to providing for upgraded and expanded sturgeon conservation aquaculture facilities, would allow the Tribe to implement a conservation aquaculture program to reintroduce burbot into the lower Kootenai River and begin rebuilding the population using genetically and behaviorally similar stock from within the subasin (from Moyie Lake in British Columbia).

Life History

The burbot is the only true freshwater representative of the cod family, Gadidae (McPhail and Paragamian 2000). It normally completes its lifecycle in freshwater and rarely enters the sea, however, burbot have been documented in estuaries and brackish lagoons (Preble 1908, Percy 1975, Pulliainen et al. 1992).

Burbot that occur in the Kootenai River basin exhibit three life history strategies in several isolated groups. The first life history strategy is represented by the lower Kootenai River burbot population, which spends a portion of its life in the South Arm of Kootenay Lake, British Columbia, and then migrates up the Kootenai River during the winter months to spawn in the mainstem river or tributary streams in British Columbia or Idaho (adfluvial life form) (KTOI and MFWP 2004).

The second life history strategy is represented by burbot occurring further upstream in the Kootenai River above Kootenai Falls, which have a fluvial (riverine) life history (Paragamian et al. 1999). That is, they migrate within the river and to tributary streams for spawning. Burbot that occur in Lake Koocanusa are also considered to be fluvial, because they evolved with a fluvial life history prior to the construction of Libby Dam. This population is thought to be fluvial because it is currently unclear how readily burbot populations adopt a different life history strategy when faced with changing environmental conditions, and it does not appear appropriate to compare naturally occurring adfluvial populations of burbot to burbot that now have some adfluvial characteristics as the result of a human-created reservoir (KTOI and MFWP 2004).

The third life history strategy is represented by the only known lacustrine population in Kootenay Lake, which occurs in the North Arm of Kootenay Lake (Spence 1999). Prior to dramatic declines of burbot in Kootenay Lake, a population was believed to have spawned at the inlet of the West Arm of Kootenay Lake, but this population has completely collapsed and is now believed to be extirpated (Spence 1999; Baxter et al. 2002; Paragamian, pers. comm., 2000 from KTOI and MFWP 2004).

Burbot are cold water spawners during highly synchronized communal spawning periods, with reported optimal spawning and incubation temperatures from 0 to 4 °C (Bjorn 1940; Andersson 1942; Clemens 1951b; McCrimmon and Devitt 1954; Lawler 1963; Meshkov 1967; Chen 1969; Johnson 1981; Kouril et al. 1985; Sandlund et al. 1985; Breeser et al. 1988; Boag 1989; Arndt and Hutchison 2000; Evenson 2000). Eggs are thought to drift in the water column and lodge in interstitial spaces in the substrate.

Burbot life span varies geographically, and northern populations generally contain older fish than southern populations (McPhail and Paragamian 2000). Maximum ages recorded in northern populations ranged from 20 to 22 years (Hatfield et al. 1972; Nelichik 1979; Guinn and Hallberg 1990).

The Kootenai River Burbot Conservation Committee's Conservation Strategy (http://www.kootenai.org/documents/FinalBurbotCS-3-2-05.pdf) provides a comprehensive review of burbot life history and habitat requirements and behaviors of all burbot life stages (KVRI 2005).

Habitat Requirements and Limiting Factors

In most waters of the Kootenai subbasin, with the possible exception of Duncan and Trout lakes in British Columbia, and Montana waters, the extremely low numbers of remaining burbot appear to currently pose a greater risk to their continued existence than does any combination of key ecological correlates or non-demographic limiting factors (KTOI and MFWP 2004).

Burbot spawn in rivers, streams, and lakes. In rivers, burbot spawn in low velocity areas, in main channels, or in side channels behind deposition bars (Breeser at al. 1988, Sorokin 1971). Preferred river substrate appears to be fine silt, sand, or gravel. In lakes, spawning usually occurs over near-shore shallows (1.5-10 m deep) or over shallow offshore reefs and shoals (Clemens 1951b, McCrimmon 1959, Johnson 1981, Boag 1989). However, there is some indication of spawning in deep water in the Great Lakes (Clemens 1951b). Lake substrate is usually sand, gravel, or cobbles and is relatively free of silt (McCrimmon and Devitt 1954, Chen 1969, Sorokin 1971, Boag 1989).

Paragamian (1995) described habitat in the Kootenai and Goat rivers used during the spawning period. In the Kootenai River, burbot were rarely found in less than 6 meters of water, but maximum depth ranged from 1-30 meters where fish were sampled. Substrate in most locations was composed of silt or sand. In the lower Goat River, where spawning was thought to have occurred, the habitat was described as silt and sand substrate with water depths less than 3 meters. In the North Arm of Kootenay Lake, burbot spawning was associated with cobble and boulder substrate in 0.5 to 1.5 meter depths (Spence 1999). In Duncan Reservoir, Spence and Neufeld (2002) observed a concentration of burbot during the spawning period at the mouth of Glacier Creek. In Trout Lake, Baxter et al. (2002b) observed fish concentrations at the mouths of small creeks entering the lake; there was no observed utilization of the larger tributaries entering the lake. During winter and early spring when Trout Lake was frozen, these creek mouths were the only ice-free areas.

The Kootenai Subbasin Plan (2004) states that it seems likely that the existing post-development, post-dam environmental conditions can provide little restorative value to these remnant stocks or populations; and that restoration of native burbot populations to include natural recruitment and stable size and age class structures is unlikely to occur without improvement of current ecological conditions and restoration of ecological functions.

Burbot managers and researchers, with help from Libby Dam operators, have tried experimental alterations of Libby Dam discharge operations in order to help restore natural production. Monitoring of initial experimental discharge reductions during the historical burbot spawning season (December-March) failed to provide evidence of any natural spawning or recruitment in the Idaho portion of the Subbasin (KTOI and MFWP 2004). This may be due to extreme stock limitation (i.e., too few burbot may be left to measure a response to experimentally reduced discharge regimes, or to provide observable experimental treatment effects), or to other effects. However, Kozfkay and Paragamian (2002) found drought conditions of the winter of 2000-2001 provided ideal conditions for burbot movement and documented spawning of burbot through weight changes in recaptured fish and a limited number of postspawn biopsies.

Table 2-14 presents a summary of preferred habitat characteristics based on empirical data, literature, and expert professional judgment (see Appendix D for additional detail). Consideration is given to habitat preference at each life stage and the relevant duration or seasonality for that life stage habitat requirement. Variables noted with an "X" in the table below are believed to be important to the specified burbot life stage.

Table 2-14. Burbot life stage and preferred habitat characteristics based on empirical data, literature, and professional judgment.

Life Stage	Non-Reproductive Adult	Migrating Adult	Spawning Adult	Embryo (N/A)	Free Embryo (N/A)	Larva	Age 0+ Juvenile
Duration/ Seasonality	**Year Round**	**Fall to Winter**	**Dec to May**	**N/A**	**N/A**	**Jun to Aug**	**~ 65 days, Fall**
River Reach Used by Life Stage							
Canyon	X	X	X				
Braided Reach 1							
Braided Reach 2							
Straight Reach		X	X				
Meander Reach 1		X	X				
Meander Reach 2							
Tributaries		X	X			X	X
Temperature							
Water Temperature	X	X	X			X	X
Substrate							
Type of substrate		X	X			X	
Particle size distribution			X			X	X
Longitudinal extent (length)			X				
Interstitial spaces						X	X
Cover							
Depth/incident light	X	X	X				
Hydraulic cover			X			X	X
Large woody debris	X	X	X			X	X
Bedforms							
Hydraulics							
Velocity variability	X	X	X			X	X
Boundary sheer stress							
Bedload transport							

Table 2-14. Burbot life stage and preferred habitat characteristics based on empirical data, literature, and professional judgment.							
Life Stage	**Non-Reproductive Adult**	**Migrating Adult**	**Spawning Adult**	**Embryo (N/A)**	**Free Embryo (N/A)**	**Larva**	**Age 0+ Juvenile**
Duration/ Seasonality	**Year Round**	**Fall to Winter**	**Dec to May**	**N/A**	**N/A**	**Jun to Aug**	**~ 65 days, Fall**
Hydro operations							
Flow duration, frequency, and magnitude		X	X				X
Channel geometry							
Habitat diversity	X					X	X
Depth	X	X	X				
Channel stability	X	X	X			X	X
Single vs. braided, meander	X	X	X				
Connection with off-channel habitat						X	X
Connection with tributary habitat	X	X	X				
Slope/gradient	X	X	X			X	X
Pool/riffle/run ratio; pool spacing	X	X	X				

At this point, no single factor appears responsible for the collapse of the Kootenai River burbot population. Rather, a combination of overharvest, habitat loss and alteration due to levee constructions, impoundment, river regulation, and additive ecosystem degradation appears have contributed to burbot population loss through recruitment limitation and failure (KVRI 2005).

The Kootenai Subbasin Plan identifies the following possible interrelated Kootenai subbasin conditions that likely resulted in limiting factors that have contributed to the collapse of the Kootenai native burbot population:

- Increased winter river flow and velocities;
- Increased winter water temperature;
- Degradation of floodplain tributary channels or tributary disconnection from the river;
- Loss and degradation of in-river and off-channel habitats;
- Reduction in nutrient and food availability and biological productivity at all trophic levels;
- Kootenay Lake flood control;
- Overharvest; and
- Altered ecological community composition.

Conservation strategies for burbot identified in the KVRI burbot Conservation Strategy (2005) and the Kootenai Subbasin Plan include: habitat restoration, flow and temperature manipulation, spring management of Kootenay Lake levels, nutrient restoration, and use of donor stocks, captive broodstock and conservation aquaculture.

2.6.1.3 Bull Trout

Information in this section is drawn almost entirely from the Kootenai Subbasin Plan (KTOI and MFWP 2004).

Historical and Current Status

Historically, bull trout were one of six native salmonid species distributed throughout the Kootenai River drainage (KTOI and MFWP 2004).

The historical importance of Kootenai Falls as a barrier to fish movement is unknown, although recent radio telemetry information indicates that this series of falls is traversed by adult bull trout at certain flows. If this was the case, this bull trout population likely included migratory fish from Kootenay Lake in British Columbia as well as Kootenai River fish, which may have moved freely throughout the drainage (KTOI and MFWP 2004). Resident bull trout may have been present (KTOI and MFWP 2004). If upstream passage did not occur over Kootenai Falls, the bull trout population in the Kootenai Drainage upstream was isolated at this point, likely resulting in one-way gene flow downstream (KTOI and MFWP 2004). Libby Dam is currently a barrier blocking upstream migration as there are no fish ladders at the dam. Therefore, any bull trout that are entrained at Libby dam cannot return upstream to their natal streams to spawn.

Little quantitative information exists regarding historical bull trout abundance downstream from Kootenai Falls in Montana or Idaho (KTOI and MFWP 2004). The valleys of the lower Kootenai were developed for agriculture during the late 19th and early 20th century, and the habitat for bull trout was negatively impacted prior to the collection of substantive fishery data. The lack of information is a major gap in our knowledge of the drainage (KTOI and MFWP 2004). Suckley (1861) reported collecting a bull trout from the Kootenay River, but the exact location of this collection is unknown.

Bull trout are currently widely distributed through the lower Kootenai River, from Libby Dam downstream to Kootenay Lake in British Columbia (KTOI and MFWP 2004). Spawning and rearing by migratory adults occur in tributaries draining portions of British Columbia, Idaho, and Montana. These migratory fish spend their adult lives in Kootenay Lake or the Kootenai River (KTOI and MFWP 2004).

In the final ESA listing rule for bull trout, five subpopulations were recognized within the Kootenai River Subbasin (USFWS 1998). These included three portions of the mainstem system: 1) Upper – upstream from Libby Dam, 2) Middle – from Libby Dam downstream to Kootenai Falls, and 3) Lower – downstream from Kootenai Falls through Idaho to the United States/Canada border.

The two disconnected subpopulations (referred to as disjunct by the Montana Bull Trout Scientific Group), in Bull Lake and Sophie Lake, were considered separate subpopulations (KTOI and MFWP 2004). At the time of listing, all Kootenai River bull trout subpopulations were considered to have unknown status and population trend, and the Sophie Lake subpopulation was considered to be at risk of stochastic extirpation due to its single spawning stream and small population size.

The U.S. Forest Service lists bull trout as a sensitive species, primarily to emphasize habitat protection. The Idaho Panhandle National Forests have named bull trout as Management

Indicator Species (MIS) in their Forest Plan to guide stream and riparian management and to monitor progress toward achieving Forest Plan objectives (KTOI and MFWP 2004).

In British Columbia, bull trout are listed as an intermediate priority candidate species (COSEWIC 2003). The British Columbia Conservation Data Centre has blue-listed bull trout in British Columbia, which means they are a species considered to be vulnerable or of special concern because of characteristics that make them particularly sensitive to human activities or natural events (BC Ministry of Sustainable Resource Management 2003).

The Kootenai Tribe consider bull trout a sensitive species and an important cultural resource.

Life History

Bull trout populations in the Kootenai may exhibit one of three life history forms: resident, fluvial, or adfluvial. Resident bull trout generally spend their entire life cycle in small headwater streams. Fluvial and adfluvial bull trout spawn in tributary streams where the juveniles rear from one to four years before migrating to either a river system (fluvial) or a lake/reservoir system (adfluvial) where they grow to maturity (Fraley and Shepard 1989; KTOI and MFWP 2004). All three life history forms are present in the Kootenai subbasin.

Adfluvial bull trout mature at four to seven years of age and may spawn every year or in alternate years (KTOI and MFWP 2004). Adfluvial fish grow larger in size and have higher average fecundities than fluvial or resident stocks.

Bull trout are fall spawners, typically migrating to spawning areas during August and early September, primarily in third and fourth-order streams. In some systems, bull trout have been observed moving into spawning tributaries during high spring runoff, giving them access to habitat that becomes inaccessible later in the year when flows are lower (Pratt and Huston 1993).

Eggs hatch after 100 to 145 days of incubation (Heimer 1965; Allan 1980; Weaver and White 1984). Fry remain in the gravel for another 65 to 90 days until yolk sac absorption is complete; parr marks develop and actual feeding begins while fry are still in the gravel. Fry emerge from gravels in early spring, usually April (Shepard et al. 1984). Bull trout generally reach lengths of about one inch (25 to 28 mm) before filling their air bladders and emerging from the stream bed (Shepard et al. 1984).

Juvenile bull trout live near the stream bottom for the first two years of life using pockets of slow water within swift stream reaches (Pratt 1984b; Shepard et al. 1984). Unembedded cobble and boulders, and dispersed woody debris are commonly used forms of cover. Juvenile bull trout typically rear close to spawning areas, usually in middle to upper stream reaches. Juvenile bull trout may migrate from natal streams during the summer or fall of their second or third growing season (Ringstad 1976; Oliver 1979; Shepard et al. 1984; Pratt 1996). Time spent migrating from natal streams to the Kootenai River has not been studied, but Goetz (1991) reported that juvenile out migrants move downstream quickly in other stream systems (KTOI and MFWP 2004).

Habitat Requirements and Limiting Factors

Bull trout are considered good indicators of aquatic ecosystem health. They have relatively strict habitat requirements. They require high quality, cold water; high levels of shade, undercut banks, and woody debris in streams; abundant gravel in riffles with low levels of fine sediments;

stable, complex stream channels; and connectivity among and between drainages (USFWS 2002). These requirements make them a good indicator of the health of an aquatic environment. Because bull trout use the entire aquatic system in the subbasin, impacts in any single component can potentially affect bull trout (KTOI and MFWP 2004).

Table 2-15 presents a summary of preferred habitat characteristics based on empirical data, literature, and expert professional judgment (see Appendix D for additional detail). Consideration is given to habitat preference at each life stage and the relevant duration or seasonality for that life stage habitat requirement. Variables noted with an "X" in the table below are believed to be important to the specified bull trout life stage.

Table 2-15. Bull trout life stage and preferred habitat characteristics based on empirical data and literature.

Life Stage	Migrating Adult	Spawning Adult	Embryo	Alevins	Fry	Fingerling	Juvenile
Duration/ Seasonality	**Summer-Fall**	**Sep to Oct**	**Winter**	**Early Spring**	**Spring**	**Summer-Winter**	**Year-round**
River Reach Used by Life Stage							
Canyon	X						X
Braided Reach 1	X						X
Braided Reach 2	X						X
Straight Reach	X						X
Meander Reach 1	X						X
Meander Reach 2	X						X
Tributaries	X	X	X	X	X	X	X
Water Quality							
Water temperature	X	X	X	X	X	X	X
Dissolved oxygen	X	X	X	X	X	X	X
Turbidity/suspended sediment	X	X	X	X	X	X	X
Nutrient availability	X	X	X	X	X	X	X
Other WQ factors	X	X	X	X	X	X	X
Substrate							
Type of substrate	X	X	X	X	X	X	X
Particle size distribution	X	X	X	X	X	X	X
Longitudinal extent (length)		X	X	X			X
Interstitial spaces		X	X	X	X	X	X
Cover							
Depth/incident light	X	X			X	X	X
Canopy/shade	X					X	X
Undercut banks	X	X			X	X	X
Hydraulic cover	X					X	X
Large woody debris	X	X			X	X	X
Bedforms	X						
Hydraulics							
Velocity	X	X	X	X	X	X	X
Velocity variability	X	X	X	X	X	X	X
Boundary sheer stress	X	X	X	X	X	X	X
Lateral sheer	X	X	X	X	X	X	X

Table 2-15. Bull trout life stage and preferred habitat characteristics based on empirical data and literature.							
Life Stage	**Migrating Adult**	**Spawning Adult**	**Embryo**	**Alevins**	**Fry**	**Fingerling**	**Juvenile**
Duration/ Seasonality	**Summer-Fall**	**Sep to Oct**	**Winter**	**Early Spring**	**Spring**	**Summer-Winter**	**Year-round**
Roughness	X		X	X	X	X	X
Bedload transport	X	X	X	X	X		X
Hydrology							
In-channel groundwater/surface water interaction			X				
Flow duration, frequency, and magnitude	X	X	X	X	X	X	X
Channel geometry							
Habitat diversity	X						X
Depth	X	X			X	X	X
Channel stability	X	X					
Single vs. braided/meander	X	X			X	X	X
Connection with off-channel habitat					X	X	X
Connection with tributary habitat	X	X			X	X	X
Slope/gradient	X	X	X	X	X	X	X
Pool/riffle/run ratio; pool spacing	X	X			X	X	X

Bull trout in the Kootenai River have been impacted by habitat degradation, altered hydrology and river hydraulics related to flow ramping, habitat fragmentation (e.g., tributary barriers, dams) and degradation (e.g. agriculture and logging), gas supersaturation due to reservoir spill, and a diminished prey base related to suppressed kokanee production caused by nutrient depletion. This risk to the bull trout population is elevated due to the small number of available core areas (Quartz, Pipe and Libby Creek drainages) available due to fragmentation caused by Libby Dam. Dam operations are considered a very high risk to the continued existence of the Kootenai subbasin population of bull trout (KTOI and MFWP 2004).

The Kootenai Subbasin Plan (2004) states that habitat attributes considered most important to resident salmonids (when averaged across all HUCs) are high temperature, riparian conditions channel stability, and fine sediment, in that order. In the regulated mainstem, they are altered flows, riparian condition fine sediment and channel stability (KTOI and MFWP 2004).

2.6.1.4 Kokanee

Information in this section is drawn primarily from the Kootenai Subbasin Plan (KTOI and MFWP 2004).

Historical and Current Status

Pre-dam population levels of kokanee are unknown. There are currently six populations of kokanee in the Kootenai River Subbasin in Idaho, Montana, and British Columbia. Native

kokanee in the Kootenai subbasin are found downstream from Kootenai Falls in Montana. All populations upstream from Libby Dam, in Lake Koocanusa and elsewhere were introduced, and are not considered native.

Kokanee are the non-anadromous or land locked form of sockeye salmon found in the large lake systems throughout the entire Columbia River Basin (McPhail and Carveth 1992). In British Columbia they are indigenous in all drainages except the Peace River drainage. They overlap the distribution of sockeye salmon in British Columbia, but are also found in lakes that are now cut off to sockeye as a result of human interventions, the best example being the upper Columbia River system. Morphologically, kokanee and sockeye are identical and are considered to be the same species (*Onchorynchus nerka*) (KTOI and MFWP 2004).

Kokanee in the Kootenai subbasin have been isolated for at least 10,000 years due to a natural barrier located on the lower Kootenay River at Bonnington Falls approximately 20 km upstream from the confluence with the Columbia River (Northcote 1973). Discrete natural populations are currently found in Trout, and Kootenay lakes, and Duncan reservoir, whereas the Moyie and Koocanusa reservoir kokanee populations are naturalized from hatchery introductions.

Duncan Dam, which was completed in 1967, isolated Kootenay Lake kokanee from those inhabiting the Duncan Reservoir. A major waterfall on the lower Moyie River in Northern Idaho prevents fish movement to Moyie Lake. Kootenai Falls in Montana serves as a barrier to all upstream movement of kokanee. However, kokanee introductions into the Lake Koocanusa in the 1970s have resulted in an extension of their distribution to the very upper reaches of the Upper Kootenay River and tributaries.

Native kokanee salmon runs in lower Kootenai River tributaries in Idaho have experienced dramatic population declines during the past several decades (Ashley and Thompson 1993; Partridge 1983). The kokanee that historically spawned in these tributaries inhabited the South Arm of Kootenay Lake in British Columbia. Native kokanee are considered an important prey item for white sturgeon and also provided an important fishery in the tributaries of the lower Kootenai River (Partridge 1983; Hammond, J., B.C. MELP, per. comm. 2000 from KTOI and MFWP 2004).

Kokanee runs into North Idaho tributaries of the Kootenai River that numbered into the thousands of fish as recently as the early 1980s have now become "functionally extinct" (Anders 1993; KTOI, unpublished data). Since 1996, visual observations and redd counts in five tributaries found no spawners returning to Trout, Smith, and Parker Creeks, while Long Canyon and Boundary Creeks had very few kokanee returns.

A series of kokanee stream restoration activities lead by the Kootenai Tribe appear to be contributing to recent increases in spawner counts in Long Canyon and Parker creeks (KTOI and MFWP 2004). More recently, kokanee eyed-eggs have been planted in various South Arm and Kootenai River tributaries within Idaho and British Columbia in an effort to stimulate natural production. The Kootenai Tribe began planting eyed-eggs (Meadow Creek stock, North Arm Kootenay Lake) in Idaho tributaries in 1997. The number of eggs planted each year depended on the availability of Meadow Creek broodstock. For example, no eggs were available for out-planting during 2000 to 2002. The number of eyed-eggs planted increased significantly beginning in 2003. Progeny from the 2003 plant were expected to return to spawn in 2007. Although kokanee eggs have been planted in South Arm (British Columbia) tributary streams as early as 1929 (Andrusak et al. 2004), recent efforts were not initiated until 2005. Adults resulting

from these recent egg plants are not expected to return to British Columbia streams until 2009 (P. Anders, Cramer Fish Sciences, personal communication, 2009).

The 2007 return was the first year expected from the larger eyed-egg plants initiated in 2003, and likely benefited from South Arm and Kootenai River nutrient additions. In 2004, about twice as many eggs were planted in Idaho tributaries, and a corresponding increase in spawners was observed in 2008 (P. Anders, Cramer Fish Sciences, personal communication, 2009).

Life History

Most kokanee populations found in the large lakes of British Columbia migrate up tributary streams to spawn, usually in September. Information and documentation of shore spawning kokanee in British Columbia has been quite limited, but recent investigations have identified several shore spawning populations that were previously unknown.

Kokanee prefer low gradient streams for spawning, and while some will utilize streams that have gradients of 1% to 5%, they generally will select the lower gradient sites. Most often kokanee that ascend larger rivers will utilize the side channels for spawning with the exception being in a regulated stream system where spawning coincides with lower flows, e.g., Mabel Lake kokanee in the middle Shuswap River (KTOI and MFWP 2004).

Most kokanee in the southern interior large lakes such as Arrow, Okanagan, Slocan and Kootenay spawn from late August to early October with the peak of spawning around the third week of September. Kokanee in the West Arm of Kootenay Lake spawn quite early, commencing in mid-August and completed by mid-September. The South Arm of Kootenay Lake kokanee spawn earlier than their northern counterparts, usually from mid-August to mid-September whereas Lardeau River kokanee spawn in the latter part of September until late October (KTOI and MFWP 2004).

It is generally understood that kokanee fry move immediately to open waters after emergence from spawning areas, whether from tributaries or beach spawning sites. This rapid dispersion of fry to the open water is consistent with many anadromous sockeye populations. There are well-documented examples of sockeye fry undergoing rapid and intricate dispersion patterns into nursery lakes upon emergence (McCart 1967; McDonald and Hume 1984).

Once in the limnetic area, both kokanee and sockeye feed primarily on zooplankton, especially copepods and cladocerans (KTOI and MFWP 2004).

The West Arm of Kootenay Lake kokanee behave differently than most studied kokanee populations. The fry move from the natal streams and associate themselves with the shoreline for the first two months before moving to open water within the West Arm (KTOI and MFWP 2004). Benthic organisms, aquatic insects and littoral zooplankton are consumed in addition to pelagic zooplankton. As the summer advances, the fry move off shore and utilize macrozooplanktors and mysids (KTOI and MFWP 2004).

Kokanee likely provided forage for much of the historically present lower Kootenai River fish assemblage. Adfluvial rainbow trout, bull trout, sturgeon and burbot that occupied Kootenay Lake certainly relied on kokanee for forage (KTOI and MFWP 2004). It is most likely that Kootenai burbot and sturgeon also targeted on spawning kokanee when they migrated into tributary streams in the Kootenai Basin.

Kootenai sturgeon in Kootenay Lake appear to move to the mouth of the Lardeau River to prey on staging kokanee prior to their upriver spawning migration. Loss of these spawning migrations as a potential food source very likely had significant impacts on these two species. Moreover, kokanee were an important component of the diet of Native Americans and First Nations peoples in the U.S. and Canada. This traditional food source remains culturally important to the Kootenai Tribe of Idaho and the Lower Kootenay First Nation Bands in southeastern British Columbia (KTOI and MFWP 2004).

Habitat Requirements and Limiting Factors

The magnitude of the effects of Duncan Dam and Libby Dam on kokanee populations is substantial. These impacts included: changes in physical habitat; spawning, incubation and early rearing success; and nutrient and food availability for later rearing and maturation (KTOI and MFWP 2004; Ericksen et al. 2009).

Table 2-16 presents a summary of preferred habitat characteristics based on empirical data, literature, and expert professional judgment (see Appendix D for additional detail). Consideration is given to habitat preference at each life stage and the relevant duration or seasonality for that life stage habitat requirement. Variables noted with an "X" in the table below are believed to be important to the specified kokanee life stage.

Table 2-16. Kokanee life stage and preferred habitat characteristics based on empirical data and literature.

Life Stage	Migrating Adult	Spawning Adult	Embryo	Alevins	Fry	Fingerling	Juvenile
Duration/ Seasonality	**Late Summer to early Fall**	**Mid-Aug to Sep**	**Winter**	**Early Spring**	**Spring**	**Summer to Winter**	**Year-round**
River Reach Used by Life Stage							
Canyon	X						
Braided Reach 1	X						
Braided Reach 2	X						
Straight Reach	X						
Meander Reach 1	X						
Meander Reach 2	X						
Tributaries	X	X	X	X	X	X	X
Water Quality							
Temperature	X	X	X	X	X	X	X
Dissolved oxygen	X	X	X	X	X	X	X
Turbidity/suspended sediment	X	X	X	X	X	X	X
Nutrient availability	X	X	X	X	X	X	X
Other WQ factors	X	X	X	X	X	X	X
Substrate							
Type of substrate		X	X	X	X	X	X
Particle size distribution		X	X	X	X		
Longitudinal extent (length)		X	X	X			
Interstitial spaces		X	X	X			
Cover							
Depth/incident light	X	X			X	X	X
Large woody debris					X		

Table 2-16. Kokanee life stage and preferred habitat characteristics based on empirical data and literature.							
Life Stage	**Migrating Adult**	**Spawning Adult**	**Embryo**	**Alevins**	**Fry**	**Fingerling**	**Juvenile**
Duration/ Seasonality	**Late Summer to early Fall**	**Mid-Aug to Sep**	**Winter**	**Early Spring**	**Spring**	**Summer to Winter**	**Year-round**
Hydraulics							
Velocity	X	X	X	X	X	X	X
Velocity variability	X	X	X	X	X	X	X
Boundary sheer stress	X	X	X	X	X	X	X
Lateral sheer	X	X	X	X	X	X	X
Hydrology							
In-channel groundwater/surface water interaction			X	X			
Flow duration, frequency, and magnitude		X	X	X	X		
Channel geometry							
Depth		X			X		
Channel stability		X					
Single vs. braided, meander		X			X		
Connection with off-channel habitat					X		
Connection with tributary habitat		X			X		
Slope/gradient		X	X	X	X		
Pool/riffle/run ratio; pool spacing					X		

Based on an analysis of stream habitat conducted as part of the Kootenai Subbasin Planning effort in 2004, of the eleven stream habitat attributes considered key to resident salmonids, the most degraded for kokanee trout in tributaries in the U.S. portion of the subbasin (when averaged across all the tributary HUCs) are pollutants, altered thermal regime, channel stability, and fine sediment, in that order. In the regulated mainstem they are altered hydrograph, altered thermal regime, fine sediment, and channel stability (KTOI and MFWP 2004).

2.6.1.5 Columbia River Redband Trout

The following sections summarize Columbia River redband trout (redband trout) historical and current population status, habitat requirements, and limiting factors affecting the population. The information in this section focuses primarily on the Kootenai River and Kootenay Lake population. Most of the following information is taken directly from the Kootenai River Subbasin Assessment (KTOI and MFWP 2004).

Historical and Current Status

Redband trout of the Columbia River basin (*Oncorhynchus mykiss gairdneri*) are a subspecies of the rainbow trout evolutionary line (*Oncorhynchus mykiss*) native to the Fraser River Basin and Columbia River Basin east of the Cascade Mountains to barrier falls on the Pend Oreille, Spokane,

Snake and Kootenai rivers (Allendorf et al. 1980; Behnke 1992). They are also native to Kootenay Lake, British Columbia and the Kootenai River in Idaho and Montana. For years, the upper distribution of redband trout in the Columbia River Basin was believed to extend upstream to Kootenai Falls, which was considered a barrier falls (Allendorf et al. 1980; Chapman and May 1986), but it is now thought the barrier was not Kootenai Falls, but one that existed in geologic time near the present day Libby Dam or Fisher River (Hensler et al. 1996). Genetic surveys also indicate that Columbia River redband trout were not just found in headwater reaches as they are now, but were native to low-gradient valley-bottom streams throughout the Kootenai River drainage (Muhlfeld 1999). This range contraction may have occurred in response to past and present land use and fishery management practices.

Region 1 of the US Forest Service lists Columbia River redband trout as a sensitive species. The USFWS was formally petitioned to consider the Kootenai River population of Columbia River redband trout as an endangered species under the ESA on April 4, 1994. However, the petition was dismissed due to lack of information. Concern has arisen in recent years that Columbia River redband trout in the Kootenai River basin are at high risk of extinction (Muhlfeld 1999).

On the Idaho Panhandle National Forest, little is known about the status of Kootenai-drainage Columbia River redband trout populations. In all but five of the 6-field HUCs in the Idaho portion of the Kootenai, the Columbia River redband trout status is described by the USFS as "presence unknown". In three HUCs, redbands are known to be present but their population status is unknown, and in two they are present but depressed.

Based on genetic analyses in Montana, populations of Columbia River redband trout have been identified in Callahan Creek, the East Fork Yaak River and its tributaries, the Yaak River (downstream from Yaak Falls), the North Fork Yaak River, and tributaries to Libby Creek and the upper Fisher River (including the Pleasant Valley Fisher, East Fisher River drainages) (Allendorf et al. 1980; Leary et al. 1991; Huston 1995; Hensler et al. 1996; Knudsen et al. 2002). Currently, unintrogressed Columbia River redband trout populations are restricted to headwater reaches. Columbia River redband trout inhabiting Callahan Creek and the upper Yaak drainage are isolated into two separate regions by Yaak River Falls, a falls-chute barrier located 4 km from the mouth of Callahan Creek and a barrier falls located in the lower East Fork of the Yaak River.

In Idaho, genetics studies have documented Columbia River redband trout in the Boulder, Boundary, and Deep creek drainages, and North and South Callahan Creeks (Sage 1993, 1995; Leary 1997; Knudsen et al. 2002). Spawning and rearing habitat in several Idaho tributaries has been lost or is now inaccessible to fluvial Columbia River redband trout due to anthropogenic factors (Partridge 1983). These streams include, but are not limited to, Caboose, Cow, Debt, and Twenty-Mile creeks.

Life History

A variety of life history strategies can be found among Columbia River redband trout. Anadromous stocks (which are known commonly as steelhead) historically migrated to the middle and upper Columbia River drainage, but this range probably became more restricted when barriers formed during the last (Tahoe stage) glacial advance (Behnke 1992). There are presently redband trout populations isolated from anadromous influence, such as in Kootenay Lake and the Kootenai River upstream. An adfluvial form, the Kamloops redband trout of Kootenay Lake, British Columbia, has a piscivorous diet and therefore grows quite large and exhibits an advanced size at sexual maturity. Kamloops redband trout spawn in Kootenai River

tributaries in Montana and Idaho but do not migrate upstream from Kootenai Falls (Huston 1995). Fluvial stocks occupy large rivers and spawn in smaller tributaries. Resident forms complete their entire life cycles in smaller tributaries and headwater areas. The Kootenai River drainage supports all three life histories (Downs 1999, 2000; Muhlfeld et al. 2001b; Walters and Downs 2001; Knudsen et al. 2002). The different redband trout life history forms are indistinguishable using meristic counts, coloration patterns, or allozyme data (Knudsen et al. 2002).

Habitat Requirements and Limiting Factors

Seasonal habitat requirements of Columbia River redband trout in the Kootenai River drainage in Montana were investigated during 1997 and 1998 (Muhlfeld 1999; Hensler and Muhlfeld 1999; Muhlfeld et al. 2001a; Muhlfeld et al. 2001b). Summer results demonstrated that juvenile (36-125 mm) and adult (> 126 mm) Columbia River redband trout preferred deep microhabitats (>0.4 m) with low to moderate velocities (< 0.5 m/s) adjacent to the thalweg. Conversely, age-0 (<35mm) Columbia River redband trout selected slow water (< 0.1 m/s) and shallow depths (< 0.2 m) located in lateral areas of the channel. Age-0, juvenile and adult Columbia River redband trout strongly selected pools and avoided riffles; runs were used generally as expected (based on availability) by juveniles and adults and more than expected by age-0 Columbia River redband trout.

At the macrohabitat scale, a multiple regression model indicated that low-gradient, mid-elevation reaches with an abundance of complex pools were critical areas for the production of Columbia River redband trout. Mean reach densities ranged from 0.01-0.10 fish/m2. During the fall and winter period, adult Columbia River redband trout occupied small home ranges and found suitable overwintering habitat in deep pools with extensive amounts of cover in headwater streams. In Basin Creek, adult Columbia River redband trout began spawning (e.g., redd construction) during June as spring flows subsided following peak runoff. Columbia River redband trout generally selected redd sites in shallow pool tailout areas (mean depth = 0.27 m; range: 0.20-0.46) with moderate water velocities (mean velocity = 0.50 m/s; range: 0.23-0.69 m/s) dominated by gravel substrate.

Table 2-17 presents a summary of preferred habitat characteristics based on empirical data, literature, and expert professional judgment (see Appendix D for additional detail). Consideration is given to habitat preference at each life stage and the relevant duration or seasonality for that life stage habitat requirement. Variables noted with an "X" in the table below are believed to be important to the specified Columbia River redband trout life stage.

Table 2-17. Columbia River redband trout life stage and preferred habitat characteristics based on empirical data and literature.

Life Stage	Migrating Adult	Spawning Adult	Embryo	Alevins	Fry	Fingerling	Juvenile
Duration/ Seasonality	**Winter to Spring**	**Mar to Apr**	**Mar to May**	**Apr to May**	**May to Jun**	**Summer to Winter**	**Year-round**
River Reach Used by Life Stage							
Canyon	X						
Braided Reach 1	X						
Braided Reach 2	X						
Straight Reach	X						
Meander Reach 1	X						
Meander Reach 2	X						
Tributaries	X	X	X	X	X	X	X
Water Quality							
Temperature	X	X	X	X	X	X	X
Dissolved oxygen	X	X	X	X	X	X	X
Turbidity/suspended sediment		X	X	X	X		
Nutrient availability	X	X	X	X	X	X	X
Substrate							
Type of substrate	X	X	X	X	X	X	X
Particle size distribution	X	X	X	X	X	X	X
Longitudinal extent (length)		X	X	X			
Interstitial spaces		X	X	X		X	X
Cover							
Depth/incident light	X	X			X	X	X
Canopy/shade	X					X	X
Undercut banks	X					X	X
Turbidity/suspended sediment	X					X	X
Hydraulic cover	X					X	X
Large woody debris	X				X	X	X
Hydraulics							
Velocity	X	X	X	X	X	X	X
Velocity variability	X	X	X	X	X	X	X
Boundary sheer stress	X	X	X	X	X	X	X
Lateral sheer	X	X	X	X	X	X	X
Hydrology							
In-channel groundwater/surface water interaction			X	X			
Flow duration, frequency, and magnitude	X	X	X	X	X	X	X
Channel geometry							
Depth	X	X			X	X	X
Channel stability		X					

Table 2-17. Columbia River redband trout life stage and preferred habitat characteristics based on empirical data and literature.							
Life Stage	**Migrating Adult**	**Spawning Adult**	**Embryo**	**Alevins**	**Fry**	**Fingerling**	**Juvenile**
Duration/ Seasonality	**Winter to Spring**	**Mar to Apr**	**Mar to May**	**Apr to May**	**May to Jun**	**Summer to Winter**	**Year-round**
Single vs. braided, meander	X	X	X	X	X	X	X
Connection with off-channel habitat					X	X	X
Connection with tributary habitat	X	X			X	X	X
Slope/gradient	X	X	X	X	X	X	X
Pool/riffle/run ratio; pool spacing	X	X			X	X	X

Columbia River redband trout populations have been impacted by degraded riparian condition, fine sediment, high water temperatures, and channel instability in tributary habitat to the Kootenai River (KTOI and MFWP 2004). In the mainstem Kootenai River, limiting factors include altered hydrograph and thermograph due to Libby Dam, degraded riparian condition, and fine sediment. Fish passage barriers that restrict Columbia River redband trout spawning migrations are also considered to be a limiting factor. Recent concern has arisen that Kootenai River Basin Columbia River redband trout populations are at a high risk of extinction due to hybridization with non-native coastal rainbow trout, habitat fragmentation, and stream habitat degradation (Perkinson 1993; Muhlfeld 1999).

2.6.1.6 Westslope Cutthroat Trout

The following sections summarize westslope cutthroat trout historical and current population status, habitat requirements, and limiting factors affecting the population. The information included in this section focuses primarily on the Kootenai River and Kootenay Lake population. Most of the following information is taken directly from the Kootenai River Subbasin Assessment (KTOI and MFWP 2004).

Historical and Current Status

The westslope cutthroat trout is one of fourteen subspecies of cutthroat trout native to interior regions of western North America. Although the extent of its range is not precisely known, the historical range of the westslope cutthroat is considered the most geographically widespread among the 14 subspecies of inland cutthroat trout (Behnke 1992). It is believed they inhabited all major drainages west of the Continental Divide (Leary et al. 1991). Shepard et al. (2005) estimates they historically occupied 2,640 miles of stream in the Upper Kootenai, Fisher, Yaak, Lower Kootenai, and Moyie drainages.

In June of 1997, the USFWS was petitioned to list the westslope cutthroat trout as threatened and designate critical habitat. In 1998, the USFWS published a notice of a 90-day finding that the petition provided substantial information indicating that the requested action may be warranted and immediately began a comprehensive status review for westslope cutthroat trout. In 2002, based on the results of the status review, the USFWS determined that the westslope cutthroat trout was not likely to become a threatened or endangered species within the foreseeable

future. That determination was challenged by the petitioners and in 2003, the agency reevaluated their finding and again concluded that the subspecies does not warrant listing as a threatened species under the ESA because abundant, stable, and reproducing populations of westslope cutthroat remain well distributed throughout its historic range. (The USFWS listing determination is provided at the following link: http://www.thefederalregister.com/d.p/2003-08-07-03-20087.)

Region I of the U.S. Forest Service lists westslope cutthroat trout as a sensitive species. The state rank for both Montana and Idaho is S2, which means the species is considered imperiled because of rarity or because of other factors, demonstrably making it very vulnerable to extinction throughout its range. In the Idaho portion of the Lower Kootenai watershed, stocks of westslope cutthroat trout are known to occur in 33 stream reaches. Data indicate westslope cutthroat trout stocks are strong or predicted to be strong in two HUCs and depressed or predicted depressed in the remaining 31 HUCs (KTOI and MFWP 2004). Twenty-five years of population estimates reveal a population decline for westslope cutthroat trout in the Kootenai subbasin (Hoffman et al. 2002). Severe declines in westslope cutthroat trout abundance in Koocanusa Reservoir tributaries have been measured since the early eighties in population index streams (Marotz et al. 1998).

Life History

Westslope cutthroat trout usually mature at 4 or 5 years of age and spawn entirely in streams, primarily small tributaries. Spawning occurs between March and July, when water temperatures warm to about 10 C (50 F) (Trotter 1987; Behnke 1992). Natal homing, the return of adult fish to spawning areas where they were produced, is believed to occur in westslope cutthroat trout.

Three westslope cutthroat trout life-history types (resident, fluvial, and adfluvial) are recognized (Trotter 1987; Behnke 1992). Resident fish spend their lives entirely in the natal tributaries; fluvial fish spawn in small tributaries but their resulting young migrate downstream to larger rivers where they grow and mature; and adfluvial fish spawn in streams but their young migrate downstream to mature in lakes. After spawning in tributaries, adult fluvial and adfluvial westslope cutthroat trout return to the rivers or lakes (Behnke 1992). All three life-history types occur within the Kootenai subbasin (Marotz et al. 1998).

Westslope cutthroat trout feed primarily on macroinvertebrates, particularly immature and mature forms of aquatic insects, terrestrial insects, and, in lakes, zooplankton (Liknes and Graham 1988). These preferences for macroinvertebrates occur at all ages in both streams and lakes. Westslope cutthroat trout rarely feed on other fishes (Liknes and Graham 1988; Behnke 1992).

Growth of individual westslope cutthroat trout, like that of fish of other species, depends largely upon the interaction of food availability and water temperature. Resident westslope cutthroat trout usually do not grow longer than 30 cm (12 inches), presumably because they spend their entire lives in small, coldwater tributaries. In contrast, fluvial and adfluvial westslope cutthroat trout often grow longer than 30 cm (12 inches) and attain weights of 0.9-1.4 kg (2-3 pounds). Such rapid growth results from the warmer, more-productive environments afforded by large rivers, lakes, and reservoirs (Trotter 1987; Behnke 1992).

Habitat Requirements and Limiting Factors

Like bull trout, westslope cutthroat trout are often considered an indicator of the health of the aquatic ecosystem. Both species require high quality, cold water and clean gravel for spawning, and both species do best in complex habitats, much of which is created by large woody debris. Proximity to cover is an important component of spawning habitat. Adult westslope cutthroat trout are strongly associated with pools and cover (McIntyre and Riemen 1995).

Historically, habitats of westslope cutthroat trout ranged from cold headwater streams to warmer, mainstem rivers (Behnke 1992). Today, remaining stocks of westslope cutthroat trout occur primarily in colder, headwater streams (Liknes and Graham 1988). Westslope cutthroat trout may exist in these streams not because the thermal conditions there are optimal for them, but because nonnative salmonid competitors like brook trout cannot exploit these cold, high-gradient waters (Griffith 1988; Fausch 1989).

Table 2-18 presents a summary of preferred habitat characteristics based on empirical data, literature, and expert professional judgment (see Appendix D for additional detail). Consideration is given to habitat preference at each life stage and the relevant duration or seasonality for that life stage habitat requirement. Variables noted with an "X" in the table below are believed to be important to the specified westslope cutthroat trout life stage.

Table 2-18. Westslope cutthroat trout life stage and preferred habitat characteristics based on empirical data and literature.

Life Stage	Migrating Adult	Spawning Adult	Embryo	Alevins	Fry	Fingerling	Juvenile
Duration/ Seasonality	**Winter to Spring**	**Mar to May**	**Mar to Jun**	**May to Jul**	**May to Jul**	**Summer to Winter**	**Year-round**
River Reach Used by Life Stage							
Canyon	X						X
Braided Reach 1	X						X
Braided Reach 2	X						X
Straight Reach	X						X
Meander Reach 1	X						X
Meander Reach 2	X						X
Tributaries	X	X	X	X	X	X	X
Water Quality							
Temperature	X	X	X	X	X	X	X
Dissolved oxygen	X	X	X	X	X	X	X
Turbidity/suspended sediment	X	X	X	X	X	X	X
Nutrient availability	X	X	X	X	X	X	X
Other WQ factors	X	X	X	X	X	X	X
Substrate							
Type of substrate	X	X	X	X	X	X	X
Particle size distribution	X	X	X	X	X	X	X
Longitudinal extent (length)		X	X	X			
Interstitial spaces		X	X	X	X		X
Cover							
Depth/incident light	X	X			X	X	X
Canopy/shade	X	X			X	X	X
Undercut banks	X	X				X	X

Table 2-18. Westslope cutthroat trout life stage and preferred habitat characteristics based on empirical data and literature.

Life Stage	Migrating Adult	Spawning Adult	Embryo	Alevins	Fry	Fingerling	Juvenile
Duration/ Seasonality	**Winter to Spring**	**Mar to May**	**Mar to Jun**	**May to Jul**	**May to Jul**	**Summer to Winter**	**Year-round**
Turbidity/suspended sediment		X					
Hydraulic cover	X	X				X	X
Large woody debris	X	X			X	X	X
Hydraulics							
Velocity	X	X	X	X	X	X	X
Velocity variability	X	X	X	X	X	X	X
Boundary sheer stress	X	X	X	X	X	X	X
Lateral sheer	X	X	X	X	X	X	X
Hydrology							
In-channel groundwater/surface water interaction		X	X				
Flow duration, frequency, and magnitude	X	X	X	X	X		
Channel geometry							
Habitat diversity	X	X			X	X	X
Depth	X	X			X	X	X
Channel stability	X	X					
Single vs. braided, meander	X	X			X	X	X
Connection with off-channel habitat		X			X	X	X
Connection with tributary habitat	X	X			X	X	X
Slope/gradient	X	X	X	X	X	X	X
Pool/riffle/run ratio; pool spacing	X	X			X	X	X

Habitat factors considered to be most limiting to westslope cutthroat trout populations in the US portion of the Kootenai subbasin include degraded riparian condition, fine sediment, channel instability and lack of habitat diversity (KTOI and MFWP 2004). The Montana Chapter of the American Fisheries Society identified the following factors as the primary reasons for the decline of westslope cutthroat trout: overexploitation, genetic introgression and competition from non-native fish species, and habitat degradation. Fish passage barriers that restrict westslope cutthroat trout spawning migrations also negatively affect the species.

2.6.2 Altered Ecosystem Effects on Aquatic Habitat

Considering only one life stage of a single focal species, it might be possible to identify a single habitat component that could be restored to address that species and life stage. However, when considering all life stages of all focal species, it is apparent that aquatic species depend on

functioning aquatic habitat that is supported by a diverse, functioning river and floodplain ecosystem.

The following sections outline how river management has led to limiting factors that impact focal species' aquatic habitat. Because Kootenai sturgeon are greatly impacted by the identified limiting factors, and because recovery of Kootenai sturgeon is an important regulatory and practical driver of this Master Plan, the following discussion emphasizes relationships between Kootenai sturgeon and altered habitats. However, the Tribe believes that addressing the factors that limit naturally self-sustaining populations of Kootenai sturgeon by restoring ecosystem function in the Kootenai River will also benefit other native focal species identified and discussed in this Master Plan.

The following excerpt is from the Kootenai sturgeon critical habitat designation (USFWS 2008) explaining Kootenai sturgeon spawning habitat conditions since the closure of Libby Dam.

> Since the construction of Libby Dam, most Kootenai sturgeon spawn over sandy substrates in the Meander Reach below Bonners Ferry. The Meander Reaches have a low stream gradient, and substrates are composed primarily of sand and other fine materials overlying lacustrine clay (Barton 2003, p. 45; Barton et al. 2004, pp. 1, 18–21). Many of the eggs that are located in this reach are found drifting along the river bottom, covered with fine sand particles in sites without rocky substrate (Paragamian et al. 2001, p. 26), and where mean water column velocities seldom exceeded 3.3 ft/s (1.0 m/s) (Paragamian et al. 2001, Table 2, p. 26; Barton et al. 2005, Table 3). The sandy substrate in the current spawning sites in the Kootenai River differs from the rocky substrate that occurs in successful white sturgeon spawning sites elsewhere in the Columbia River Basin (Paragamian et al. 2001, pp. 28–29; Parsley et al. 1993, Table 2, p. 220 and Figure 6, p. 222; Parsley and Beckman 1994, pp. 812–827; Kock et al. 2006, pp. 134–135, 139 and references therein).

River management has affected the historical hydrograph by regulating river flow. As reviewed in Section 2.4, Libby Dam operations have decreased peak flows by approximately half. Diminished spring flows equate to shallower water depths and lower velocities in the Master Plan project area. Some regional sturgeon experts have proposed that the shallower channel is a behavioral passage barrier for Kootenai sturgeon migrating from the Meander reaches to the Straight and Braided reaches where coarser channel bed material is located (P. Anders, Cramer Fish Sciences, personal communication, 2009). Figure 2-44 illustrates river depths through the project area associated with pre-dam discharge of 65kcfs, the approximate pre-dam bankfull discharge. Figure 2-45 shows river depths in the post-dam era using a revised post-dam bankfull discharge of 30kcfs. The 1,763 ft elevation of the Kootenai River at Porthill was selected to represent the pre-dam bankfull discharge downstream boundary condition as it was the median river elevation associated with the 65kcfs pre-dam discharge based on the historical record. Because water surface elevations at gaging stations on Kootenay Lake and the Kootenai River through the backwater extent have similar patterns and are generally linearly correlated although with different elevations (Berenbrock 2005), river stage recorded at the Porthill gage was used as a surrogate for backwater conditions. The 1,754 ft elevation of the Kootenai River at Porthill was used for the post-dam 30kcfs bankfull event downstream boundary condition as that elevation was the median post-BiOp elevation associated with a 30kcfs discharge.

Because Kootenai sturgeon spawning activities correspond to rising streamflows and water temperature associated with spring runoff (Paragamian and Kruse 2001), the 65kcfs (1,840 cms) discharge used to represent the pre-dam bankfull flood event most likely would have elicited a Kootenai sturgeon spawning response based on observations presented in Paragamian and Kruse (2001). Additionally, Kootenai sturgeon have been observed in spawning areas at flows exceeding the modeled post-dam 30kcfs (850 cms) bankfull discharge event (Paragamian and Kruse 2001). Female Kootenai sturgeon abandoned spawning areas when flows dropped to between 24kcfs (700 cms) and 11kcfs (300 cms). Although discharge has been reported as an important spawning cue, water temperature is also an important condition influencing Kootenai sturgeon spawning (Paragamian and Kruse 2001). Shallower depths through the upstream project reaches may cause Kootenai sturgeon to return to the deeper Meander Reaches where they spawn over finer sediment, resulting in poor embryo survival.

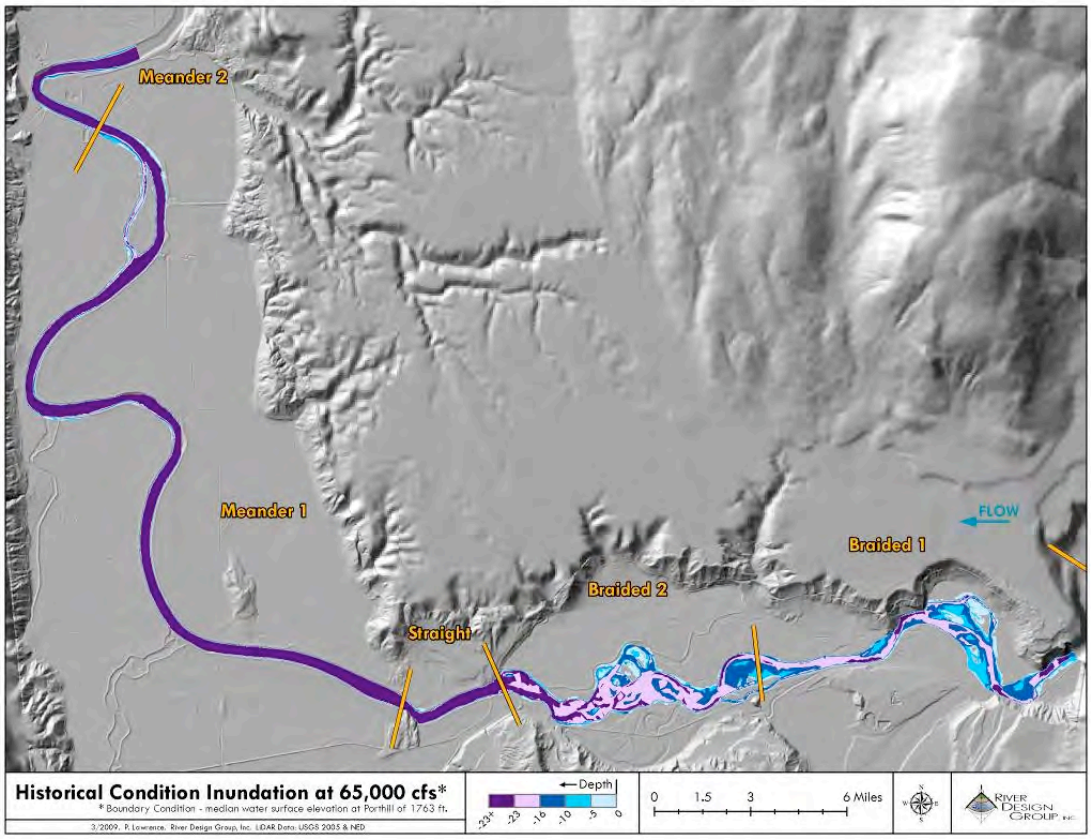


Figure 2-44. River channel depths associated with a discharge of 65kcfs (pre-dam mean annual peak flow. River depths exceeding 23 ft (Kootenai sturgeon BiOp spawning habitat depth target) are located throughout the Straight and Meander reaches. Shallower depths characterize the Braided Reach.

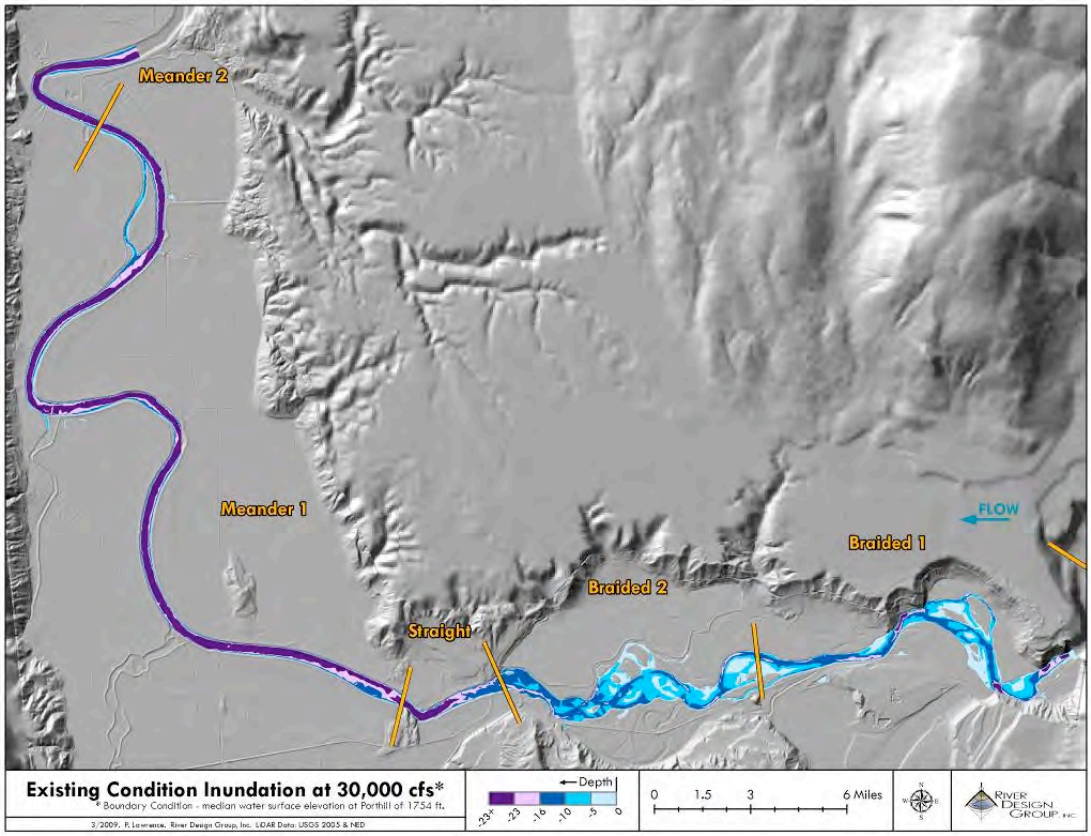


Figure 2-45. River channel depths associated with a discharge of 30kcfs (post-dam mean annual peak flow). River depths exceeding 23 ft (Kootenai sturgeon BiOp spawning habitat depth target) are located in the downstream half of the Straight Reach and throughout the Meander Reach. Shallower depths characterize the Braided Reach and upstream half of the Straight Reach.

Data presented in the above depth figures were used to quantify pre-dam (65kcfs) and post-dam (30kcfs) mean annual peak flow depths to evaluate changes in mainstem habitat with river management. Channel depths were delineated into five depth categories to compare the two eras. Based on the Libby Dam BiOp as revised (USFWS 2006, clarified in 2008), it is suggested that channel depths exceeding 23 ft in the project area will provide favorable depths for migrating and spawning Kootenai sturgeon.

Table 2-19 summarizes mean annual peak flow channel depths for the pre-dam period. Table 2-20 includes information for the post-dam period. Figure 2-46 includes the percentages of the depth categories for each project reach by period.

In general, there has been an increase in the percentage of shallow depth categories and a decrease in deeper depth categories from the pre-dam to post-dam eras. The Straight Reach and Braided Reach 2 have experienced the greatest reduction in channel depths exceeding 23 ft suggesting a downward trend in preferred Kootenai sturgeon spawning habitat depths based on the guidance provided in the Libby Dam BiOp (USFWS 2008). This change in channel depths may be important for Kootenai sturgeon spawning as Kootenai sturgeon have been observed abandoning spawning areas following rapid decreases in flow (Paragamian and Kruse 2001).

Alternatively, such observations could simply be natural post-spawning behaviors consistently observed for post-spawned females (Anders 1991; Apperson and Anders 1990, 1991).

Table 2-19. Pre-dam channel thalweg depths (ft) and percentage of reach length for five channel depth categories based on 65 kcfs discharge.

Channel Depth Categories (ft)	Braided Reach 1		Braided Reach 2		Straight Reach		Meander Reach 1		Total
	Length (feet)	%	Length (feet)	%	Length (feet)	%	Length (feet)	%	Length (feet)
0-5	0	0.0	0	0.0	0	0.0	0	0.0	0
5-10	0	0.0	0	0.0	0	0.0	0	0.0	0
10-16	1445	7.0	0	0.0	0	0.0	0	0.0	1445
16-23	12420	60.2	2619	15.7	0	0.0	0	0.0	15039
23+	6772	32.8	14079	84.3	5817	100.0	51148	100.0	77816
Total	**20637**	**100**	**16698**	**100**	**5817**	**100**	**51148**	**100**	**94,300**

Table 2-20. Post-dam channel thalweg depths (ft) and percentage of reach length for five channel depth categories based on 30 kcfs discharge.

Channel Depth Categories (ft)	Braided Reach 1		Braided Reach 2		Straight Reach		Meander Reach 1		Total
	Length (feet)	%	Length (feet)	%	Length (feet)	%	Length (feet)	%	Length (feet)
0-5	316	1.5	0	0.0	0	0.0	0	0.0	316
5-10	1258	6.1	458	2.7	0	0.0	0	0.0	1716
10-16	10796	52.3	7542	45.2	0	0.0	0	0.0	18338
16-23	5609	27.2	7847	47.0	2412	41.5	97	0.2	15965
23+	2658	12.9	851	5.1	3405	58.5	51051	99.8	57965
Total	**20637**	**100**	**16698**	**100**	**5817**	**100**	**51148**	**100**	**94300**

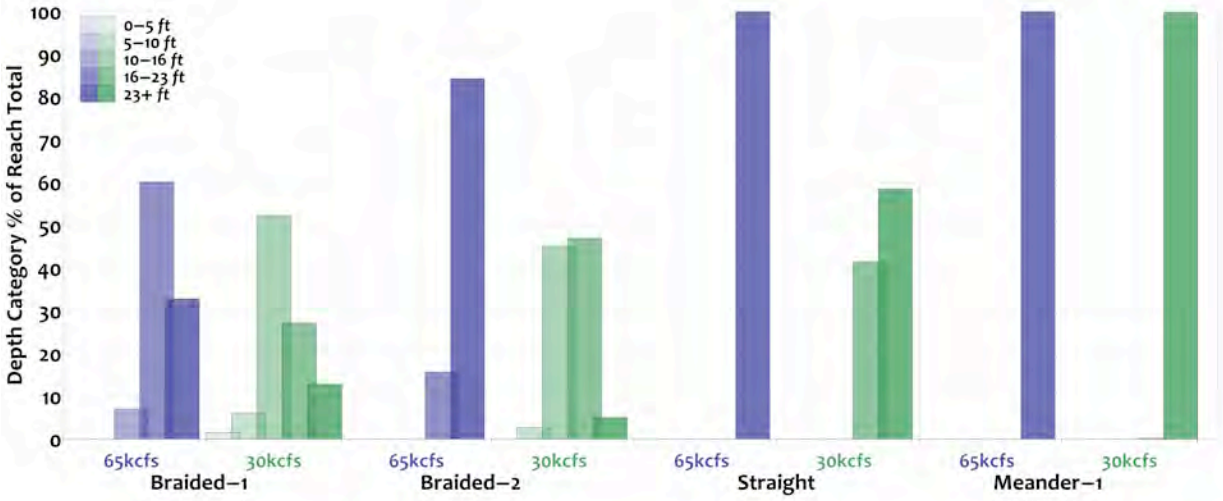


Figure 2-46. A comparison of channel depth categories in the project reach for the pre-dam mean annual peak flow (65kcfs) and post-dam mean annual peak flow (30kcfs). The proportion of shallower depth categories increases from the pre-dam to post-dam periods. Meander Reach 1 exhibits the least amount of change due to the consistent presence of the Kootenay Lake backwater.

Based on changes in depth, ***insufficient depth for Kootenai sturgeon migration has been identified as an aquatic habitat limiting factor***.

In addition to depth, water velocity and turbulence are reported to be important cues for Kootenai sturgeon spawning site selection (Paragamian et al. 2001). Due to the diminished flows as well as changes in the extent of the Kootenay Lake backwater, areas of the channel with sufficient water velocity and turbulence are thought to be less common in the post-dam era relative to the pre-dam period (Paragamian et al. 2001). Additionally, the frequency of higher velocities in the vicinity of coarse bed substrate is further limited in the post-dam era (Paragamian et al. 2001). Figure 2-47 illustrates the distribution of water velocities in the project area during the pre-dam period based on an average historical bankfull discharge of 65kcfs. Figure 2-48 presents water velocities in the project area during the post-dam period based on a bankfull discharge of 30kcfs. A comparison of the two figures illustrates the contraction in channel length with water velocities exceeding 3.3 fps, the velocity value reported as a requirement for successful sturgeon spawning in the Libby Dam BiOp (USFWS 2006, clarified in 2008). Historically, much of Braided Reach 1, the Straight Reach, and the Meander Reaches maintained bankfull velocities in excess of 3.3 fps. River regulation has reduced water velocities to the extent that bankfull water velocities are now limited to Braided Reach 1, a portion of Braided Reach 2, and the most upstream extent of the Straight Reach.

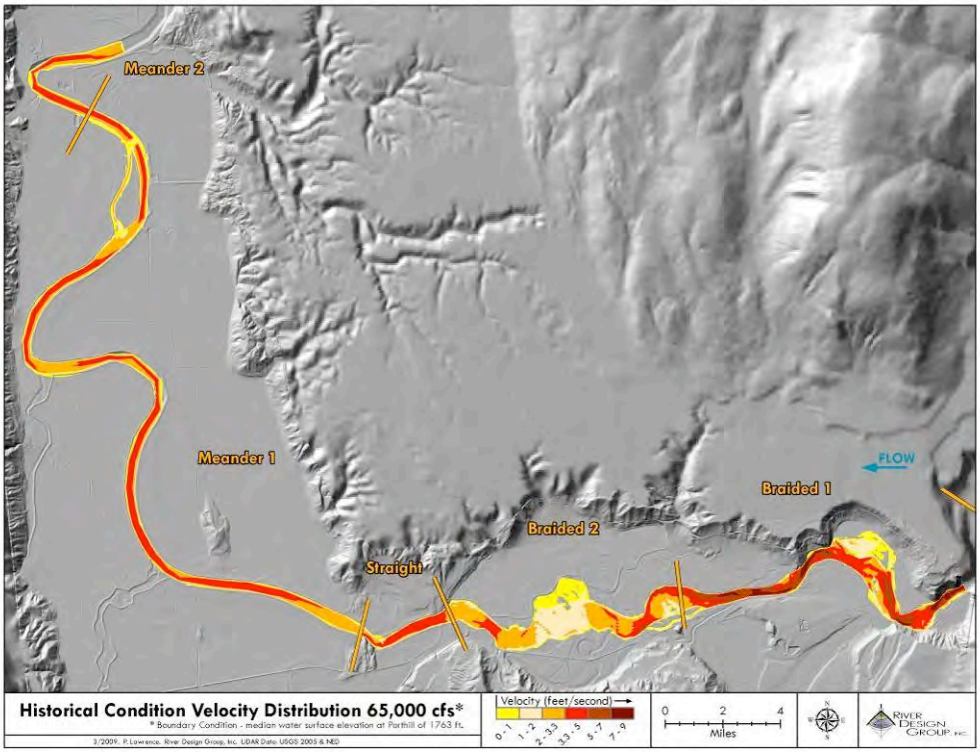


Figure 2-47. Water velocities associated with a discharge of 65kcfs (pre-dam mean annual peak flow). Velocities exceeding 3.3 fps (Kootenai sturgeon BiOp spawning habitat velocity target), shown in red or darker colors, are located throughout the Straight and Meander reaches, and sporadically through the Braided Reach. The lowest range of velocities is in Braided Reach 2 due to the broad channel cross-section.

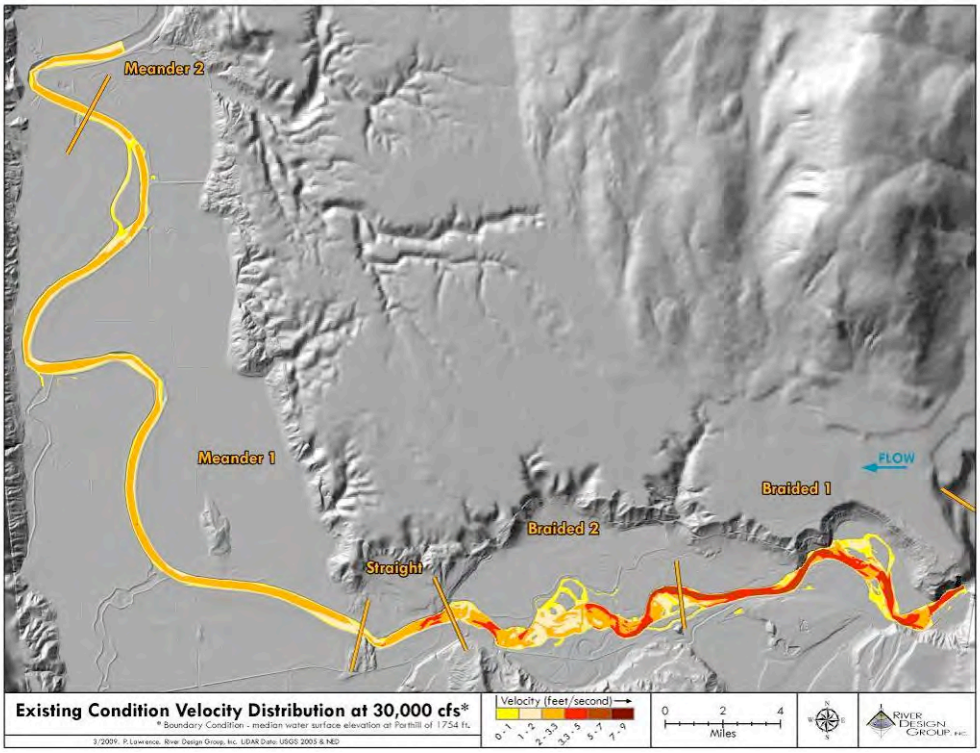


Figure 2-48. Water velocities associated with a discharge of 30kcfs (post-dam mean annual peak flow). Velocities exceeding 3.3 fps (Kootenai sturgeon Libby Dam BiOp spawning habitat velocity target), shown in red or darker colors, are limited to portions of the Straight and Braided reaches.

Data presented in the above velocity distribution figures were used to quantify average pre-dam (65kcfs) and post-dam (30kcfs) bankfull discharge velocities to evaluate changes in mainstem habitat with river management. Water velocities were delineated into seven velocity categories. Based on the Libby Dam BiOp (USFWS 2008), velocities 3.3 fps or greater in the project area are believed to provide velocities suitable for Kootenai sturgeon spawning, although most sturgeon spawning in the Kootenai River likely occurs over a considerably lower velocity range (P. Anders, Cramer Fish Sciences, personal communication, 2009).

Table 2-21 summarizes bankfull water velocities for the pre-dam period. Table 2-22 includes velocity data for the post-dam period. Figure 2-49 includes the percentages of the velocity categories for each project reach by period. In general, there has been an increase in the percentage of lower water velocity categories and a decrease in higher water velocity categories from the pre-dam to post-dam eras. The Straight Reach and Meander Reach 1 have experienced the greatest reduction in water velocities exceeding 3.3 fps, suggesting a downward trend in preferred Kootenai sturgeon spawning habitat velocities according to the Libby Dam BiOp (USFWS 2006, clarified in 2008).

Table 2-21. Pre-dam water velocities (fps) in the thalweg and percentage of reach length for seven velocity categories.

Velocity Categories (ft/s)	Braided Reach 1		Braided Reach 2		Straight Reach		Meander Reach 1		Total
	Length (feet)	%	Length (feet)	%	Length (feet)	%	Length (feet)	%	Length (feet)
0-1	0	0.0	0	0.0	0	0.0	213	0.4	213
1-2	64	0.3	2461	14.7	0	0.0	94	0.2	2619
2-3.3	0	0.0	5301	31.7	266	4.6	7740	15.1	13307
3.3-5	3269	15.8	6480	38.8	5551	95.4	43101	84.3	58401
5-7	8066	39.1	2456	14.7	0	0.0	0	0.0	10522
7-9	8502	41.2	0	0.0	0	0.0	0	0.0	8502
9-11.1(max)	736	3.6	0	0.0	0	0.0	0	0.0	736
Total	**20637**	**100**	**16698**	**100**	**5817**	**100**	**51148**	**100**	**94300**
Total ≥3.3 ft/s	**20573**	**99.2**	**8936**	**53.5**	**5551**	**95.4**	**43101**	**84.3**	**78161**

Table 2-22. Post-dam water velocities (fps) in the thalweg and percentage of reach length for seven velocity categories.

Velocity Categories (ft/s)	Braided Reach 1		Braided Reach 2		Straight Reach		Meander Reach 1		Total
	Length (feet)	%	Length (feet)	%	Length (feet)	%	Length (feet)	%	Length (feet)
0-1	38	0.2	0	0.0	0	0.0	455	0.9	493
1-2	0	0.0	638	3.8	0	0.0	451	0.9	1089
2-3.3	623	3.0	5879	35.2	4221	72.6	50242	98.2	60965
3.3-5	5354	25.9	6281	37.6	1596	27.4	0	0.0	13231
5-7	14622	70.9	3161	18.9	0	0.0	0	0.0	17783
7-9	0	0.0	739	4.4	0	0.0	0	0.0	739
9-11.1(max)	0	0.0	0	0.0	0	0.0	0	0.0	0
Total	**20637**	**100**	**16698**	**100**	**5817**	**100**	**51148**	**100**	**94,300**
Total ≥3.3 ft/s	**19976**	**96.8**	**10181**	**60.9**	**1596**	**27.4**	**0**	**0**	**31753**

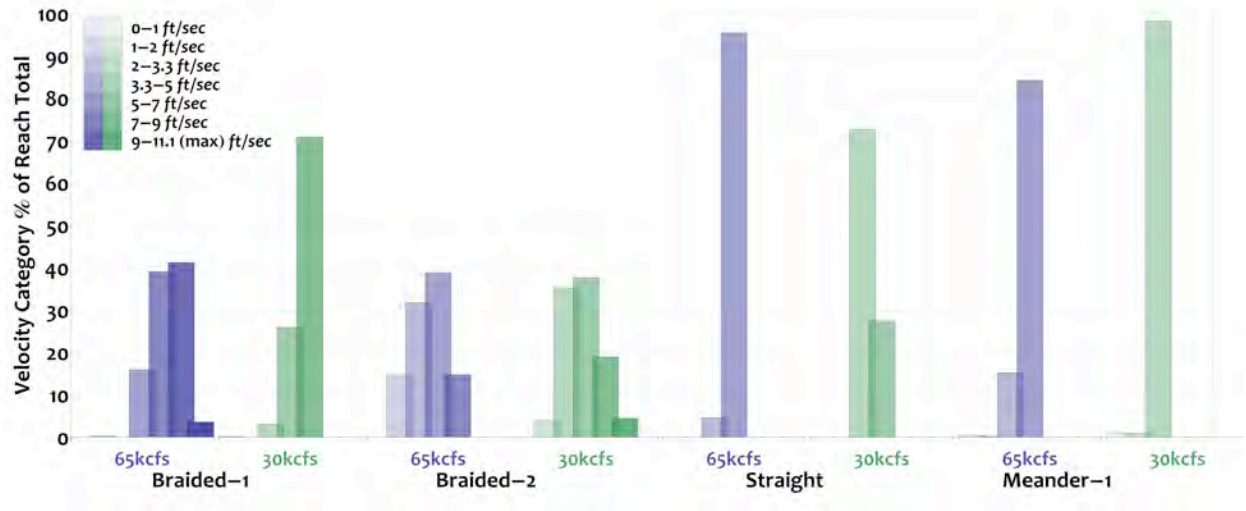


Figure 2-49. A comparison of water velocities in the project reaches for the pre-dam (65 kcfs) and post-dam (30 kcfs) mean annual peak flows.

Based on changes in velocity, ***insufficient velocity for Kootenai sturgeon spawning has been identified as an aquatic habitat limiting factor***.

Post-dam changes in hydraulics that have caused reduced depths and velocities have also resulted in finer channel bed sediments. Figure 2-50 displays a sediment facies map for portions of the project area. The sediment composition is based on coring data and underwater videography completed by USGS. Although areas of coarser bed material are found in the Meander Reaches, embeddedness of coarse substrate with finer material has occurred. Finer bed materials are reported to negatively affect Kootenai sturgeon embryos (Koch et al. 2006). An explanation of how sediment transport has changed in the project area is included in Section 2.4.

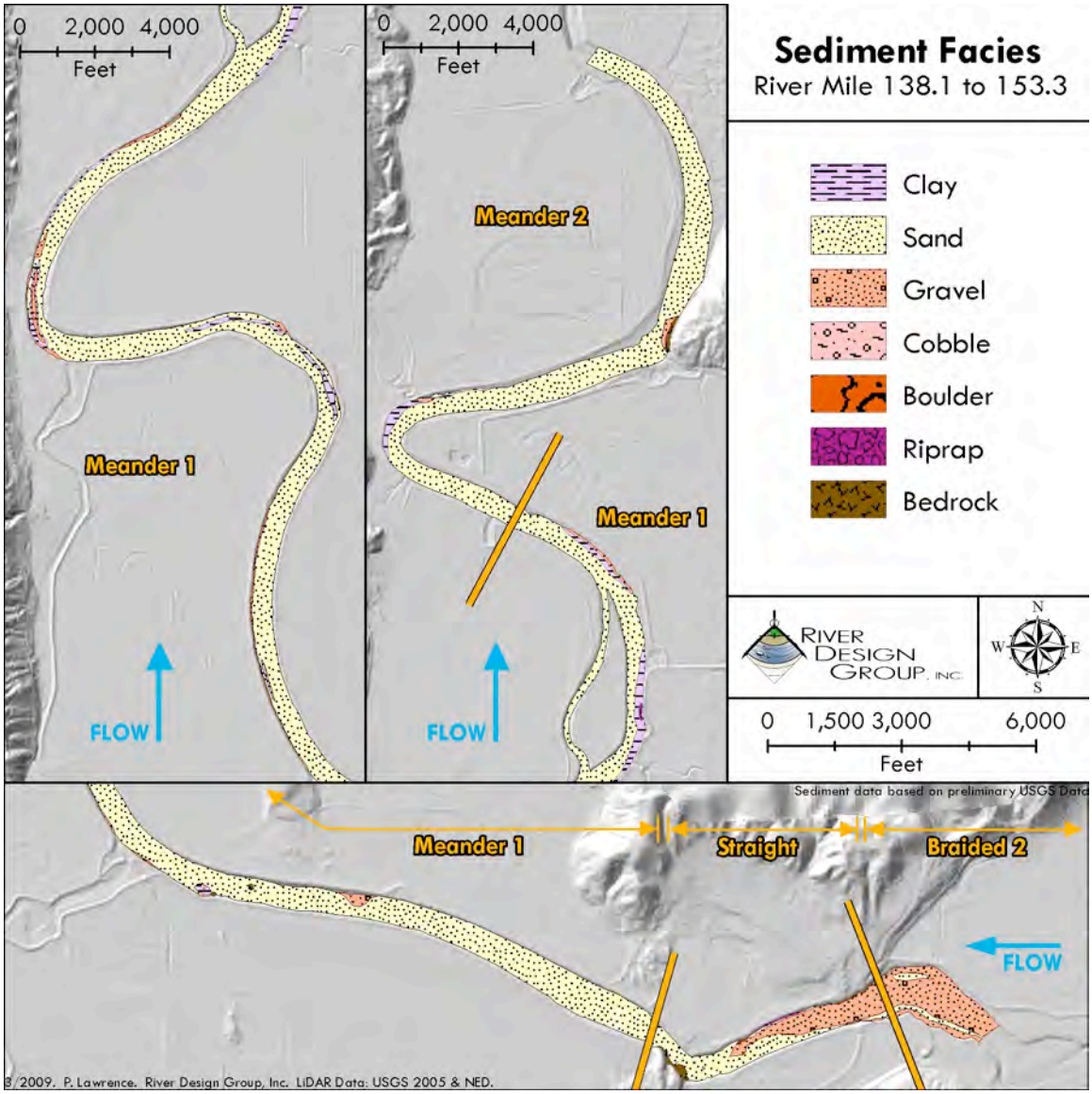


Figure 2-50. Existing condition channel bed materials in the project area. Coarse substrate suitable for spawning has become increasingly embedded with finer substrate.

Based on changes in substrate composition, ***lack of coarse substrate for egg attachment has been identified as an aquatic habitat limiting factor***.

While water depth, velocity, and substrate are important indicators of Kootenai sturgeon spawning habitat conditions, it is the combined presence of sufficient water depth, higher water velocities, and coarse channel substrate that forms the range of conditions reported to be required for successful Kootenai sturgeon spawning and embryo survival (USFWS 2008).

While changes in hydraulics have affected depth, velocity and substrate, these changes have also resulted in less complex aquatic habitat in terms of pool and riffle distribution. Habitat suitability maps were completed for the project area to evaluate the distribution of pool and riffle habitat in the project area. Areas within the channel with maximum depths that exceeded twice the

mean reach depth were delineated as pools. Areas of the channel with depths less than twice the mean reach depth were delineated as riffle habitat. Figure 2-51 displays the distribution of pool and riffle habitats in the project area. Pool habitat is currently less common in the Braided Reaches, accounts for over half of the Straight Reach, and defines slightly over a third of the mainstem habitat in the Meander Reaches. Riffle habitat dominates the Braided and Meander reaches and accounts for less than half of the Straight Reach (Table 2-23). An explanation of how channel morphology has changed from the pre-dam era to the present time is included in Section 2.4.

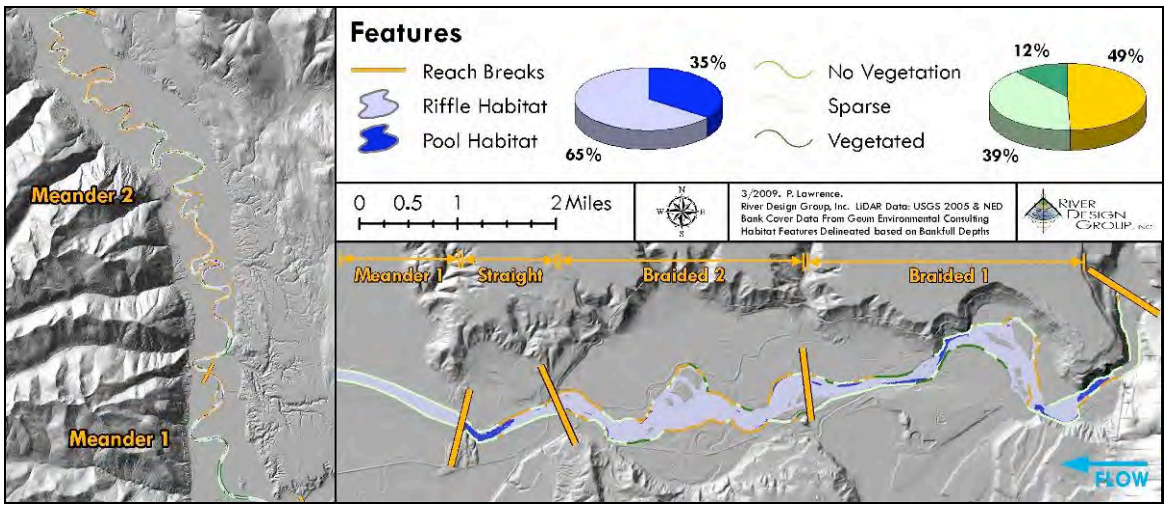


Figure 2-51. The distribution of pool and riffle habitats in the project reaches based on thalweg depth relative to mean depth. Thalweg depths exceeding twice mean depth are considered to be pool features.

Table 2-23. Pool and riffle habitat unit lengths and the percentage of the habitat unit's portion of each reach within the Master Plan project area.

Reach	Pool Length		Riffle Length		Total
	Length (ft)	% of Reach	Length (ft)	% of Reach	(mi)
Braided 1	8,897	43.1	11,736	56.9	3.9
Braided 2	1,678	10.1	15,006	89.9	3.2
Straight	3,307	56.8	2,517	43.2	1.1
Meander 1	18,636	36.5	32,492	63.5	9.7
Meander 2	67,209	35.8	120,402	64.2	35.5
Total	**99,727**	**35.4**	**182,152**	**64.6**	**53.4**

Based on changes in pool/riffle habitat distribution in some reaches, ***lack of pool-riffle complexity*** and ***insufficient pool frequency have been identified as aquatic habitat limiting factors***.

Nutrient fluxes in the Kootenai subbasin have also changed over time in response to extensive levee construction, transitions in land uses, operation and then closure of fertilizer production facilities and mines, and construction and operation of Libby Dam. Reduced nutrients have simplified the food web in the Kootenai River (Holderman and Hardy 2004; Holderman et al. 2009b). Nutrient sequestration in Lake Koocanusa and loss of over 50,000 acres of historical floodplain habitat diversity and productivity are cited as primary reasons for diminished nutrient loads downstream from Libby Dam (Snyder and Minshall 1996; Anders et al. 2002). As described in Section 2.5, conversion of native vegetation to agricultural crops and invasive plant species has reduced primary productivity in the floodplain, likely resulting in diminished nutrient inputs to the river.

Altered water quality directly affects biological productivity at all trophic levels, and may decrease food availability for fish including Kootenai sturgeon. Decreased prey availability for some life stages of sturgeon, and a possible reduction in the overall carrying capacity for the Kootenai River and Kootenay Lake to sustain populations of Kootenai sturgeon and other native fishes may be a significant limiting factor. A limited food supply for young-of-year fish could contribute to increased mortality rates, either through starvation or through increased predation mortality, because young of the year would spend more time feeding, thereby exposing themselves to higher predation risk. Based on these factors, ***simplified food web from lack of nutrients has been identified as an aquatic habitat limiting factor***.

Water quality conditions have varied over the period of Euro-American settlement in the Kootenai River drainage. In the late 1800s through 1974 (Libby Dam closure), agriculture, mining, logging, pulp mill operations, and development contributed sediment, nutrients, and mining-related metals to the Kootenai subbasin. The delivery of these materials to the river network degraded water quality. Agriculture, urban runoff, and wastewater treatment discharge to the river continue to influence water quality.

Channel bed sediment contamination by heavy metals and other chemicals likely affects benthic fishes like Kootenai sturgeon and burbot inhabiting the Kootenai River. Georgi (1993) noted that the chronic effects on wild sturgeon spawning in "chemically polluted" water and rearing over contaminated sediments, in combination with bioaccumulation of contaminants in the food web, is possibly reducing the successful reproduction and early-age recruitment to the Kootenai

sturgeon population. Results from a contaminant study performed in 1998 and 1999 showed that water concentrations of total iron, zinc, and manganese, and the PCB Arochlor 1260 exceeded suggested environmental background levels (Kruse 2000). Increased exposure to copper and Arochlor 1260 significantly decreased survival and incubation time of white sturgeon embryos and could be a potentially significant additional stressor to the white sturgeon population.

However, the high sturgeon fertilization and hatch rates in the hatchery, often exceeding 90%, along with consistent post-release, in-river survival rates of 60% during the first year at large, and 90% during all subsequent years among age 1 and older fish (Ireland et al. 2002; KTOI 2008) do not support an acute toxicity explanation for sturgeon limitation at the population level.

Flow regulation at Libby Dam has led to typically warmer water temperatures in the winter and cooler water temperatures in the summer (Partridge 1983). Changes in the thermal regime have affected the focal species by influencing seasonal behavior patterns, most notably spawning cues for Kootenai sturgeon (Paragamian et al. 2001) and burbot (KTOI and MFWP 2004), as well as the potential to influence young-of-year over-wintering energy expenditure (B. Kynard, BK RiverFish, personal communication, 2009). Figure 2-52 illustrates the average thermal regime for the pre-dam and post-dam periods.

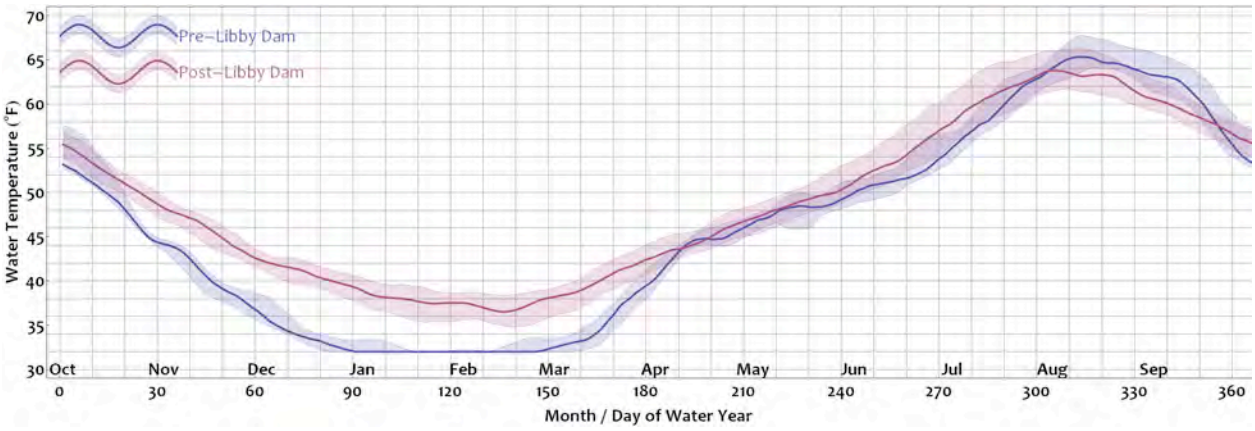
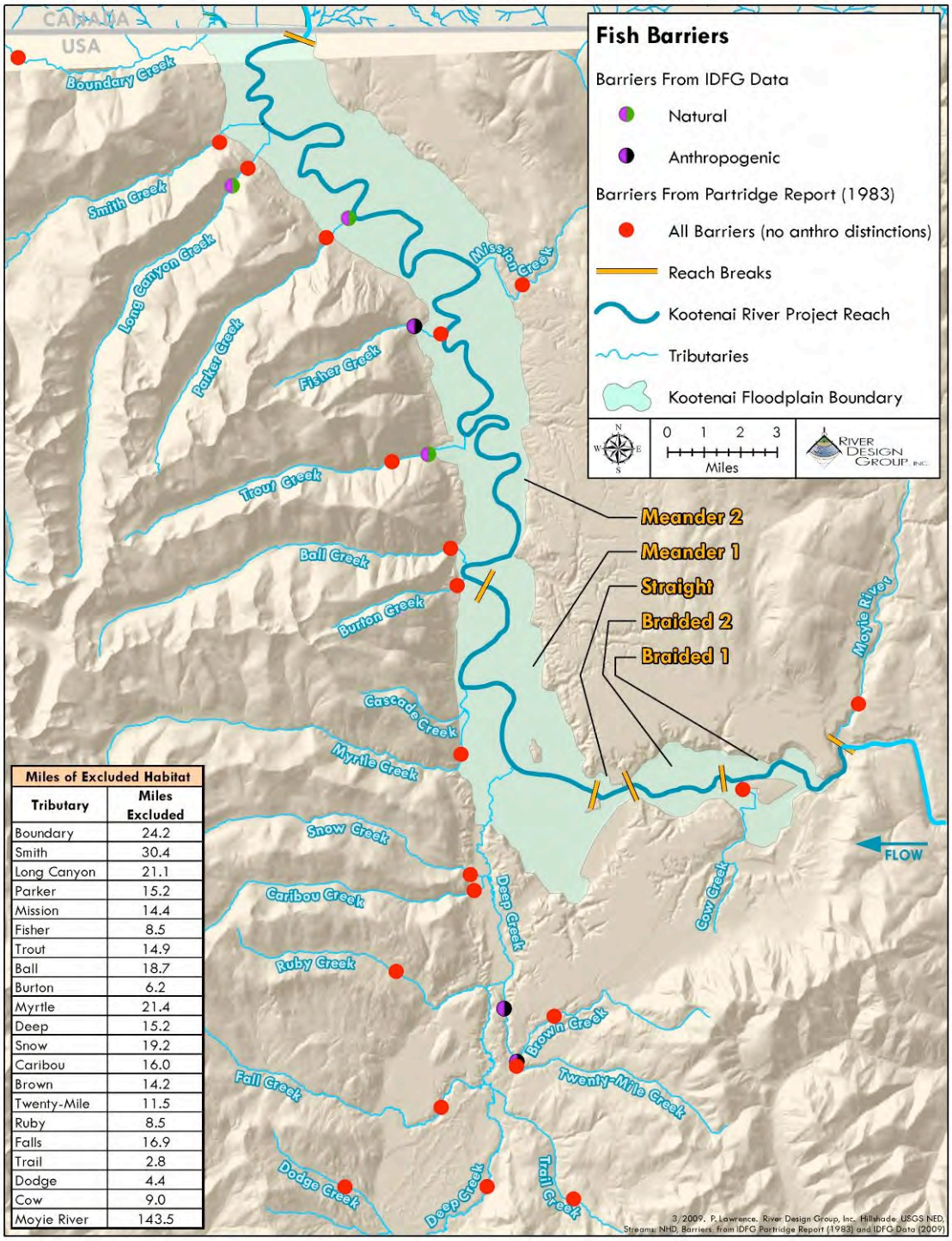


Figure 2-52. Average pre- and post-dam water temperature for the Kootenai River at Porthill (USGS Station #12322000).

Based on factors related to contaminants and changes in the thermal regime, ***altered water quality has been identified as an aquatic habitat limiting factor***.

Tributary connectivity with the Kootenai River is influenced by channel modifications, coarse bedload deposition in tributary deltas, and human infrastructure. Channel modifications including straightening, relocations, and dredging have affected tributary connectivity. Altered sediment-transport and deposition patterns have caused aggradation of sediments in the deltas of many tributaries to the Kootenai River upstream of the project area (KTOI and MFWP 2004). As a result, many of these deltas have become barriers to fish passage, especially at low flows. Other tributaries are impacted by both natural and anthropogenic fish passage barriers including natural falls and road crossings, respectively (Figure 2-53). Tributaries serve as important spawning and rearing habitat for many of the focal fish species, especially native trout and kokanee salmon.



Miles of Excluded Habitat	
Tributary	Miles Excluded
Boundary	24.2
Smith	30.4
Long Canyon	21.1
Parker	15.2
Mission	14.4
Fisher	8.5
Trout	14.9
Ball	18.7
Burton	6.2
Myrtle	21.4
Deep	15.2
Snow	19.2
Caribou	16.0
Brown	14.2
Twenty-Mile	11.5
Ruby	8.5
Falls	16.9
Trail	2.8
Dodge	4.4
Cow	9.0
Moyie River	143.5

Figure 2-53. Recognized fish passage barriers on tributaries to the Kootenai River project area. Barriers include both natural barriers like waterfalls, as well as human barriers such as road crossings. Many barriers are located at the transition from the valley floor to steeper forested reaches.

Based on this information about fish barriers in tributaries, ***lack of fish passage into tributaries has been identified as an aquatic habitat limiting factor***.

As described in Section 2.2 and 2.5, the aboriginal floodplain of the Kootenai River was modified to reduce flooding and optimize agriculture. Filling of floodplain wetlands and side channels, removal of large woody debris, and displacement of native riparian vegetation have simplified the floodplain ecosystem and resulted in the loss of off-channel habitat that likely supported life stages of some focal species in at least some years.

Removal of large woody debris, displacement of riparian vegetation, and filling of off-channel habitats has diminished cover habitats for juvenile fish rearing. Historically, the Kootenai River floodplain was a complex environment characterized by the mainstem river, backwater channels, and seasonal wetlands. Juvenile fish reared in floodplain tributaries and the mainstem would have inhabited shallow complex off-channel habitats influenced by vegetation and large wood. Flood protection measures and agricultural practices filled these habitats, creating a simplified mainstem river with little habitat complexity. Figure 2-54 illustrates the distribution of vegetation cover in the Kootenai River project area. The "No Vegetation" category dominates bank vegetation conditions. Table 2-24 presents descriptive statistics for the project area vegetation cover categories. Limited streamside vegetation equates to both short-term and long-term aquatic and riparian cover as vegetation that would recruit to a mature riparian forest is not currently present on the Kootenai River's floodplain.

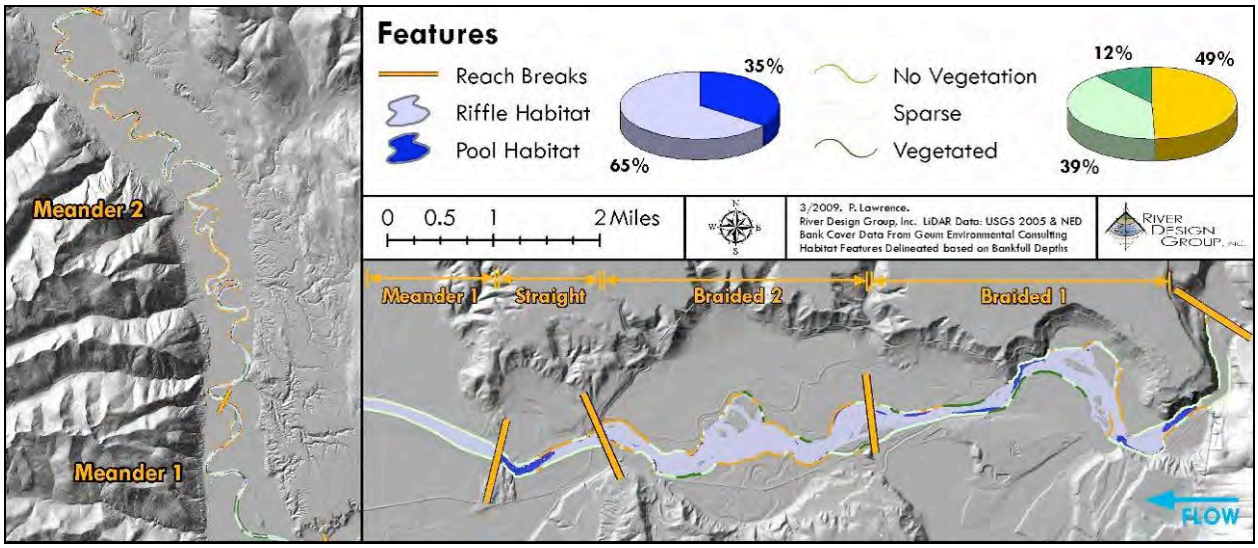


Figure 2-54. The distribution of bank vegetation cover conditions are presented as a proxy for streambank cover.

Table 2-24. Kootenai River bank cover conditions for the Master Plan project reach.							
Reach	**No Bank Cover**		**Sparse Bank Cover**		**Dense Bank Cover**		**Total**
	Length (ft)	% of Reach	Length (ft)	% of Reach	Length (ft)	% of Reach	(mi)
Braided 1	9,216	19.4	31,602	66.4	6,792	14.3	9.0
Braided 2	18,991	60.1	9,204	29.1	3,428	10.8	6.0
Straight	3,151	27.1	8,189	70.3	302	2.6	2.2
Meander 1	25,039	26.4	45,755	48.3	23,936	25.3	17.9
Meander 2	204,134	60.0	110,110	32.4	25,834	7.6	64.4
Total	**260,530**	**49.6**	**204,860**	**39.0**	**60,292**	**11.5**	**99.6**

Levees simplify the floodplain by restricting flood flows to the main channel. Similarly, flood water confinement to the channel reduces the overall productivity of the river-floodplain system as the shallow water habitats that are created on the floodplain during high flows are excluded by the levee network. Therefore, levees have reduced access to backwater and off-channel habitats which historically provided diverse microhabitats, food sources, and resting areas for fish in the Kootenai subbasin. Decreased floodplain-channel connectivity has resulted in fewer off-channel habitats in the system.

In-filling of gravel and fine gravel substrates with sand is reported to have reduced hiding habitat for free embryos and larval stage Kootenai sturgeon. Channel bed material simplification has decreased rearing habitat diversity and extent. Based on changes in the floodplain, loss of bank vegetation and construction of levees, and sand intrusion into interstitial spaces in the channel bed materials; ***lack of cover for larval and juvenile fish*** and ***lack of off-channel habitat for rearing have been identified as limiting factors for aquatic habitat***.

Development activities in the Kootenai subbasin dating to the early 1900s led to river corridor and aquatic habitat degradation. Extractive land uses affected the river ecosystem by disrupting river and floodplain functions; contributing sediment, nutrients, and contaminants to the river; and either erecting barriers in floodplain channels or impairing habitat in tributary streams. Further, over-fishing of Kootenai sturgeon and other focal species diminished the abundance of Kootenai River fish populations. The closure of Libby Dam in 1974 altered river hydraulics, sediment-transport, and river morphology resulting in additional adverse changes to the river ecosystem. Nutrients, water quality, and the thermal regime have also been affected by dam management. Combined with the ecosystem degradation that occurred prior to Libby Dam closure, river regulation has accentuated the ecosystem's departure from pre-European settlement river corridor conditions. The aforementioned conditions have created a suite of limiting factors that affect aquatic habitat in the project area.

2.7 Summary

In summary, the limiting factors presented in this chapter describe how human activities have affected the Kootenai River ecosystem in the project area. Limiting factors are defined as physical, biological, and ecological conditions that limit ecosystem sustainability and resiliency, negatively influence Kootenai sturgeon and other focal species, and affect the local social, cultural, and economic conditions. The detailed limiting factors analysis highlights how the Kootenai River ecosystem has been influenced largely by river and floodplain management. The

following chapter, Restoration Strategies, Treatments, and Habitat Actions (Chapter 3), proposes a hierarchical approach to overcoming the limiting factors through the implementation of habitat actions. The restoration "toolbox" approach is designed to apply specific restoration treatments to address limiting factors in each reach of the Kootenai River project area.