Upper Columbia Alternative Flood Control and Fish Operations

Columbia River Basin

Draft Environmental Impact Statement
Executive Summary

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Boise, Idaho

U.S. Department of Defense
Army Corps of Engineers
Seattle District
Seattle, Washington

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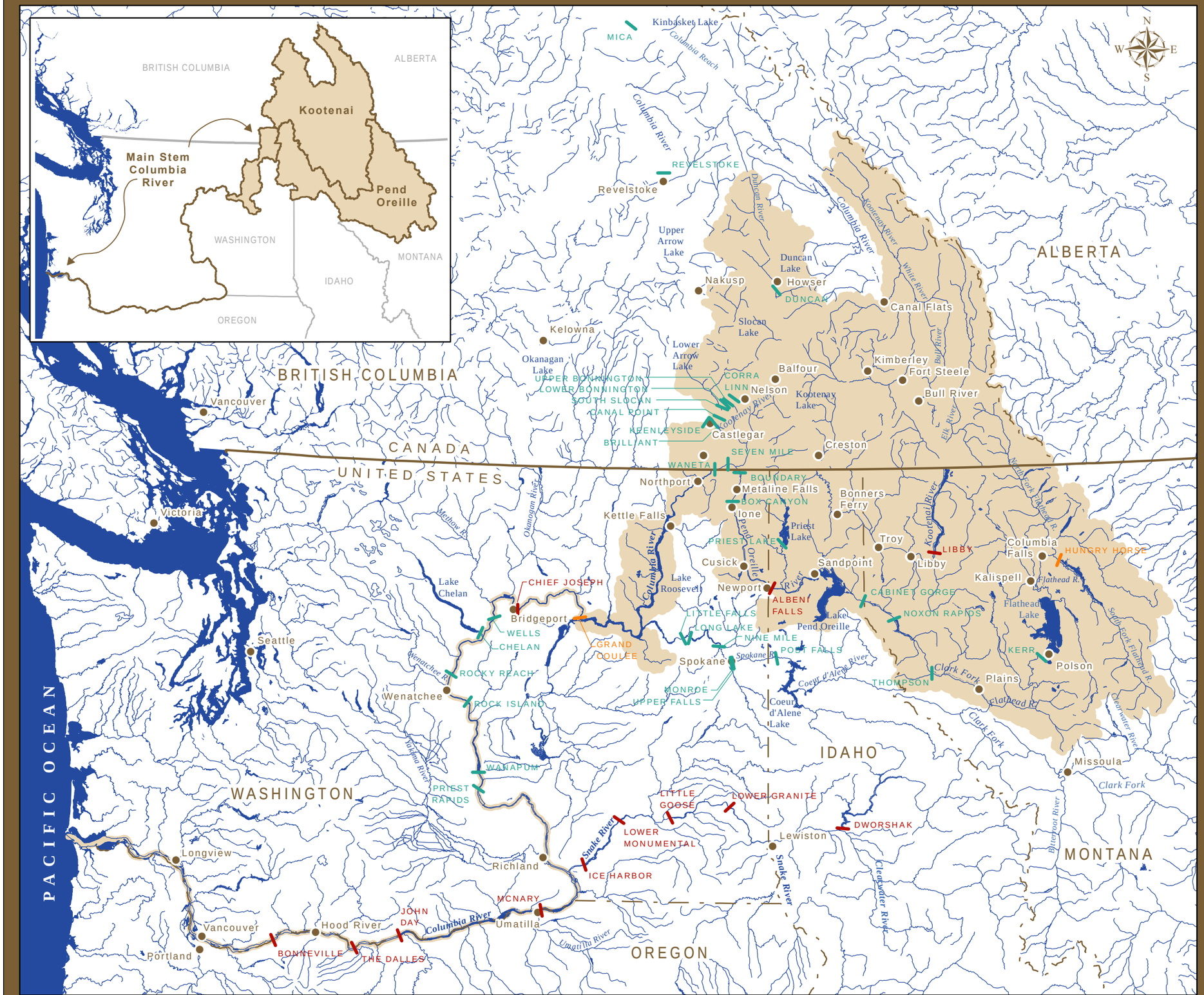

Frontispiece

Major Dams of the Columbia River System

- Army Corps of Engineers
- Bureau of Reclamation
- Other
- Study Area of Interest

0 25 50 75 100

Miles

DRAFT

Sources:

Bureau of Reclamation, Pacific Northwest Region GIS
Government of British Columbia, Ministry of Sustainable Resource Management

June 2005

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EXECUTIVE SUMMARY

Introduction

In accordance with the National Environmental Policy Act of 1969 (NEPA), 42 USCA §§ 4321-4370e, the U.S. Army Corps of Engineers (Corps) and the Bureau of Reclamation (Reclamation) have prepared a draft environmental impact statement (DEIS) to assess the potential effects of a proposed Federal action and alternatives, which have the potential to significantly affect the human environment. The Corps and Reclamation, the lead agencies for this project, identified alternative flood control operations for Libby Dam on the Kootenai River and Hungry Horse Dam on the South Fork Flathead River. The agencies developed the alternatives based on scoping comments, the 2000 U.S. Fish and Wildlife Service Biological Opinion and the 2004 NOAA Fisheries Biological Opinion concerning operations of Federal Columbia River Power System dams. The 2004 NOAA Fisheries Biological Opinion was remanded but remains in effect until reconsultation is completed.

The proposed Federal action consists of:

1. Implementation of alternative flood control at Libby Dam on the Kootenai River and Hungry Horse Dam on the South Fork Flathead River. Called variable discharge flood control, this alternative action is known as "VARQ FC," with VAR representing "variable," Q representing engineering shorthand for discharge, and FC representing flood control.

2. Flow augmentation that such alternative flood control would facilitate in the Kootenai River, the Flathead River, and main stem Columbia River for fish populations listed as threatened or endangered under the Endangered Species Act (ESA). Flow augmentation (i.e., fish flows) includes release of water from Libby and Hungry Horse dams for bull trout, salmon, and steelhead, and from Libby Dam for white sturgeon. Releases for salmon and steelhead are at McNary Dam and releases for Chum Salmon are at Bonneville.

Purpose of the Proposed Action

The purpose of the proposed action is to provide reservoir and flow conditions at and below Libby and Hungry Horse Dams for anadromous (main stem Columbia River) and resident fish listed as threatened or endangered under the ESA, consistent with authorized project purposes, including maintaining the current level of flood control benefits.

Need for the Proposed Action

Multiple purpose project operations at Libby, Hungry Horse, and other dams have altered the natural river hydrology of the Columbia River and some of its major tributaries. These dams store the spring snowmelt runoff to control floods, and release water for multiple uses. Populations of threatened and endangered fish in the Columbia River Basin (Kootenai River white sturgeon, Columbia Basin bull trout, and several Columbia River salmon and steelhead stocks) benefit from certain high flow periods, which historically were determined by natural runoff patterns driven by snowmelt and rainfall. While the status of bull trout populations in the Kootenai and Flathead Rivers is generally better than some others in the Columbia River Basin, Kootenai River white sturgeon numbers are estimated at fewer than 500, down from numbers of 5,000 to 6,000 in the 1980s, and are declining at approximately 9 percent per year. Several salmon and steelhead populations in the Columbia River Basin are in various states of decline. For example, lower Columbia River coho salmon were listed as threatened in June 2005.

The 2000 NOAA Fisheries biological opinion on the operation of the Federal Columbia River Power System (FCRPS) included a reasonable and prudent alternative with a recommendation to implement VARQ FC at Libby and Hungry Horse Dams. In response to a Court-ordered remand of this biological opinion, the Action Agencies (Corps, Reclamation, and Bonneville Power Administration) prepared an Updated Proposed Action (UPA) which carried forward implementation of interim VARQ FC operations at Libby and Hungry Horse Dams, pending completion of this EIS. The 2004 NOAA Fisheries Service Biological Opinion, issued in November 2004, considered the Action Agencies UPA and made a no-jeopardy determination. This biological opinion was also remanded and the reconsultation is to be completed September 30, 2006. The 2004 biological opinion and the UPA are in effect in the interim.

The U.S. Fish and Wildlife Service (USFWS) determined Kootenai River white sturgeon were jeopardized by the operation of Libby Dam, bull trout were jeopardized by the operations of Libby and Hungry Horse Dams, and recommended actions in their 2000 Biological Opinion on the operation of the FCRPS. Some of those actions, including VARQ FC, would modify dam operations and river flows to avoid jeopardizing the continued existence of threatened Columbia Basin bull trout and endangered Kootenai River white sturgeon.

Columbia River System and Local Flood Control

The basic objective of Columbia River system flood control operations is to regulate the total reservoir system to minimize flooding at all potential flood-prone areas in Canada and the United States when possible and, in years with very high runoff, to regulate flows at The Dalles, Oregon, for the protection of Portland, Oregon, and Vancouver,

Washington. Storage dam operations are designed to manage for local and system flood control while increasing probability of refill of storage reservoirs at the end of the spring runoff.

In the context of system flood control operations, storage reservoirs throughout the Columbia River Basin release water from January through April using guidance provided by a storage reservation diagram (SRD) to create flood control storage space. A SRD shows how much water storage space is required on a certain date in each reservoir for the most current seasonal water supply forecast. In early January, water supply forecasts (WSFs) are developed for each subbasin and for the Columbia River system to The Dalles. Based on the WSF, and using the SRD as guidance, the Corps calculates the end-of-January reservoir target elevation required to provide storage space to meet flood control objectives at The Dalles. In early February, a new WSF is used to develop updated end-of-February reservoir target elevations. The process repeats for each month through April. Reservoirs typically reach their maximum flood control draft on or about May 1. Reservoir refill in May and June is based on the calculated natural flow at The Dalles, the remaining water supply forecast, reservoir space available, and the weather forecast.

In addition to providing water storage for system flood control, Libby and Hungry Horse Dams provide local flood control for downstream river reaches in the vicinity of the dams. Operations for local flood protection occur on a real-time basis and are provided by individual dams.

Standard and VARQ Flood Control

In the past, Libby and Hungry Horse Dams operated using Standard FC. Under Standard FC, the dams would generally release high flows from January through April in order to make space to capture the spring runoff in May, June, and July; from January through April, reservoir levels typically dropped. This process of reducing reservoir levels by releasing water is called “drafting.” Because the reservoirs drafted a large amount of storage under Standard FC, they historically released little water during the May through July period in order to refill. An assumption of the Standard FC procedure was that each dam could minimize outflow during the refill period.

The Corps and Reclamation now release water from Libby and Hungry Horse Dams for flow augmentation. At Hungry Horse Dam, for example, these releases occur during the summer months for salmon flow augmentation and year-round in the form of minimum flows for bull trout. Libby Dam provides flow augmentation for white sturgeon in addition to summer bull trout minimum flows and salmon flow augmentation. Because these fish flow releases are higher than those originally designed into Standard FC, the reservoirs have a noticeably reduced likelihood and frequency of refilling.

Variable discharge flood control was developed to improve the multipurpose operation of Libby and Hungry Horse Dams while not reducing the level of local or main stem flood protection in the Columbia River. As a flood control procedure, VARQ FC was not designed specifically for flow augmentation for fish. However, implementation of VARQ FC at Libby and Hungry Horse Dams enables the Corps and Reclamation to more reliably supply spring and summer flows for fish while simultaneously better ensuring higher reservoir elevations in the summer. The USFWS and NOAA Fisheries support VARQ FC because of the improved probability of providing flows for listed fish in spring and summer.

Generally, VARQ FC requires less system flood control space at Libby and Hungry Horse Dams prior to spring runoff. The flood control space required in a given year varies based on each dam's seasonal water supply forecast (WSF) for that year. In years where the April to August seasonal WSF is between about 80 and 120 percent of average at Libby Dam and between 80 and 130 percent at Hungry Horse Dam, the VARQ FC reservoir elevation typically would be higher than Standard FC during the January through April drawdown period. For forecasts greater than 120 percent of average, Libby Dam typically does not achieve the draft required by either VARQ FC or Standard FC because Libby Dam outflows must be reduced to comply with the IJC Order of 1938 concerning Kootenay Lake levels. In years where the seasonal water supply forecast is higher than about 120 percent of the average volume at Libby Dam and 130 percent at Hungry Horse Dam, storage space for flood control would be the same for either VARQ FC or Standard FC.

During reservoir refill, VARQ FC and Standard FC also differ. Standard FC may reduce dam releases to minimum flows during the refill period from May through July. In contrast, in years where the WSF at Libby and Hungry Horse Dams are about 80 to 120 percent of average, the VARQ FC refill outflow is generally greater than minimum flows. The basic premise of VARQ FC is that the dam discharges during the refill period can vary based on the seasonal WSF, actual reservoir elevation, and the estimated duration of flood control. Some of the water that would be stored during the refill period under Standard FC is instead passed through the dam, which reduces the flood control storage space needed under VARQ FC without compromising system flood control.

Since the flood control draft at Grand Coulee Dam is based, in part, on the available storage space upstream from The Dalles, VARQ FC at Libby and Hungry Horse Dams influences operations for system flood control at Grand Coulee Dam. In years when VARQ FC operations result in higher reservoir elevations and less flood control storage space at Libby and Hungry Horse Dams, Grand Coulee Dam may draft deeper to maintain system flood protection at The Dalles. In practice, Grand Coulee Dam typically may draft deeper for flood control in years with seasonal WSFs between 86 and 100 percent of average. The increase in flood control draft at Grand Coulee Dam would be

less than the net decrease in draft at Libby and Hungry Horse Dams caused by VARQ FC operations.

Interim Implementation of VARQ FC

Based on analyses of the effects of interim (short-term) implementation of VARQ FC operation at Hungry Horse and Libby Dams, Reclamation implemented VARQ FC at Hungry Horse Dam in winter 2002 and the Corps implemented VARQ FC at Libby Dam in winter 2003. This DEIS addresses long-term implementation of VARQ FC at both dams. In addition, this DEIS evaluates potential effects of fish flow operations at Libby Dam involving discharges greater than the existing powerhouse capacity, actions which were beyond the scope of the interim decision-making process.

Libby Dam Alternatives

The alternatives are referred to by the abbreviations shown in Table S-1. The alternatives for Libby Dam operations vary in terms of flood control and recommended fish flow augmentation.

Table S- 1. Alternative abbreviations used in this EIS.

Abbreviation	Project Feature or Alternative Operation
L	Libby Dam
H	Hungry Horse Dam
S	Standard FC
V	VARQ FC
1	fish flows up to powerhouse capacity (25 kcfs)
2	fish flows 10 kcfs above powerhouse capacity (35 kcfs)
kcfs = thousand cubic feet per second	

Alternative LS1 – Standard FC with fish flows up to powerhouse capacity (No Action Alternative)

Alternative LS1, the no action alternative for Libby Dam, consists of Standard FC with sturgeon, bull trout, and salmon flow augmentation. Sturgeon flow augmentation would provide tiered sturgeon volumes as modified from the 2000 USFWS FCRPS Biological Opinion using a maximum Libby Dam discharge rate up to the existing powerhouse capacity (about 25,000 cubic feet per second, or 25 kcfs).

Alternative LV1 – VARQ FC with fish flows up to powerhouse capacity (Preferred Alternative)

Alternative LV1 is the preferred alternative for Libby Dam. As of 2003, it is the current interim operation for Libby Dam and consists of VARQ FC with sturgeon, bull trout, and

salmon flow augmentation. Sturgeon flow augmentation would provide tiered sturgeon volumes from the 2000 USFWS FCRPS Biological Opinion using a maximum Libby Dam discharge rate up to the existing powerhouse capacity (about 25 kcfs).

Alternative LS2 – Standard FC with fish flows up to powerhouse capacity plus 10 kcfs

Alternative LS2 is the same as alternative LS1, except that it would provide sturgeon flow augmentation up to 35 kcfs from Libby Dam (about 10 kcfs above existing Libby Dam powerhouse capacity).

While this EIS evaluates the effects of increasing flow capacity at Libby Dam for sturgeon, it does not consider the mechanism by which such flows could be achieved. Based on engineering analyses, Libby Dam would require modifications such as changes to the spillway configuration or installation of additional units to achieve an additional 10 kcfs above existing powerhouse capacity within Montana's total dissolved gas (TDG) standard of 110 percent saturation. To date, a reliable method has not been identified that would provide the additional flows within existing TDG standards, or within existing power system limitations concerning power markets and transmission facilities.

Impacts on TDG and any other impacts specific to any mechanism for providing additional flows are not addressed in this EIS because the mechanism for achieving the additional 10 kcfs discharge capacity is unknown. If a decision were made to pursue additional flow capacity in the future, a study of potential mechanisms could be evaluated as part of future dam modification alternatives.

Alternative LV2 – VARQ FC with fish flows up to powerhouse capacity plus 10 kcfs

Alternative LV2 would provide sturgeon flows using a maximum Libby Dam discharge rate up to 10 kcfs above the existing powerhouse capacity (to a total discharge of about 35 kcfs). As with alternative LS2, impacts of the flows are addressed, but the impacts of the dam modifications that may be necessary to achieve the additional flow capacity would be subject to future potential NEPA processes because no mechanism to achieve additional flow capacity has been identified within existing TDG standards, or power market and transmission limitations.

LS and LV Benchmarks

The 1995 Columbia River System Operation Review (SOR) EIS evaluated effects of Libby Dam fish flows. New information became available after publication of the SOR EIS which included modification of the fish flows, and prompted further evaluation through this EIS.

The LS and LV benchmarks do not include fish flows from Libby Dam. However, these benchmarks afford the opportunity to address additional information on potential effects of fish flows up to existing Libby Dam powerhouse capacity, and were included only for that purpose. This new information also provides an opportunity to update the evaluation of groundwater seepage in the Kootenai River valley in Idaho and to evaluate the effects of flows on sturgeon reproduction. The benchmarks are not included as alternatives because they do not meet the purpose and need of the proposed action.

Hungry Horse Dam Alternatives

The alternatives for Hungry Horse Dam operations vary in terms of flood control and both alternatives provide bull trout minimum flows and salmon flow augmentation. The effects of bull trout minimum flows and drafts for salmon flow augmentation were addressed in the 1995 Columbia River SOR EIS.

Alternative HS – Standard FC with fish flows (No Action Alternative)

Alternative HS, the no action alternative for Hungry Horse Dam is Standard FC with bull trout and salmon augmentation flows. Standard FC operations are the historic operations and are based on the principle of deep winter drafts of the reservoir for flood control then minimizing outflow during the refill period from May through June 30.

Alternative HV – VARQ FC with fish flows (Preferred Alternative)

Alternative HV, the preferred alternative for Hungry Horse Dam, consists of flood control using VARQ FC with bull trout and salmon augmentation flows. This is the current interim operation at Hungry Horse Dam and is based on less winter reservoir draft for flood control during years with 80% to 130 % normal forecast and increases releases during the refill period in May and June.

Main Stem Columbia River Alternative and Benchmark Combinations

The effects of Libby Dam and Hungry Horse Dam alternatives and benchmarks are evaluated in the main stem Columbia River downstream from the Kootenai River and Pend Oreille River tributary systems. Thus, for analysis of the environmental effects in the Columbia River upstream and downstream from Grand Coulee Dam for power generation and related economic values, alternative and benchmark combinations are derived by combining Libby Dam and Hungry Horse Dam alternatives and benchmarks

(Table S-1). As with Libby Dam benchmarks LS and LV, benchmark combinations LS+HS and LV+HV are included as a tool to derive the effects of fish flows from Libby Dam on the main stem Columbia River.

Table S- 2. Main stem Columbia River alternative combinations and benchmarks.

	Flood Control Method at Libby and Hungry Horse Dams		Fish Flows Provided at Libby Dam				Fish Flows Provided at Hungry Horse Dam	
Alternative Combinations	Standard FC	VARQ FC	Sturgeon up to ~25 kcfs	Sturgeon up to ~35 kcfs	Bull trout	Salmon	Bull trout	Salmon
LS1+HS	x		x		x	x	x	x
LV1+HV		x	x		x	x	x	x
LS2+HS	x			x	x	x	x	x
LV2+HV		x		x	x	x	x	x
Benchmark Combinations								
LS+HS	x		none				x	
LV+HV		x	none					x

Issues Addressed in this EIS

The Corps and Reclamation initiated a joint NEPA process to analyze the effects of long-term implementation of the VARQ FC strategies at Libby and Hungry Horse Dams with publication in the Federal Register of the Notice of Intent to prepare an EIS on October 1, 2001.

Public scoping meetings were held at Grand Coulee, Washington; Sandpoint, Idaho; Bonners Ferry, Idaho; Portland, Oregon; Libby, Montana; Eureka, Montana; Kalispell, Montana; and in Creston, British Columbia, Canada. In addition to the meeting comments, comment forms and letters from tribes, agencies, and interested parties were also received.

Through scoping and interdisciplinary analysis, the following issues were identified for consideration in this DEIS.

Issue 1: Flood control and related impacts

Libby Dam and Hungry Horse Dam are important facilities for controlling local and system flooding and related impacts. The DEIS addresses how the alternatives would modify flood control operations and fish flows.

Issue 2: Fisheries and other biological impacts and benefits

The proposed modifications to flood control operations and fish flows are primarily intended to benefit fish stocks listed under the ESA, including Kootenai River white sturgeon (endangered), bull trout (threatened), and various stocks of Chinook, chum, coho, and sockeye salmon, and steelhead (threatened and endangered). The DEIS addresses how the alternatives would affect the fisheries resource.

Issue 3: Water and air quality impacts

The DEIS addresses how the changes in flood control operations and fish flows may directly influence water quality and may have indirect effects on air quality.

Issue 4: Cultural resource protection and related impacts

The DEIS addresses how changes in reservoir elevations and shoreline erosion and exposure can influence the likelihood of discovery, looting, and vandalism of prehistoric artifacts and human remains along Lake Roosevelt (the reservoir behind Grand Coulee Dam) and elsewhere.

Issue 5: Recreation impacts

The DEIS addresses how changes in reservoir levels and streamflows can influence the quality and availability of water-based recreation opportunities.

Issue 6: Power generation impacts

The DEIS addresses how changes in flood control operations and fish flows can affect power generation at Hungry Horse Dam, Libby Dam, and numerous dams downstream.

Issue 7: Economic impacts

The DEIS addresses how changes in flood control operations and fish flows can directly or indirectly influence local and regional economies.

Cumulative Impacts

Cumulative impacts for the Kootenai and Pend Oreille subbasins and along the main stem Columbia River were analyzed based on the incremental consequences of the different alternatives when added to other past, present, and reasonably foreseeable future actions. Notable potential cumulative impacts are summarized below.

Kootenai River Basin

Adaptive management of dam operations would consider multiple uses to provide more normative flow conditions and help maintain Lake Koocanusa levels during the summer. While the flow patterns that are possible under the alternatives would provide a semblance of normative river conditions, over the course of any given year, they would still be significantly different from pre-dam conditions in terms of magnitude, duration, and timing. Due to heat storage in Lake Koocanusa as a result of Libby Dam construction, the addition of fish flows would tend to increase the possibility of temperature fluctuations in the river downstream of the dam. The expansion of Brilliant Dam on the Kootenay River downstream of Kootenay Lake may serve to decrease the duration or degree of high total dissolved gas levels resulting from fish flows or VARQ FC operations.

Physical modification of riparian and floodplain areas and various operational requirements (Kootenay Lake operations, flood control requirements) can, under certain circumstances, constrain opportunities for ecosystem and species recovery actions that rely solely on operational flexibility that would be provided by the various alternatives. Such constraints could prevent or diminish effectiveness of the suite of actions that are possible under the different alternatives and likely necessary to successfully recover and sustain ecosystem functions. All of the alternatives would provide a degree of flexibility to provide more normative river flows during the spring and summer, with resultant synergistic benefits to ecosystem functions (i.e. riparian habitat development, habitat connectivity) and sensitive, threatened, and endangered species such as sturgeon, bull trout, burbot, and bald eagles. The VARQ FC alternatives and higher fish flows possible under LS2 and LV2 provide the greatest flexibility to manage river flows in concert with ecosystem recovery efforts to generate higher relative ecosystem benefits.

Benefits to the regional ecosystem could provide long-term recreational opportunities to anglers and eco-tourists, with resulting benefits to local economies. Future expansion of crops that are sensitive to shallow groundwater would further worsen agricultural impacts from groundwater seepage linked to higher river flows during the spring and summer. Floodplain development could also influence the development of flow regimes intended for ecosystem and species recovery.

Libby Dam construction and the resulting creation of Lake Koocanusa has placed some cultural resources out of reach of looters and vandals, but has allowed exposure of others in wave-affected zones. All known sites around Lake Koocanusa have been impacted by reservoir operations since 1972. The better the chance of refill under the VARQ FC alternatives would reduce exposure.

Pend Oreille River Basin

The various state programs such as the 1998 Watershed Planning Act in Washington, the water quality restoration plans and new TMDL program in Montana and the establishment of TMDLs in Idaho are intended to improve water quality, water supply, and habitat.

Cumulatively, ongoing stream and riparian restoration measures, TMDL processes, state agency programs, and other conservation activities in conjunction with Federal recovery efforts, could help preserve and possibly improve habitat conditions for bull trout populations.

Main Stem Columbia River

Climate changes may alter development patterns in floodplains, depending on shifts in runoff patterns and the ability of the Federal Columbia River Power System to manage them for flood control. Since system flood control under all alternative combinations is essentially equivalent, cumulative impacts under all the alternative combinations would also be comparable.

Alternative combinations with fish flows and with VARQ FC would assist in efforts to provide more normative hydrographs in the main stem Columbia River which would likely provide a cumulative benefit to overall ecosystem health. Such normative flow conditions would likely need to be adaptively managed to determine the most effective multi-purpose operation given the changes in river character due to the existence of the main stem Columbia River dams and recognize that such flow patterns likely would not maximize other uses of the system (such as hydropower generation and its economic benefits). At Grand Coulee Dam and Lake Roosevelt, small changes in the timing and degree of reservoir fluctuation that would result from the various alternative combinations will not substantially alter the character, scope, or nature of Lake Roosevelt, particularly since any observed changes will be within the current operating range.

Alternative combinations that result in lower annual or monthly generation may result in more power generation from sources such as fossil fuel-powered generators that can quickly meet demand. Changes in flow patterns resulting from climate changes may force additional changes in system operations to better balance power generation with ecosystem recovery objectives. Any reduction in flows from drought or climate shifts may lead to relatively lower ecosystem recovery capability. No cumulative impacts on the electrical transmission system are anticipated.

Actions now being undertaken, such as flow deflector construction at Chief Joseph Dam, expansion of Brilliant Dam, and the generation and spill switch between Grand Coulee

and Chief Joseph dams, would enhance the ability of the system to manage spill and TDG generation. Further population growth in the region might cause development of greater power generating and transmission capacity, but the utility of that to ameliorate TDG issues would depend on the ability of the system to incorporate it in a manner that would offset spill.

The provision of more normative flows for fish and aquatic life presents opportunities for successful maintenance of habitat conditions they need. Fish flows in all alternative combinations would cumulatively improve the ability of the system to meet flow objectives at Priest Rapids and McNary Dams for anadromous fish migration and would provide more options to achieve recovery of threatened and endangered fish stocks over the long term. Demands for water, and impacts to watersheds would continue to be a factor in determining the health of aquatic species. It is conceivable that aquatic species would continue to be adversely affected in the long run as development and mitigation balance against each other. If anadromous fish passage should be instituted at Chief Joseph and Grand Coulee dams, then reservoir management under all alternative combinations might need to be adjusted for smolt migration.

Continued regional growth is expected to add to demand for recreational use, and possibly to facilities and types of opportunities, but may negatively impact some of the resources at which that demand is targeted. Degradation of water quality is a possibility, as is overall loss of fish and wildlife habitat, to the detriment of those resources. Visual resources and esthetic values might also decline. To the extent that habitat is maintained or enhanced, and to the extent that fish and wildlife resources can be maintained and recovered in the face of competing interests, then cumulative impacts to recreation would be decreased.

All known historic properties at Lake Roosevelt have undergone impacts from the operation of Lake Roosevelt over the past 70 years, including loss of site integrity and of individual items. Cumulative effects from past, present, and foreseeable future actions include increased weathering to organic materials, artifact movement or damage from human and animal use of the shoreline, and loss from illegal collecting activities.

Mitigation

Potential mitigation measures are identified, even if they might be outside the jurisdiction of the the Corps or Reclamation. Some of the identified measures may be undertaken by other entities or individuals. Implementation of mitigation actions would be subject to authority and funding available to the Corps, Reclamation, or any other entity which may carry them out. No commitments are made in this EIS to any mitigation action, particularly those that are not currently authorized, programmed, and funded. Notable potential mitigation measures are summarized below.

Kootenai River Basin

It is not possible to avoid flooding at all times, and the presence and operation of the dam reduces flooding considerably compared to without-dam conditions. No mitigation is proposed for occasional flooding, because the alternatives are not considered to increase flood risk. If local landowners wish to further decrease flood risk above that provide by Libby Dam operations, then discussion of levee repairs and upgrades, structural relocation, and individual structural floodproofing are potential measures that may be pursued. To decrease impacts due to high groundwater, capacity of drainage systems such as pumping facilities could be increased. Local drainage districts would be the most appropriate organizations to fund and carry out any drainage upgrades.

Modification of the dam to provide for spillway deflectors, additional discharge capacity via the powerhouse, or other options could reduce TDG loadings due to rare flood control spill events (i.e. when the current dam configuration would require forced spill over the existing spillway) and resulting adverse impacts to aquatic life. However, such dam modifications that may provide water quality and aquatic ecosystem benefits on relatively rare occasions could be ineffective or costly, making implementation of these options unlikely in the near-term. Ongoing fertilization of the Kootenai River and Kootenay Lake will help minimize effects from any increased nutrient flushing. Options to reduce potential adverse effects from flooding of waterfowl and shorebird nesting areas, as well as reptile and amphibian reproductive sites, could include increased pumping capacity or increasing the height of levees protecting sensitive nesting areas, or compensation for pumping costs in the Creston Valley Wildlife Management Area. Other possible mitigation may include connection to the river for nesting areas which are currently behind dikes, so that water level rises in nesting areas are more synchronous with onset of lowland runoff. These actions would be the responsibility of Canadian land and resource management organizations.

Appropriate mitigation for adversely affected cultural resources sites is being formulated in Site Treatment Plans and Site Protection Plans by the Corps, and mitigation planning will continue under the current cultural resources management program at Libby Dam—Lake Koocanusa. Mitigation may include documentation, surface collection of artifacts and features, site stabilization, or more intensive data recovery. The Corps, BPA, Kootenai National Forest, Confederated Salish and Kootenai Tribes, and the Montana SHPO will continue to coordinate to mitigate impacts as needed under the current program.

Potential mitigation for economic impacts due to agricultural impacts due to groundwater seepage include upgrades to drainage and pumping systems or removing seepage-affected areas out of agricultural production. The cost-effectiveness of mitigation for agricultural seepage may be low.

Pend Oreille River Basin

No mitigation needs were identified based on the impact analysis.

Main stem Columbia River

Adaptive management of river flows would minimize exceedance of total dissolved gas standards. Flow deflector construction at Chief Joseph Dam and operational shifts of generation and spill between Chief Joseph and Grand Coulee dams would cumulatively reduce the magnitude of high total dissolved gas events below Grand Coulee Dam.

Mitigation for cultural resources could include appropriate additional management actions for historic properties affected by implementation of VARQ FC including erosion monitoring targeted to affected sites, completion of the evaluation process for affected sites to determine appropriate mitigation efforts, and public outreach/education. Protective patrols are already in place during the April drawdown, and Reclamation would work with patrolling agencies and tribes to make any needed adjustments in spatial focus.

Discovery of new sites or site components, or impacts to known sites, would be managed through the current cultural resources program at Lake Roosevelt. No specific mitigation is needed or planned for cultural resources impacts below Grand Coulee Dam.

Effects on other resources are expected to be beneficial, minor, or not capable of being mitigated.

Unavoidable Adverse Effects

The various alternatives may create some unavoidable and adverse effects on some resources in some impact areas. Notable unavoidable adverse effects are summarized below.

Kootenai River Basin

Potential unavoidable adverse impacts in the Kootenai River basin include:

- Possible flooding under any of the alternatives since Libby Dam cannot prevent flooding under all circumstances.
- Increased likelihood of forced spill, in terms of frequency and duration, at Libby Dam with the VARQ FC alternatives compared to the Standard FC alternatives. Spill would increase TDG concentrations in the river downstream, between the dam and Kootenai Falls, which could adversely affect aquatic life (including sensitive and threatened fish species).

- Increased heat storage in Lake Koocanusa under VARQ FC alternatives due to higher winter elevations.
- Increased nutrient flushing from Kootenay Lake.
- Fish stranding in the Duncan River delta.
- Adverse effects on spawning burbot due to relatively high winter water temperatures under VARQ FC.
- Adverse effects to wetland vegetation under Standard FC due to relatively lower spring and summer river levels and resulting poor hydrologic connectivity between the river and riparian areas.
- Adverse effects to amphibians, and nesting waterfowl and shorebirds in the Creston Valley Wildlife Management Area due to high water levels under VARQ FC.
- Reduction in recreational use and access along Lake Koocanusa, and reduction in swimming and shore fishing days on the Kootenai River downstream of Libby Dam.
- Impacts to archaeological sites and other historic properties along the reservoir shoreline due to their static and perishable nature.
- Increased costs for agricultural drainage pumping along the Kootenai River.
- Economic losses due to impacts from groundwater seepage in agricultural lands.
- Economic losses due to less-reliable Lake Koocanusa refill under Standard FC or alternatives with fish flows to 10 kcfs above current Libby powerhouse capacity.

Pend Oreille River Basin

- The existing potential for adverse flooding effects would remain under the implementation of either alternative.
- The existing potential for elevated TDG saturation during high water events would continue under the implementation of either alternative.
- Impacts arising from implementation of either alternative to archaeological sites or other historic properties along the reservoir shoreline are unavoidable because of the static nature of historic properties.

Main Stem Columbia River

Potential unavoidable adverse impacts along the main stem Columbia River include:

- Potential flooding since the Federal Columbia River Power System can never prevent all flooding.

- Under VARQ alternative combinations, reduction in power generation in winter, a high-demand and high-value time of year.
- Occasional total dissolved gas levels above 120% saturation, with a high incidence under VARQ FC alternative combinations, at Cabinet Gorge, Priest Rapids, Wanapum, Rock Island, and Rocky Reach dams, which may adversely affect aquatic life, including threatened and endangered fish, in the main stem river.
- Some increased vandalism, erosion, and looting arising from VARQ FC alternative combinations at archaeological sites and other historic properties along the Lake Roosevelt shoreline, primarily because of the static nature of these resources.
- Reduction in power generation in the winter under VARQ FC alternative combinations would reduce revenues from power sales to Federal, non-Federal, and Canadian power producers.

Summary Comparison of Alternatives

The following tables provide summary comparisons of the alternatives and benchmarks at Libby Dam, alternatives at Hungry Horse Dam, and alternative and benchmark combinations in the main stem Columbia.

Table S-3. Summary comparison of the no action and action alternatives and benchmarks at Libby Dam.

Resource	Alternative LS1 (No Action)	Alternative LV1 (Preferred)	Alternative LS2	Alternative LV2	Benchmark LS	Benchmark LV
Hydrology and Flood Control						
Lake Koocanusa	Median draft 2370'; median July elevation 2440'; within 5' of full in 12% of years. Libby Dam peak discharges at about 25 kcfs. Fish flows eliminate need for flood control spills above powerhouse capacity.	Median draft 2396'; median July elevation 2446'; within 5' of full in 31% of years. Libby Dam peak discharges similar to LS1. Highest average outflow during July/Aug. of any alternative. Increased likelihood of 1' higher flood stage at Bonners Ferry than LS1 (below 1764').	Median draft 2370'; median July elevation 2440'; within 5' of full in 10% of years. Libby Dam peak discharges at about 35 kcfs. Peak stages at Bonners Ferry are the second highest of any alternative 20% of time, but lowest river stage 80% of time.	Median draft 2396'; median July elevation 2445'; within 5' of full in 31% of years. Libby Dam peak discharges slightly higher than LS2 (35 kcfs) during drier years, similar to LS2 in wetter years. Peak stages at Bonners Ferry are the highest of any alternative.	Median draft 2370'; median July elevation 2458'; within 5' of full in 98% of years. Average Libby Dam discharges and Bonners Ferry stages during May, June, and August are the lowest of any alternative. Peak discharges are distinctly lower than all fish flow alternatives for most years below flood stage.	Median draft 2396'; median July elevation 2458'; within 5' of full in 98% of years. Libby Dam peak discharges are lower than all fish flow alternatives. Below flood stage, tends to produce peak Bonners Ferry stages higher than LS, but below all of the alternatives with fish flows.
Kootenay Lake	Levels fall within the middle of the range for the various alternatives.	Peak elevation is slightly higher than LS1, but lower than LS2 or LV2.	Peak elevation is higher than any alternative other than LV2.	Produces the highest likelihood of any given Kootenay Lake peak stage.	Tends to produce the lowest Kootenay Lake peak stages of any alternative.	Produces lower Kootenay Lake peak stages than any of the fish flow alternatives.
Water Quality						
Lake Koocanusa and Kootenai River	Possibly cooler in winter than VARQ FC alternatives, with resulting cooler winter releases; TDG saturation >110% in 1 out of 52 yrs, >120% in 0 out of 52 yrs	Possibly warmer in winter than Standard FC alternatives, with resulting warmer winter releases; TDG saturation >110% in 3 out of 52 yrs, > 120% in 2 out of 52 yrs, > 130% in 1 out of 52 yrs	Water temperatures in lake and river similar to LS1; no evaluation of TDG since mechanism to achieve add'l 10 kcfs of flow not known.	Water temperatures in lake and river similar to LV1; no evaluation of TDG since mechanism to achieve add'l 10 kcfs of flow not known	Water temperatures in lake and river similar to LS1;TDG saturation >110% in 11 out of 52 yrs, >120% in 6 out of 52 yrs, >130% in 3 out of 52 yrs	Water temperatures in lake and river similar to LV1; TDG saturation > 110% in 13 out of 52 yrs, >120% in 7 out of 52 yrs, > 130% in 5 out of 52 yrs

Resource	Alternative LS1 (No Action)	Alternative LV1 (Preferred)	Alternative LS2	Alternative LV2	Benchmark LS	Benchmark LV
Aquatic Life						
Lake Koocanusa	Relative to VARQ FC alternatives, reduced primary productivity; low zooplankton production; lower benthic production; low terrestrial insect deposition; low kokanee growth.	Relative to Standard FC alternatives, higher primary productivity; higher zooplankton production; higher benthic production; higher terrestrial insect deposition; high kokanee growth.	Lake productivity similar to LS1	Lake productivity similar to LV1	In lake, second highest primary productivity and zooplankton production; low benthic production; mostly high terrestrial insect deposition; high kokanee growth.	In lake, highest primary productivity and zooplankton production; high benthic production; highest terrestrial insect deposition; highest kokanee growth.
Kootenai River	Mixed benthic production; low TDG risk; less likelihood of low winter flow for burbot; flow benefits for sturgeon.	High benthic production; somewhat higher TDG risk; greater likelihood of low winter flow for burbot; flow benefits for sturgeon.	Productivity similar to LS1; less likelihood of low winter flow for burbot; higher flow benefits for sturgeon.	Productivity similar to LV1; greater likelihood of low winter flow for burbot; higher flow benefits for sturgeon.	MIxed benthic production; relatively high TDG risk; less likelihood of low winter flow for burbot; no flow benefits for sturgeon.	Relatively high benthic production; highest TDG risk; greater likelihood of low winter flows for burbot; no flow benefits for sturgeon.
Kootenay Lake	Possible washout of nutrients and plankton; possible fish stranding in Duncan delta.	Possibly higher washout of nutrients and plankton; possilble fish stranding in Duncan delta.	Possible washout of nutrients and plankton; possible fish stranding in Duncan delta.	Possible washout of nutrients and plankton; possible fish stranding in Duncan delta.	Possibly lower washout of nutrients and plankton; possible fish stranding in Duncan delta.	Lower washout of nutrients and plankton; possible fish stranding in Duncan delta.
Sensitive, Threatened and Endangered Species						
	No likely effect on terrestrial species exc. bald eagle; moderate flow benefits for sturgeon; relatively low likelihood of winter low flows for burbot; minimum flows maintained for bull trout.	No likely effect on terrestrial species exc. bald eagle; flow benefits for sturgeon same as LS1; relatively high likelihood of low flows in winter for burbot; minimum flows maintained for bull trout.	No likely effect on terrestrial species exc. bald eagle; highest flow benefits for sturgeon; same winter flows as LS1 for burbot; minimum flows maintained for bull trout.	No likely effect on terrestrial species exc. bald eagle; flow benefits for sturgeon same as LS2; same winter flows as LV1 for burbot; minimum flows maintained for bull trout.	No likely effect on terrestrial species exc. bald eagle; no flow benefits for sturgeon; same winter flows as LS1 for burbot; no minimum flows for bull trout.	No likely effect on terrestrial species exc. bald eagle; no flow benefits for sturgeon; same winter flows as LV1 for burbot; no minimum flows for bull trout.

Resource	Alternative LS1 (No Action)	Alternative LV1 (Preferred)	Alternative LS2	Alternative LV2	Benchmark LS	Benchmark LV
Vegetation and Wildlife						
Lake Koocanusa	LIttle or no riparian vegetation below full reservoir level. Minimal effect on wildlife.	Similar to LS1 around L. Koocanusa.	Similar to LS1 around L. Koocanusa.	Similar to LS1 around L. Koocanusa.	Similar to LS1 around L. Koocanusa.	Similar to LS1 around L. Koocanusa.
Kootenai River downstream from Libby Dam	Some riparian vegetation enhancement due to fish flows. Wildlife benefit from this, but may be impacted by high water in Creston Valley Wildlife Mgmt. Area. Possible Duck Lake overfilling.	Some riparian vegetation enhancement due to fish flows; possible enhancement due to lower winter flows. Wildlife benefit from this, but may be impacted by high water in Creston Valley Wildlife Mgmt. Area. Possible Duck Lake overfilling.	Some riparian vegetation enhancement due to fish flows. Wildlife benefit from this, but may be impacted by high water in Creston Valley Wildlife Mgmt. Area. Possible Duck Lake overfilling.	Some riparian vegetation enhancement due to fish flows; possible enhancement due to lower winter flows. Wildlife benefit from this, but may be impacted by high water in Creston Valley Wildlife Mgmt. Area. Possible Duck Lake overfilling.	Little or no benefit to riparian vegetation; possible loss, with corresponding effects on wildlife.	Little or no benefit to riparian vegetation; possible loss, with corresponding effects on wildlife.
Kootenay Lake	Little or no change in existing lakeshore vegetation, which should remain extensive.	Similar to LS1.	Similar to LS1.	Similar to LS1.	Similar to LS1.	Similar to LS1.
Recreation						
Lake Koocanusa in United States	1,340 boat ramp days May-Sep; 107 swimming days Jun-Aug; 45 camping days above elev. 2439' May-Sep; 113 camping days above 2439' May-Sep	1,467 boat ramp days May-Sep; 150 swimming days Jun-Aug; 65 camping days above elev. 2439' May-Sep; 126 camping days above 2439' May-Sep	1,351 boat ramp days May-Sep; 92 swimming days Jun-Aug; 42 camping days above elev. 2439' May-Sep; 112 camping days above 2439' May-Sep	1,454 boat ramp days May-Sep; 142 swimming days Jun-Aug; 61 camping days above elev. 2439' May-Sep; 124 camping days above 2439' May-Sep	1,627 boat ramp days May-Sep; 217 swimming days Jun-Aug; 102 camping days above elev. 2439' May-Sep; 122 camping days above 2439' May-Sep	1,665 boat ramp days May-Sep; 221 swimming days Jun-Aug; 104 camping days above elev. 2439' May-Sep; 130 camping days above 2439' May-Sep

Resource	Alternative LS1 (No Action)	Alternative LV1 (Preferred)	Alternative LS2	Alternative LV2	Benchmark LS	Benchmark LV
Canada	352 boat ramp days May-Sep, and 29 swimming days Jun-Aug.	414 boat ramp days May-Sep, and 51 swimming days Jun-Aug	343 boat ramp days May-Sep, and 24 swimming days Jun-Aug	404 boat ramp days May-Sep, 24 swimming days Jun-Aug	503 boat ramp days May-Sep, and 131 swimming days Jun-Aug	522 boat ramp days May-Sep, and 133 swimming days Jun-Aug
Kootenai River	May-Sep: 77 shore-fishing days and 88 boating days.	May-Sep: 50 shore-fishing days and 101 boating days.	May-Sep: 80 shore-fishing days and 88 boating days.	May-Sep: 54 shore-fishing days and 105 boating days.	May-Sep 74 shore-fishing days and 85 boating days.	May-Sep: 48 shore-fishing days and 115 boating days.
Kootenay Lake	135 days in nondetrimental range May-Sep; 52 boat moorage days Jan-May; 83 fishing days above elev. 1744' May-Sep; 77 swimming days below lake elev. 1749' Jun-Aug	132 days in nondetrimental range May-Sep; 52 boat moorage days Jan-May; 90 fishing days above elev. 1744' May-Sep; 76 swimming days below lake elev. 1749 Jun-Aug	134 days in nondetrimental range May-Sep; 52 boat moorage days Jan-May; 82 fishing days above elev. 1744' May-Sep; 76 swimming days below lake elev. 1749 Jun-Aug	132 days in nondetrimental range May-Sep; 52 boat moorage days Jan-May; 89 fishing days above elev. 1744' May-Sep; 75 swimming days below lake elev. 1749' Jun-Aug	142 days in nondetrimental range May-Sep; 51 boat moorage days Jan-May; 79 fishing days above elev. 1744' May-Sep; 84 swimming days below lake elev. 1749' Jun-Aug	139 days in nondetrimental range May-Sep; 52 boat moorage days Jan-May; 86 fishing days above elev. 1744' May-Sep; 82 swimming days below lake elev. 1749' Jun-Aug
Environmental Health						
Lake Koocanusa	Elev. at or below 2404' (exposed dust could become windlblown) 90% of time Jan-Apr, 87% of time May, & 32% of time June	Elev. at or below 2404' (exposed dust could become windlblown) 63% of time Jan-Apr, 60% of time May, and 13% of time June	Elev. at or below 2404' (exposed dust could become windlblown) 90% of time Jan-Apr, 88% of time May, & 37% of time June	Elev. at or below 2404' (exposed dust could become windlblown) 63% of time Jan-Apr, 62% of time May, & 18% of time June	Elev. at or below 2404' (exposed dust could become windlblown) 90% of time Jan-Apr, 83% of time May, & 14% of time June	Elev. at or below 2404' (exposed dust could become windlblown) 63% of time Jan-Apr, 56% of time May, & 7% of time June
Cultural Resources						
Lake Koocanusa in United States	268 sites possibly exposed to erosion, looting, and vandalism	247 sites possibly exposed to erosion, looting, and vandalism	Similar to LS1	Similar to LV1	Similar to LS1	Similar to LV1
Kootenai River below Libby Dam	Possible erosion at 6 sites within 5 miles of Libby Dam	Possible erosion at 6 sites within 5 miles of Libby Dam			Lowest likelihood of erosion at sites downstream from dam.	Relatively low likelihood of erosion at sites downstream from dam.

Resource	Alternative LS1 (No Action)	Alternative LV1 (Preferred)	Alternative LS2	Alternative LV2	Benchmark LS	Benchmark LV
Indian Sacred Sites						
	During informal consultations with the CSKT, they have chosen not to discuss sacred sites at Libby Dam-Lake Koocanusa. Therefore, the possible effects on TCPs are not assessed in this analysis.	Same as LS1.	Same as LS1.	Same as LS1.	Same as LS1.	Same as LS1.
Indian Trust Assets						
	No impacts	Same as LS1	Same as LS1	Same as LS1	Same as LS1	Same as LS1
Socioeconomics						
Lake Koocanusa	Relatively high impacts on employment and income from recreation/tourism.	Positive effects on employment and income from recreation/tourism.	Socioeconomic effects slightly higher than LS1.	Socioeconomic benefits slightly lower than LV1.	Positive effects on employment and income from recreation/tourism.	Positive effects on employment and income from recreation/tourism.
Idaho	Avg. annual flood damages of $21,780; 455,600 kW-hr of ag. pumping; moderate ag. losses from high groundwater.	Avg. annual flood damages same as LS1. 452,500 kW-hr of ag. pumping; relatively high ag. losses from high groundwater.	Avg. annual flood damages same as LS1. 456,100 kW-hr of ag. pumping; ag. losses from high groundwater similar to LS1.	Avg. annual flood damages same as LS1. 453,000 kW-hr of ag. pumping; highest ag. losses from high groundwater.	Avg. annual flood damages same as LS1. 457,100 kW-hr of ag. pumping; lowest ag. losses from high groundwater.	Avg. annual flood damages of $22,950 in Idaho. 455,300 kW-hr of ag. pumping; ag. losses from high groundwater higher than LS, but tend to be lower than fish flow alternatives.
Kootenay Lake	Moderate likelihood of flood damages around Kootenay Lake.	Likelihood of flood damages around Kootenay Lake similar to LS1	Highest likelihood of flood damages around Kootenay Lake.	Likelihood of flood damages around Kootenay Lake similar to LS2	Lowest likelihood of flood damages around Kootenay Lake.	Relatively low likelihood of flood damages around Kootenay Lake.
Municipal Water and Wastewater Treatment						
	No impacts identified.	Same as LS1	Same as LS1	Same as LS1	Same as LS1	Same as LS1

Resource	Alternative LS1 (No Action)	Alternative LV1 (Preferred)	Alternative LS2	Alternative LV2	Benchmark LS	Benchmark LV
Transportation						
	No impacts identified.	Same as LS1	Same as LS1	Same as LS1	Same as LS1	Same as LS1

Table S-4. Summary comparison of the no action and preferred alternatives at Hungry Horse Dam.

Resource	Alternative HS (No Action)	Alternative HV (Preferred)
Hydrology and Flood Control		
Hungry Horse Reservoir	Hungry Horse Reservoir would continue to have deeper winter flood control drafts in slightly below average to slightly above average water years. The average winter draft would be to elevation 3501 feet. The average June 30 refill would be to elevation 3558.17 feet.	Hungry Horse Reservoir would have shallower winter flood control drafts in slightly below average to slightly above average water years. The average winter draft would be to elevation 3512 feet. This would allow for a slight improvement in probability of refill; the average maximum refill would be to elevation 3558.5 feet.
Hungry Horse Outflows	Due to deeper winter flood control drafts, average outflows would be higher under HS during the January to April period. Average outflows would be about: January – 4995 cfs February – 4930 cfs April – 5648 cfs May – 3423 cfs June – 3054cfs Average outflows for flow augmentation would be about: July – 5174 cfs August - 5474 cfs	Given shallower winter flood control drafts, more water would be released later in the spring in order to maintain the same level of flood protection. Average outflows would be about: January – 4151cfs February – 3906 cfs April – 3560 cfs May – 5637 cfs June – 4243 cfs Average out flows for flow augmentation would be about: July – 5302 cfs August – 5476 cfs Releases for flow augmentation are higher under HV because of the improved probability of refill.
Columbia Falls	During slightly below average to slightly above average water years, HS flows would be higher during the January to April period. Average outflows would be about: January – 6594 cfs February – 6486 cfs April – 12681 cfs May – 23874 cfs June – 23650 cfs Under both alternatives there would continue to be an 18% probability of reaching or exceeding flood stage at Columbia Falls (14 feet).	During slightly below average to slightly above average water years, HV flows would be higher in May and June. Average outflows would be about: January – 5751 cfs February – 5461 cfs April – 10592 cfs May – 26088 cfs June – 24839 cfs Under both alternatives there would continue to be an 18% probability of reaching or exceeding flood stage at Columbia Falls (14 feet).
Flathead Lake	Under HS, there is a 7% probability of exceeding Flathead Lake's full pool elevation of 2893 feet.	Under HV there is 10% probability of exceeding Flathead Lake's full pool elevation of 2893 feet.

Resource	Alternative HS (No Action)	Alternative HV (Preferred)
Lake Pend Oreille	Due to the attenuation of flows in the river reaches downstream from Hungry Horse Dam and reregulation of flows through Flathead Lake and Kerr Dam, water surface elevations at Lake Pend Oreille would be essentially identical.	Same as HS.
Downstream from Albeni Falls Dam	Average outflows from Lake Pend Oreille would higher in June. Average outflows would be about: January – 17411 cfs February – 19434 cfs April – 28588 cfs June – 54518 cfs There would continue to be a 27% probability of exceeding the flood stage of 100,000 cfs below Albeni Falls Dam.	Average outflows from Lake Pend Oreille would be slightly lower in January to April period. The slight reduction in April flows could provide flood relief in the Cusick area when Calispell and Trimble Creeks are high. Average outflows would be about: January – 16981 cfs February – 18033 cfs April – 28020 cfs June – 56578 cfs There would continue to be a 27% probability of exceeding the flood stage of 100,000 cfs below Albeni Falls Dam.
Water Quality		
	Under simulated releases, there is less chance of HS exceeding TDG standards.	Under simulated releases, the chance of HV exceeding the 15 percent spill is 1 % in June. Overall, spill analysis indicates that implementation of HV could result in increases in TDG saturation levels from May through July. Changes in the saturation levels are not quantifiable with the available data, but appear to be minor. Based on modeling, HV operations would generally increase benthic biomass production in the Flathead River because the natural temperature regime and other physical properties of the river would be more closely mimicked.
Aquatic Life		
	Deep drafts implemented under HS would continue to limit food availability and habitat quality at Hungry Horse Reservoir and the Flathead River. Modeling results showed minimal differences between alternatives from Flathead Lake downstream.	Implementation of HV would likely benefit resident fish, especially those in Hungry Horse Reservoir and immediately downstream in the Flathead River. Hungry Horse discharges would follow a more normative hydrograph and would be higher in March, May, and June. Reduced winter drafts would help achieve refill at Flathead Lake, especially in dry years. Higher late-spring discharges would help meet Kerr Dam minimum outflow requirements, thus providing minor benefits to aquatic resources in Flathead Lake and downstream from Kerr Dam.

Resource	Alternative HS (No Action)	Alternative HV (Preferred)
Federally Endanagered and Threatened Species		
	Deep drafts implemented under HS would continue to limit food availability and habitat quality at Hungry Horse Reservoir and the Flathead River. Modeling results showed minimal differences between alternatives from Flathead Lake downstream.	Implementation of HV would benefit bull trout through general improvements in biological conditions at Hungry Horse Reservoir and immediately downstream in the Flathead River. Below Flathead Lake, HV would result in a slightly more normative hydrograph and minor increases in TDG saturation levels. Neither alternative is likely to appreciably affect existing conditions within designated bull trout critical habitat HV may result in minor benefits to the fish prey base for bald eagles at Hungry Horse Reservoir and Flathead Lake and neither alternative is likely to affect bald eagle nesting, roosting, and feeding habitats.
Wildlife		
	Existing riparian and wetlands habitat would remain unchanged.	May provide minor benefits to riparian and wetland habitats and associated wildlife along Flathead Lake and immediately upstream on the Flathead River. Otherwise, existing wildlife habitats generally would not be affected.
Vegetation		
	Existing riparian and wetlands would remain unchanged.	May provide minor benefits to riparian areas and wetlands along Flathead Lake and immediately upstream on the Flathead River.
Recreation		
	Slightly more fishing and kayaking days on the Flathead River downstream from Hungry Horse Dam in the early summer due to optimal flows.	May result in minor improvements in boater access to Hungry Horse Reservoir and Flathead Lake owing to higher average water surface elevations during the recreation season and an increase in the usability of boat ramps. Slightly better aesthetics due to higher surface water elevations.
Environmental Health		
	No measurable effect on human or environmental health within the affected area.	Same as HS.
Cultural Resources		
	Some erosion and slumping would continue at archaeological sites within Hungry Horse Reservoir.	Likely would be a minor increase in the potential for winter erosion and ice impacts to cultural resources. HV also may provide minor benefits to cultural resources during the summer recreation season owing to the increased probability of reservoir refill. Once full, the reservoir helps protect cultural sites below the high water line which otherwise would be exposed to impacts from summer erosion and visitor use.
Indian Sacred Sites		
	No Indian sacred sites have been identified.	Same as HS.
Indian Trust Assets		
	No effect on existing ITAs	Same as HS.
Transportation		
	No effect on existing transportation systems	Same as HS.

Resource	Alternative HS (No Action)	Alternative HV (Preferred)
Municipal Water and Wastewater Treatment		
	No effect likely on existing municipal water sources or treatment/disposal facilities.	Same as HS.
Socioeconomics		
	Existing levels of flood protection would continue.	Results in a minor (4%) increase in potential flood effects at Flathead Lake, primarily for damage to waterfront land and docks. HV would also result in a 12% increase in potential flood effects below Albeni Falls Dam, primarily for damages to agricultural and residential property.

Table S-5. Summary comparison of alternative and benchmark combinations on the main stem Columbia River.

Resource	LS1+HS	LS2+HS	LV1+HV	LV2+HV	LS+HS	LV+HV
Hydrology and Flood Control						
Grand Coulee Dam -upstream	Of 10 years modeled, only 1948 exceeds 280 kcfs flood stage at Birchbank	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Birchbank: 99% exceedance frequency 93.6 kcfs, 50% exceedance. frequency 162.5 kcfs; 1% exceedance frequency 250 kcfs	Birchbank: 99% exceedence frequency 95.1 kcfs, 50% exceedance frequency 167 kcfs; 1% exceedance frequency 251 kcfs
Lake Roosevelt	Apr2 elevations (feet): Minimum 1208.0 Maximum 1280.0 Average 1244.0	Same as LS1+HS	Apr2 elevations (feet): Minimum 1208.0 Maximum 1280.0 Average 1242.4	Same as LV1+HV	Same as LS1+HS	Apr2 same as LV1+HV Lower Jan-May elevations during some years
Grand Coulee Dam –downstream	Of 10 years modeled, 4 would exceed the 450 kcfs flood flow threshold and only 1948 would exceed the major damage level of 600 kcfs	Of 10 years modeled, 4 would exceed the 450 kcfs flood flow threshold and only 1948 would exceed the major damage level of 600 kcfs	Of 10 years modeled, 4 would exceed the 450 kcfs flood flow threshold and only 1948 would exceed the major damage level of 600 kcfs	Of 10 years modeled, 4 would exceed the 450 kcfs flood flow threshold and only 1948 would exceed the major damage level of 600 kcfs	The Dalles: 99% exceedance frequency 205 kcfs 50% exceedance frequency 401 kcfs; 1% exceedance frequency 670 kcfs	The Dalles: 99% exceedance frequency 211 kcfs 50% exceedance frequency 411 kcfs; 1% exceedance frequency 670 kcfs
System Power						
winter (Jan-Mar)	Monthly average winter generation (aMW): 16,799 System; 8,390 Federal; 3,783 non-Federal	Monthly average winter generation (aMW): 16,798 system; 8,390 Federal; 3,783 non-Federal	Monthly average winter generation (aMW): 16,377 System; 8,085 Federal; 3,664 non-Federal	Monthly average winter generation (aMW): 16,376 System; 8,085 Federal; 3,664 non-Federal	Monthly average winter generation (aMW): 16,810 System; 8,398 Federal; 3,784 non-Federal	Monthly average winter generation (aMW): 16,389 System; 8094 Federal; 3,666 non-Federal

Resource	LS1+HS	LS2+HS	LV1+HV	LV2+HV	LS+HS	LV+HV
spring/summer (May-Aug)	Monthly average generation (aMW): 16,984 System 9,005 Federal 4,270 non-Federal	Monthly average generation (a MW): 16,985 System 9,003 Federal 4,271 non-Federal	Monthly average generation (a MW): 17,244 System; 9,231 Federal; 4,315 non-Federal	Monthly average generation (aMW): 17,244 System; 9,229 Federal; 4,315 non-Federal	Monthly average generation (aMW): 16,706 System 8,757 Federal 4,217 non-Federal	Monthly average generation (aMW): 16,983 System; 8,996 Federal; 4,268 non-Federal
Water Quality						
Grand Coulee Dam –upstream TDG	Existing seasonally-elevated TDG levels in the Columbia River at the international border and in Lake Roosevelt would continue, as would ongoing efforts to ameliorate them.	Same as LS1+HS	TDG levels in the Columbia River at the international border likely would be marginally higher than at present, primarily due to minor increases in spill at hydropower facilities on the Kootenai River.	Same as LV1+HV	Same as LS1+HS	Same as LV1+HV
Temperature	Operational changes at Hungry Horse and Libby Dams are unlikely to affect Columbia River temperatures because of the large intervening distance involved.	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS
Grand Coulee Dam –downstream TDG	Slightly increase spill cap exceedance index and the amount of spill in excess of the spill cap compared to benchmarks which indicates the potential to increase TDG levels.	Same as LS1+HS	Highest spill cap exceedance index and the amount of spill in excess of the spill cap.	Same as LS1+HS and has a higher spill cap exceedance index at Rock Island and Priest Rapids Dams than LV1+HV.	Spill cap exceedance index and spill in excess of spill cap would be lower than Standard FC alternative combinations.	Spill cap exceedance index and spill in excess of spill cap would be lower than VARQ FC alternative combinations.

Resource	LS1+HS	LS2+HS	LV1+HV	LV2+HV	LS+HS	LV+HV
Aquatic Life						
Grand Coulee Dam -upstream	The present habitat characteristics, species assemblages, and population dynamics at Lake Roosevelt generally would remain unchanged. Large annual flood control drafts would continue to limit natural reproduction of many fish species in the reservoir and would continue to facilitate entrainment. Nutrient flushing and low spring water surface elevations would continue to limit the growth of some species.	Same as LS1+HS	Minor increases in spring drawdowns at Lake Roosevelt could result in periodic, small reductions in present levels of spawning success for smallmouth bass, yellow perch, and shoreline spawning kokanee. Minor reductions in water retention times may result in small increases in the loss of nutrients from the reservoir which in turn may lead to minor decreases in growth rates for some species. Minor increases in entrainment would occur in some years.	Same as LV1+HV	Same as LS1+HS	Same as LV1+HV
Grand Coulee Dam –downstream	Continued similar influence on the timing and magnitude of flows in the Columbia River. The present habitat characteristics and presence/ absence of species generally would remain unchanged.	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS

Resource	LS1+HS	LS2+HS	LV1+HV	LV2+HV	LS+HS	LV+HV
Federally Listed Endangered and Threatened Species and Canadian Species of Special Concern						
Grand Coulee Dam -upstream	The present habitat characteristics, species presence, and population dynamics at Lake Roosevelt and upstream generally would remain unchanged. Large annual flood control drafts would continue to limit benthic productivity and may also continue to limit the juvenile-growth potential of bull trout in the reservoir. Bald eagle numbers and distribution would likely remain unchanged.	Same as LS1+HS	Minor increases in spring drawdowns at Lake Roosevelt could result in small reductions in present levels of benthic productivity. Primary impacts to bull trout would most likely be growth-related. The fish prey base for bald eagles would not likely be noticeably affected, and bald eagle numbers and distribution would likely remain unchanged.	Same as LV1+HV	Same as LS1+HS	Same as LV1+HV
Grand Coulee Dam -downstream	River flows and reservoir elevations would remain within the current range of operations. Related ongoing effects to threatened and endangered species would remain unchanged from those previously consulted upon and addressed in biological opinions.	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LV1+HV

Resource	LS1+HS	LS2+HS	LV1+HV	LV2+HV	LS+HS	LV+HV
Anadromous Fish – Priest Rapids Dam	Monthly flow objectives met in 32-49 of 52 years.	Monthly flow objectives met in 32-49 of 52 years.	Monthly flow objectives met in 32-49 of 52 years.	Monthly flow objectives met in 32-49 of 52 years.	Monthly flow objectives met in 32-47 of 52 years.	Monthly flow objectives met in 32-49 of 52 years.
Anadromous Fish - McNary Dam	Monthly flow objectives met in 4-42 of 52 years.	Monthly flow objectives met in 4-42 of 52 years.	Monthly flow objectives met in 4-42 of 52 years.	Monthly flow objectives met in 3-42 of 52 years.	Monthly flow objectives met in 3-42 of 52 years.	Monthly flow objectives met in 2-42 of 52 years.
Spill	Some risk of forced spill with elevated TDG. Incremental effects on anadromous fish should be minimal, but this alternative combination results in slightly lower potential TDG levels and durations as compared to the VARQ FC alternative combinations.	Same as LS1+HS	Some risk of forced spill with elevated TDG. Incremental effects on anadromous fish should be minimal, but this alternative combination results in a slight potential increase in TDG levels and durations as compared to the Standard FC alternative combinations.	Some risk of forced spill with elevated TDG. Incremental effects on anadromous fish should be minimal, but this alternative combination results in the highest potential TDG levels and durations as compared to all other alternative combinations.	Some risk of forced spill with elevated TDG. Incremental effects on anadromous fish should be minimal, but this benchmark combination results in the lowest potential TDG levels and durations.	Same as LV1+HV
Vegetation						
	River flows and reservoir elevations would remain within the current range of river and reservoir operations, and; therefore, related effects on vegetation would be similar. Riparian and wetland areas within the influence of the Columbia River and its impoundments generally would remain unchanged.	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS

Resource	LS1+HS	LS2+HS	LV1+HV	LV2+HV	LS+HS	LV+HV
Wildlife						
	Riparian and wetland habitats within the influence of the Columbia River and its impoundments generally would remain unchanged. Associated terrestrial wildlife populations also are not likely to be affected.	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS
Recreation						
Grand Coulee Dam -upstream	Current levels of recreation access and scenic quality at Lake Roosevelt generally would remain unchanged. There would be no change in usable boat ramp days during the summer.	Same as LS1+HS	There would be a minor decrease (less than 5%, primarily in May) in average usable boat ramp days at Lake Roosevelt. Otherwise, there would be no change in the present function of boat ramps or marinas, particularly during the summer. A slight degradation in visual resources may be noticeable in May due to slightly lower reservoir elevations.	Same as LV1+HV	Same as LS1+HS	Same as LV1+HV
Grand Coulee Dam -downstream	No change in present levels and quality of boating and shoreside recreation.	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS

Resource	LS1+HS	LS2+HS	LV1+HV	LV2+HV	LS+HS	LV+HV
Environmental Health						
Grand Coulee Dam -upstream	There would be no change in the timing, duration, or magnitude of annual flood control drawdowns at Lake Roosevelt. Similarly, there would be no change in the annual exposure of lake bed sediments, nor in the exposure of humans and other organisms to contaminants present in those sediments. Preliminary results of an ongoing air quality study indicate that none of the samples taken at Lake Roosevelt study sites have exceeded established standards.	Same as LS1+HS	There would be slightly lower reservoir surface elevations and thus slightly increased exposure of lake bed sediments during the spring flood control draft in average to moderately dry water years. When compared to present conditions, the likelihood of measurable impacts to environmental and human health through inhalation, ingestion, or direct contact with contaminated bed-sediments is expected to be extremely low.	Same as LV1+HV	Same as LS1+HS	Same as LV1+HV
Grand Coulee Dam -downstream	There are no identified flow-related environmental health concerns below Grand Coulee. All alternative combinations would continue to similarly influence the timing and magnitude of flows in the Columbia River.	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS

Resource	LS1+HS	LS2+HS	LV1+HV	LV2+HV	LS+HS	LV+HV
Cultural Resources						
Grand Coulee Dam –upstream	There would be no change in the timing, duration, or magnitude of annual flood control drawdowns at Lake Roosevelt. Similarly, there would be no change in the periodic exposure of cultural resources to wave action, erosion, displacement, weathering, or collection/looting.	Same as LS1+HS	There would be slightly lower reservoir surface elevations and thus slightly increased exposure of cultural resources during the spring flood control draft in average to moderately dry water years. When compared to present conditions, the likelihood of impacts to cultural resources is expected to be minor.	Same as LV1+HV	Same as LS1+HS	Same as LV1+HV
Grand Coulee Dam –downstream	There would be essentially no change in management or protection of cultural resources downstream from Grand Coulee Dam. Effects to cultural resources (primarily erosion and site exposure) from river flows and reservoir operations would be similar for all alternative combinations.	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS
Indian Sacred Sites						
	No sacred sites have been identified.	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS

Resource	LS1+HS	LS2+HS	LV1+HV	LV2+HV	LS+HS	LV+HV
Indian Trust Assets						
	Tribal interests in fishing would be affected by all alternative combinations to the extent that salmon and steelhead survival and recovery are affected. The analysis for anadromous fish discusses how the flow objectives at McNary and Priest Rapids dams are achieved by the various alternative combinations. Fish flows from Libby and Hungry Horse in July and August are intended to assist salmon outmigration. Spring flow augmentation for Kootenai River white sturgeon also can assist in meeting flow objectives in the lower Columbia River.	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS

Resource	LS1+HS	LS2+HS	LV1+HV	LV2+HV	LS+HS	LV+HV
Socioeconomics						
Floods	No increase in economic losses from floods to areas protected by major levee systems. Fish flows may cause minor increase in levee maintenance costs.	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS
Hydropower	Annual hydropower values (billions): $4.946 System; $2.516 Federal; $1.211 non-Federal	Annual hydropower values (billions): $4.944 System; $2.525 Federal; $1.212 non-Federal	Annual hydropower values (billions): $4.932 System; $2.504 Federal; $1.202 non-Federal	Annual hydropower values (billions): $4.931 System; $2.508 Federal; $1.202 non-Federal	Annual hydropower values (billions): $4.967 System; $2.533 Federal; $1.213 non-Federal	Annual hydropower values (billions): $4.948 System; $2.520 Federal; $1.203 non-Federal
Transportation and Navigation	No effects to Keller or Inchelium Ferries	Same as LS1+HS	Keller Ferry north landing would be used more frequently.	Same as LV1+HV	Same as LS1+HS	Same as LV1+HV
Municipal Water and Wastewater Treatment						
	No affect on municipal water sources, wastewater treatment or disposal.	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS

Resource	LS1+HS	LS2+HS	LV1+HV	LV2+HV	LS+HS	LV+HV
Transportation						
Grand Coulee Dam –upstream	The Keller and Inchelium Ferries would continue normal operations within the current range of reservoir levels. Lake Roosevelt end-of-April elevation would be less than 1248 feet approximately 60% of all years.	Same as LS1+HS	The Keller and Inchelium Ferries would continue normal operations within the current range. Lake Roosevelt end-of-April elevation would be less than 1248' approximately 70% of all years, therefore, the Keller Ferry's alternative north landing would have to be used more frequently than at present.	Same as LV1+HV	Same as LS1+HS	Same as LV1+HV
Grand Coulee Dam –downstream	No effect	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS	Same as LS1+HS