Revised Study Plan

Boundary Hydroelectric Project (FERC No. 2144)

Study No. 7
Mainstem Aquatic Habitat Modeling Study

Seattle City Light

February 2007

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1.0 INTRODUCTION

The Boundary Project (Project) is operated in a load-following mode, generating power during peak-load hours and curtailing generation during off-peak hours. This operating regime allows Seattle City Light (SCL) to meet continued service area load growth and provide regional system reliability. The capacity of the six turbines is about 55,000 cfs, which is more than double the average annual flow of the Pend Oreille River (SCL 2006a). The combination of little reservoir storage capacity in relation to inflow and the large turbine capacity means that load-following operations can cause the water surface elevations in the Forebay and Tailrace reaches to fluctuate more than 10 feet per day. (See section 1.3.5 of the Proposed Study Plan [PSP; SCL 2006b] for a description of Project operations.) These flow and associated pool level fluctuations alternately inundate and dewater shallow water areas of the Pend Oreille River, affecting aquatic habitats and biota. This section describes modeling of mainstem aquatic habitats to support an evaluation of the effects of Project operations.

Fluctuations in the elevation of the Boundary Reservoir pool occur in response to natural flow fluctuations and the load-following operations at the Project. Flow fluctuations in the Boundary Project forebay extend upstream but attenuate, or dampen, as they travel the 17.5 mile reach upstream to Box Canyon Dam. Variations in channel morphology of the Pend Oreille River upstream of Boundary Dam affect the rate of travel time and attenuation of reservoir pool level fluctuations. For instance, the constriction and change in bed profile at the site of Metaline Falls (Figure 1.0-1) slows the passage of water which delays the response time of the Upper Reservoir Reach to rapid changes in downstream pool level fluctuations. When the Project is operating at reservoir water surface elevations lower than the hydraulic control at Metaline Falls, fluctuations in water levels observed at the Boundary forebay may not extend upstream of Metaline Falls.

BC Hydro's Seven Mile Dam is located 11 miles downstream of Boundary Dam, and at full pool the Seven Mile Dam backs water up to the tailwater of Boundary Dam. Similar to the Boundary Project, the Seven Mile Project is operated as a load-following hydropower facility, and pool level fluctuations at the Seven Mile forebay can travel upstream to the Boundary Dam tailrace. Consequently, the effects of Boundary Project operations on aquatic habitats below Boundary Dam are influenced by Seven Mile Project operations. At low Seven Mile pool levels, riverine habitat is present in the Boundary Dam tailwater, but at high Seven Mile pool levels the riverine habitat becomes reservoir habitat.

The Seven Mile Project completed upgrades in April 2003 to provide increased generation capacity (Calder et al. 2004). There are also plans by the Columbia Power Corporation to add capacity at the downstream Waneta Project. As of January 2007, the Waneta capacity upgrade was under environmental review in British Columbia. If implemented, the Waneta upgrade could affect the power generation strategy at both the Waneta Project and the Seven Mile Project. If the Waneta capacity upgrade is implemented, it is likely that changes to Seven Mile operations will increase the frequency and duration of inundation of the Boundary Dam tailrace.

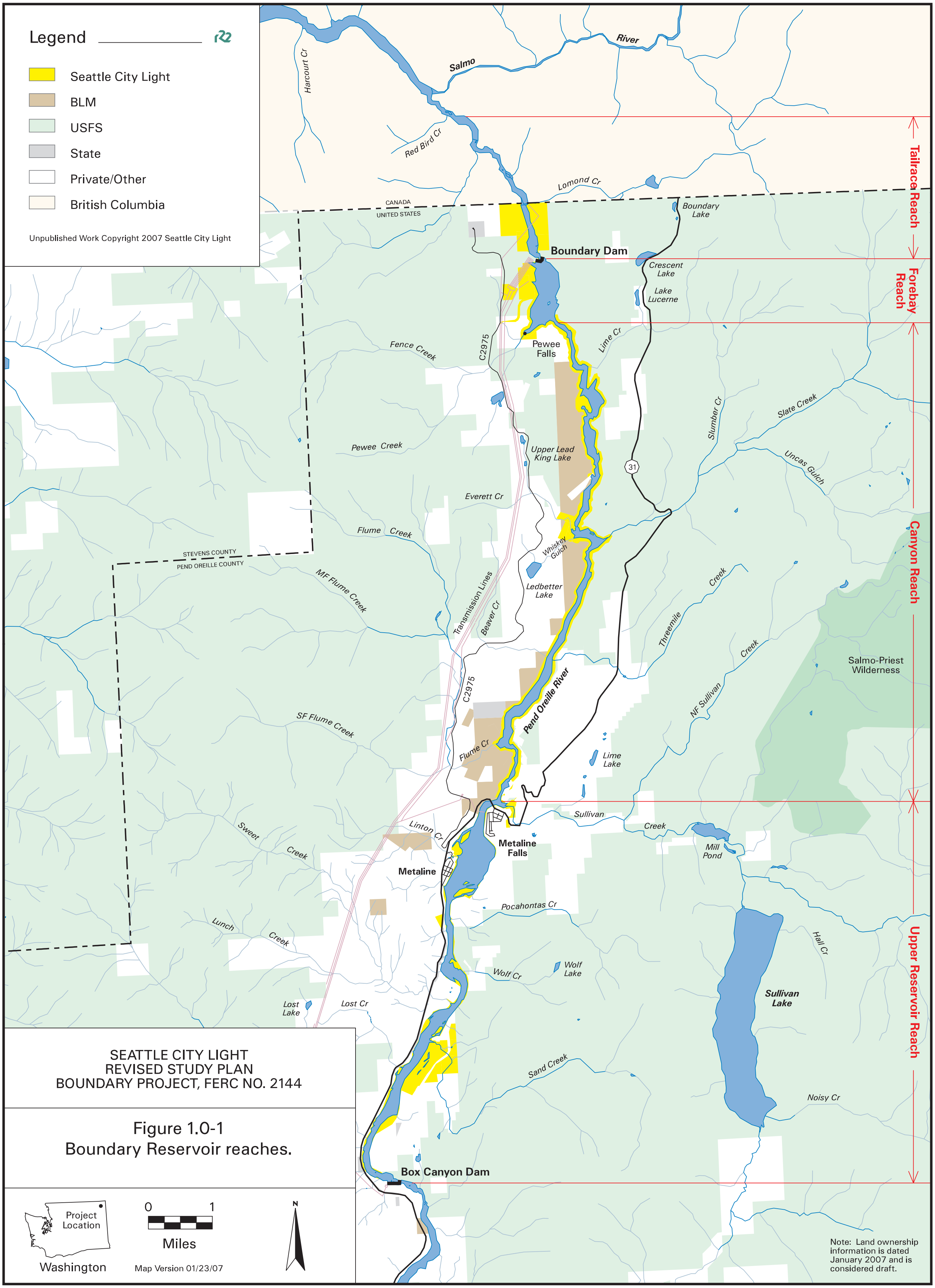

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Figure 1.0-1
Boundary Reservoir reaches.

In general, aquatic habitat in Boundary Reservoir can be divided into shallow and deep water habitats. The littoral zone, or shallow water habitat, is the bottom area along the shoreline where the level of light penetration is sufficient for photosynthesis. This area usually supports larger and more diverse populations of plants and animals than deep water habitats. Depending upon the substrate type, water velocity, and other characteristics, portions of the littoral zone may have aquatic macrophytes that contribute to primary production and provide unique habitat for some aquatic species or lifestages. The deep water zone consists of the open water parts of the reservoir. In general, the deep water zone is less productive than the littoral zone and has a different community of aquatic fauna, although some species (perhaps at different lifestages) may be found in both zones.

Areas of the river channel that are alternately wetted and dewatered by water level fluctuations are termed the varial zone (Figure 1.0-2). The varial zone typically encompasses some or all of the littoral zone. If the magnitude and frequency of water level fluctuations is low, the varial zone can be highly productive. However, as the magnitude and frequency of water level fluctuations increase, the abundance and diversity of periphyton and benthic macroinvertebrates (BMI) are reduced (Fisher and LaVoy 1972; Ward 1992).

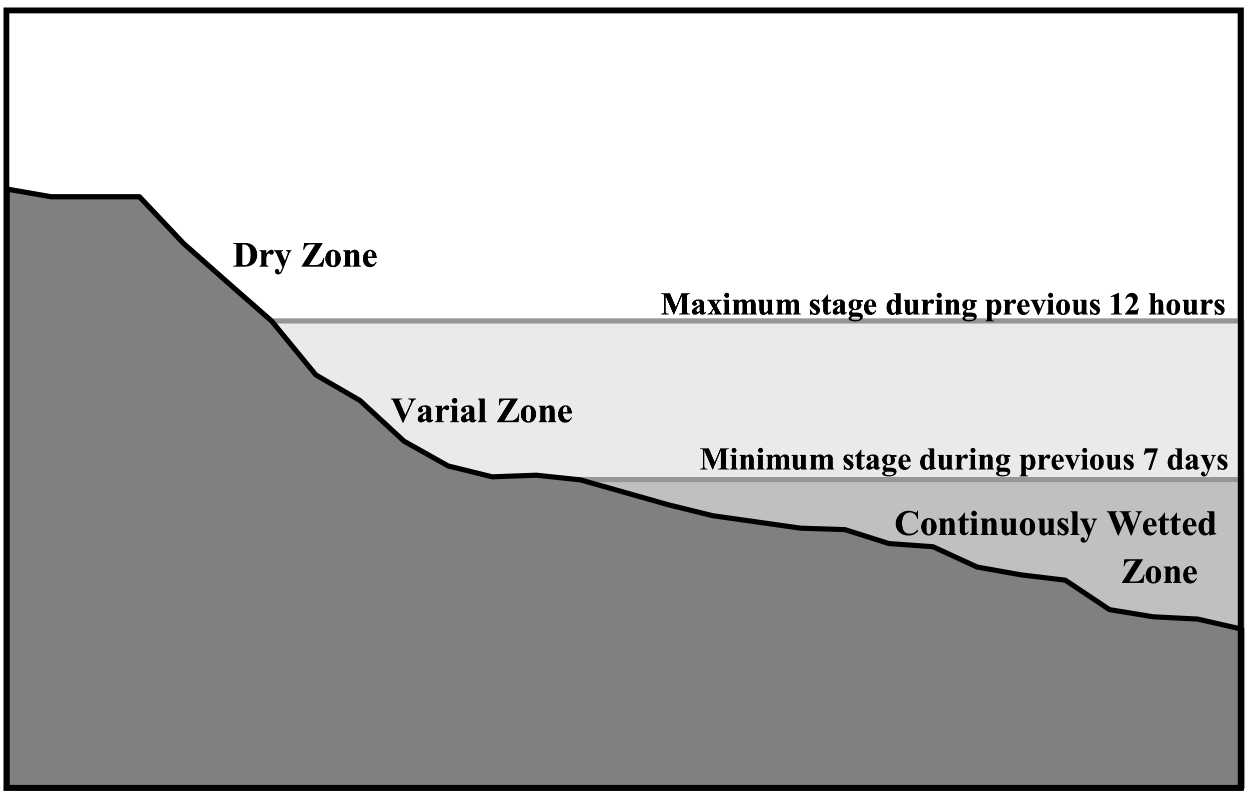

Figure 1.0-2. Example cross-section of a hypothetical channel margin that depicts extent of varial zone as defined by maximum stage during previous 12 hours.

The mainstem aquatic habitat model is the core tool that will be used for assessing changes in aquatic habitat under alternative operational scenarios at the Boundary Project. A conceptual framework for the mainstem aquatic habitat model is depicted in Figure 1.0-3. Several of the Boundary Project relicensing fish and aquatic resource studies are designed as components to the aquatic habitat model or provide, verify, or improve upon biological information critical to running the model. Fundamentally, the mainstem aquatic habitat model is a spatial and temporal representation of physical characteristics considered biologically important as aquatic habitat in Boundary Reservoir and the tailrace. The physical characteristics considered in the model include the following:

- Water depth
- Water level fluctuations (including magnitude, frequency and rate of change)
- Water velocity
- Substrate type (e.g., boulder, cobble, gravel, sand, fines, etc.)
- Cover for fish (including macrophytes)

The mainstem aquatic habitat model integrates hydraulic modeling, reservoir bathymetry, and biological information on the distribution, timing, abundance, and suitability of habitat to estimate metrics (such as varial zone area and frequency of inundation and dewatering) that will be used to compare the effects of alternative operational scenarios.

The mainstem aquatic habitat model will estimate metrics along transects selected to describe representative and distinct habitats. Distinct habitats may include low-gradient bars, depressions, backwater sloughs, fish spawning locations, macrophyte beds or other habitats. These habitat features may support high-value aquatic resources, but because they are found in only a small proportion of the reach, they may not be adequately described by transects selected to describe major morphological channel types. The number, location, and placement of transects will be selected in coordination with relicensing participants.

The following study efforts provide information for, or are components to, the mainstem aquatic habitat model. These studies may also have objectives beyond support of the mainstem aquatic habitat model:

- *Scenario Tool* (see Attachment 1, section 3.2 of this RSP). This tool will be used to model Boundary Project power generation under alternative operational scenarios. Hourly data on Boundary Project forebay and tailrace water surface elevations, flow, and power generation metrics will be developed for each alternative operational scenario to be considered during the relicensing process. Output from the Scenario Tool is used as input to the hydraulic routing model.
- *Habitat Mapping* (this study plan). This study component inventories and maps current aquatic habitat types in Boundary Reservoir. The results will be used for selecting the location and weighting of transects to be used in the mainstem aquatic habitat model.

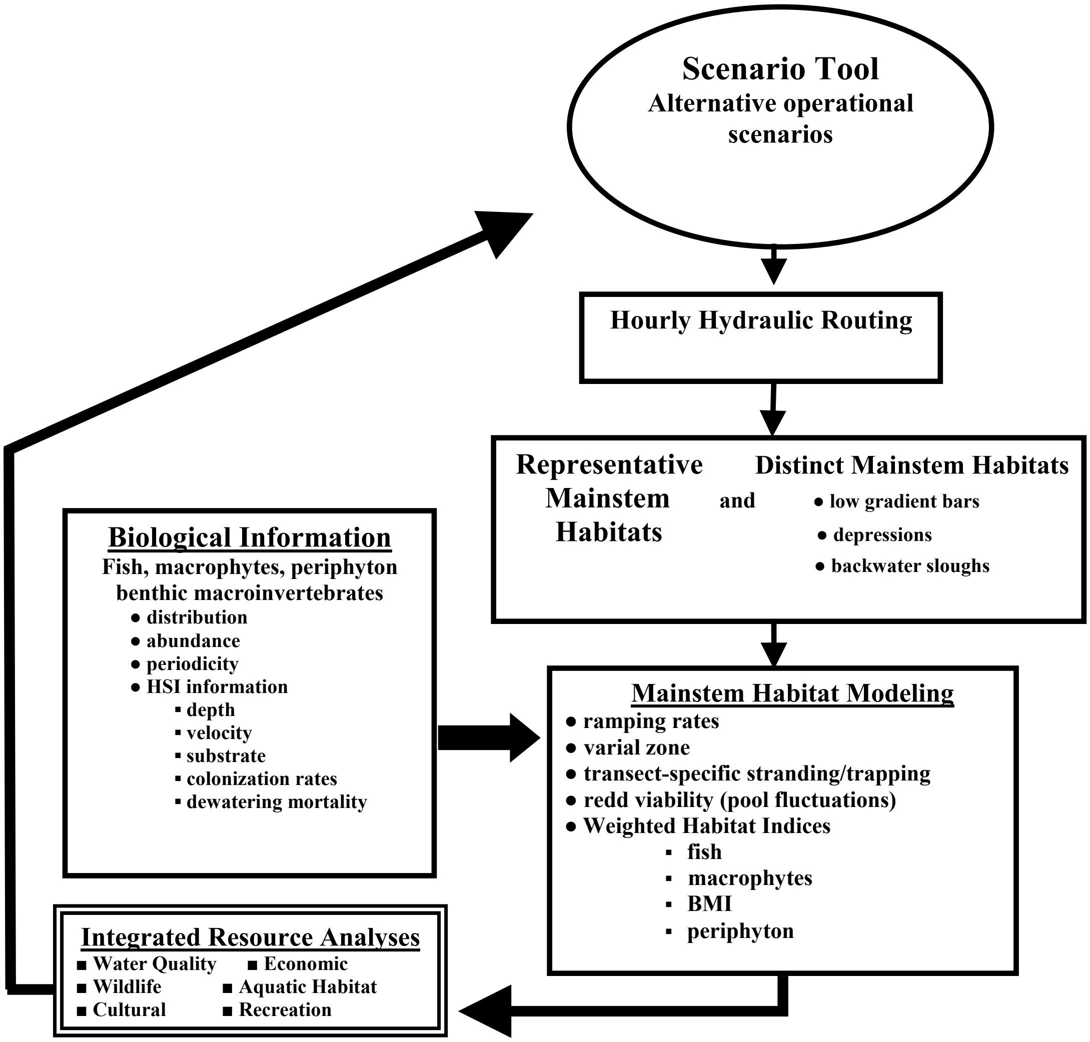

Figure 1.0-3. Conceptual workflow for Mainstem Aquatic Habitat Modeling.

- *Hydraulic Routing Model* (this study plan). This model will be developed from bathymetry data collected in 2006 and early 2007 and used to translate output from the Scenario Tool to water surface elevations and mean column velocity at each of the transects in the mainstem aquatic habitat model on an hourly basis.

- *Habitat Suitability Index (HSI) Studies* [1] (this study plan). The results of these study efforts will be depth, velocity, substrate, cover, colonization and dewatering habitat suitability indices (HSI) for selected fish species and life stages, macrophytes, and macroinvertebrates. Suitability is an index value from 0.0 to 1.0, where 1.0 is optimal. HSI information will be used to translate physical characteristics under the different operational scenarios to an index of the amount of potential habitat that is suitable for the selected species.
- *Tributary Delta Habitats in Boundary Reservoir* (Attachment 2, Study No. 8 of this RSP). This study will develop models to describe the effects of Project operation on habitats within tributary deltas. Because tributaries contain a source of water separate from the mainstem river, habitat models will be developed that are similar to, but separate from, mainstem river transects. The study will also consider potential changes in delta channel morphology under different operational scenarios over a 50-year period (potential length of the new FERC license for the Project).
- *Mainstem Sediment Transport* (Study No. 8). The study will be used to estimate the net change in the volume of sediment deposited in Boundary Reservoir over the potential 50-year term of a new license. The study results will also delineate zones of sediment erosion and accumulation in the Boundary Reservoir portion of the Pend Oreille River.
- *Fish Distribution, Timing, and Abundance Studies* (Study No. 9). These studies provide biological information on fish distribution, abundance and periodicity in Boundary Reservoir using passive and active sampling methods and biotelemetry.

2.0 STUDY PLAN ELEMENTS

2.1. Nexus Between Project Operations and Effects on Resources

As described above, current load-following operations at the Boundary Project result in daily pool level fluctuations in the reservoir and tailrace. The shoreline area affected by cyclical inundation and dewatering is known as the varial zone. The varial zone potentially contributes to primary and secondary productivity and supports rearing and adult lifestages of target fish species. Alternative operational scenarios could result in changes in the frequency, magnitude

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[1] The abbreviation HSI is used in this document to refer to either Habitat Suitability Index (HSI) models or Habitat Suitability Curves (HSC), depending on the context. HSI models provide a quantitative relationship between numerous environmental variables and habitat suitability. An HSI model describes how well each habitat variable individually and collectively meets the habitat requirements of the target species and lifestage, under the structure of Habitat Evaluation Procedures (USFWS 1980). Alternatively, HSC are designed for use in the Instream Flow Incremental Methodology to quantify changes in habitat under various flow regimes (Bovee et al. 1998). HSC describes the instream suitability of habitat variables related only to stream hydraulics and channel structure. Both HSC and HSI models are scaled to produce an index between 0 (unsuitable habitat) and 1 (optimal habitat). Both models and habitat index curves are hypotheses of species-habitat relationships and are intended to provide indicators of habitat change, not to directly quantify or predict the abundance of target organisms. For the Boundary Project aquatic habitat studies, HSC (i.e., depth, velocity and substrate/cover) and HSI (i.e., light availability, duration of inundation and dewatering) models will be integrated to analyze the effects of alternate operational scenarios.

and duration of varial zone inundation and dewatering, affecting the abundance and type of aquatic biota present in the varial zone.

2.2. Agency Resource Management Goals

Several natural resources agencies have jurisdiction over aquatic species and their habitats in the Project area. These agencies will be using the results of the Mainstem Aquatic Habitat Modeling and other fish and aquatic studies to satisfy their respective mandates. The following agencies are those with management responsibility in the context of FERC relicensing of the Boundary Project and management goals related to habitat for aquatic species.

Colville National Forest

The USDA Forest Service (USFS) in general and the Colville National Forest specifically have several guidance documents related to managing aquatic habitat. These include:

- The Colville National Forest Land and Resource Management Plan (a.k.a., the Colville National Forest Plan)
- The Inland Native Fish Strategy (INFISH)

Goals pertinent to these two documents are provided in more detail below.

Colville National Forest Plan (USFS 1988)

The Colville National Forest Plan (CNFP) guides natural and cultural resource management activities on USFS-managed lands and waters and establishes management standards and guidelines. It describes resource management policies and prescriptions, levels of resource production and management, and the availability and suitability of lands for resource management. The CNFP is currently being updated by the USFS and is scheduled to be completed in the fall of 2007. Changes to the CNFP, as amended, may affect aquatic-related management within the Project vicinity.

The CNFP includes a number of broad forest management goals:

- *Fisheries* — Provide a diversity of high quality aquatic habitats which insures viable populations of fish in sufficient numbers to meet angler demands.
- *Water* — Provide for the continued supply of high quality water which meets established standards.
- *Riparian* — Provide and manage for riparian plant communities which maintain a high level of riparian dependent resources.
- *The Forest in Ten Years* — Native fish species will be encouraged with the objective of restoring populations of native trout to selected forest streams and lakes. Introduced species will continue to enhance angling in locations where they provide a superior fishery. Stream crossings of Class I and II streams will be minimized. Stream crossing structures will be designed to provide the least resistance to upstream fish passage. Bridges or bottomless arches will be used instead of culverts that

cannot be installed to allow passage of native trout. Drainage from roads and ditches will be successfully dispersed prior to entering streams.

- *The Forest in Fifty Years*:
  - Values of fisheries will continue to grow both on and off the Forest. Riparian values will be well recognized.
  - Riparian areas will be occupied by diverse, healthy plant communities and water quality will consistently exceed state standards. Water quantity may increase slightly.

The USFS has identified beaver (aquatic and riparian, aspen or willow) and trout (lacustrine, riverine & riparian) as management indicator species for aquatic or riparian habitat within the Colville National Forest because they are species with special habitat needs that may be influenced significantly by planned management programs and that are commonly hunted, fished, or trapped. For trout, the habitat capability objectives are to maintain or improve habitat with an emphasis on native species.

The CNFP includes the following standards and guidelines for fisheries, to be followed when evaluating or implementing management activities:

1. Fish habitat enhancement will be carried out as indicated in the discussion of the “Wildlife Program.” Statewide Comprehensive Fish and Wildlife Plans, coordinated with the Washington Department of Wildlife, will be updated annually as a source document to prioritize fisheries projects. The Forest's fisheries program will be responsive to the projects of the Northwest Power Planning Council, the Upper Columbia United Tribes, and the Colville Confederated Tribes.
2. Protect existing fish habitat from degradation where feasible. Rehabilitate habitats which have been degraded as a result of management activities where degradation is unavoidable. Mitigation will be at the affected site, when possible, but may be through off-site habitat enhancement when on-site mitigation is not possible.
3. Emphasize management of native fish species habitat. Non-native species may be managed for in waters where they can be expected to provide at least 15 percent more biomass production or 15 percent more angler days recreation than native species. Non-native species may be used to provide diversity only where they will not adversely affect native fish or other native organisms in the affected or adjacent waters.
4. Road crossings of Class I and II streams and fish-bearing Class III streams will be the minimum necessary. Existing crossings will be used whenever possible. New crossings will be located at areas of the least possible stream gradient. Stream crossing structures will provide the least resistance to upstream fish passage. Bridges or bottomless arches will be used instead of culverts unless the culvert can be installed in a manner that will allow passage of native trout during their spawning period. Drainage from roads will be dispersed prior to entering streams.
5. Maintain the general character of aquatic and riparian habitat features. Maintain a natural source of large woody debris to provide structural fish habitat.

6. In-stream migration barriers will normally be removed unless desired to prevent immigration by non-native, invasive fish or other aquatic organisms or when their removal would cause degradation to the stream and/or aquatic habitat.
7. Maintain water quality parameters within the range of good fish habitat conditions, and within State water quality standards, as follows:
   - Streams:
     - *Temperature* — Less than 16 degrees Celsius, provided that temperature increases resulting from a non-point source will not exceed 2.8 degrees Celsius above the natural base-line of the stream.
     - *pH* — Natural levels are normally between 6.5 and 9.0 on the Colville N.F. Man-caused variation will not exceed 0.2 units.
     - *Dissolved oxygen* — More than 9.5 mg/L.
     - *Total dissolved gas* — Not to exceed 110 percent of saturation.
     - *Turbidity* — Changes not to exceed 5 NTU where base-line turbidity is less than 50 NTU; changes not to exceed a 10 percent increase where base-line is more than 50 NTU.
     - *Sedimentation* — Management activity caused suspended and bedload sediments that accelerate channel changes and/or reduce bank stability will be considered excessive, and mitigation will be implemented. Signs of unacceptable sedimentation are new bank cutting, bar building, filling of pools, covering of spawning gravels and riffles, bright colored bottom materials, and lack of or significant changes in population composition of aquatic invertebrates. In the event of such occurring, an assessment of the drainage will be done to determine probable cause and need for action to correct or mitigate for habitat degradation.
   - Lakes:
     - Natural water quality parameters will vary in lakes depending on the depth, volume, bottom materials, water sources, soils, vegetation, etc. Meeting standards for the source streams will normally protect lakes adequately. Unacceptable changes will be assessed to determine the causes, and appropriate protective or corrective actions will be taken.

Inland Native Fish Strategy (INFISH)(USFS 1995)

INFISH was originally developed as an interim strategy for National Forest lands and BLM lands while a long-term strategy to protect native fish was under development. The long-term strategy, called the Interior Columbia Basin Ecosystem Management Project, which included a much broader scope than native fish, was completed in 2003 (See Internet URL: www.icbemp.gov). However, as part of the Memorandum of Understanding that completed the project, it was agreed that the INFISH strategy for native fish would continue until local administrative unit land use plans were amended or revised (e.g., the CNFP). The following is an excerpt from INFISH describing its goals:

- *Riparian Goals* — The goals establish an expectation of the characteristics of healthy, functioning watersheds, riparian areas, and associated fish habitats. Since the quality of water and fish habitat in aquatic systems is inseparably related to the integrity of upland and riparian areas within the watersheds, the strategy identifies several goals for watershed, riparian, and stream channel conditions. The goals are to maintain or restore:

  (1) water quality, to a degree that provides for stable and productive riparian and aquatic ecosystems;

  (2) stream channel integrity, channel processes, and the sediment regime (including the elements of timing, volume, and character of sediment input and transport) under which the riparian and aquatic ecosystems developed;

  (3) instream flows to support healthy riparian and aquatic habitats, the stability and effective function of stream channels, and the ability to route flood discharges;

  (4) natural timing and variability of the water table elevation in meadows and wetlands;

  (5) diversity and productivity of native and desired non-native plant communities in riparian zones;

  (6) riparian vegetation, to:

    (a) provide an amount and distribution of large woody debris characteristic of natural aquatic and riparian ecosystems;

    (b) provide adequate summer and winter thermal regulation within the riparian and aquatic zones; and

    (c) help achieve rates of surface erosion, bank erosion, and channel migration characteristic of those under which the communities developed.

  (7) riparian and aquatic habitats necessary to foster the unique genetic fish stocks that evolved within the specific geo-climatic region; and

  (8) habitat to support populations of well-distributed native and desired non-native plant, vertebrate, and invertebrate populations that contribute to the viability of riparian-dependent communities.

U.S. Fish and Wildlife Service (USFWS)

The U.S. Fish and Wildlife Service (USFWS) is the principal federal agency responsible for conserving, protecting and enhancing non-commercial fish, wildlife and plants and their habitats. The agency enforces federal wildlife laws, administers the Endangered Species Act (ESA), manages migratory bird populations, restores nationally significant fisheries, and conserves and restores wildlife habitat such as wetlands. For the Boundary Project, USFWS efforts include overseeing the recovery of bull trout, which are listed as threatened under the ESA. The USFWS has a number of goals and objectives during the FERC relicensing process for the Boundary Project, as follows:

- General Goals:

1. Ensure that protection, mitigation and enhancement measures are commensurate with Project effects and help meet regional fish and wildlife objectives for the basin.
2. Recover federally proposed and listed species.
3. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the Project.
4. Once the licensing process is complete, consider implementation of an adaptive management plan to incorporate new information or new management strategies over the term of the license. The adaptive approach is particularly appropriate where there are insufficient data and/or biological uncertainties about those measures that will be most effective for meeting ecosystem goals and objectives.

- Goals for Aquatic Ecosystems:
  1. Protect, enhance, or restore diverse high-quality aquatic and riparian habitats for plants, animals, food webs, and communities in the watershed, and mitigate for loss or degradation of these habitats.
  2. Maintain and/or restore aquatic habitat connectivity in the watershed to provide movement, migration, and dispersal corridors for salmonids and other aquatic organisms and provide longitudinal connectivity for nutrient cycling processes.
  3. Restore naturally reproducing stocks of resident fish to historically accessible riverine habitat, using native stocks where feasible, with priority given to the restoration of listed native stocks.
  4. Provide an instream flow regime that meets the spawning, incubation, rearing, and migration requirements of wild salmonids and other resident fish and amphibian species, throughout the Project area.
  5. Meet or exceed federal and state regulatory standards and objectives for water quality in the basin.
  6. Minimize current and potential negative Project operation effects on water quality and downstream fishery resources.
- Goals for Endangered, Threatened and Proposed Species:
  1. Reduce Project effects on bald eagles, spotted owls, and other threatened, endangered, and proposed species.
  2. Explore opportunities for potential protection, mitigation and enhancement measures for threatened, endangered, and proposed species.
  3. Gain a better understanding of bull trout population trends, migration, habitat loss, present usage and continuing impacts as related to the Project.

In addition, an overarching USFWS goal for the new licensing of the Project is to have FERC include protection, mitigation and enhancement measures that sustain normal ecosystem functional processes, including geomorphic, hydrologic and hydraulic patterns, and water chemical and physical parameters, as license conditions. Maintaining and improving these functional processes throughout the term of the new license will, in turn, provide the habitat to support healthy fish and wildlife populations.

Environmental Protection Agency (EPA)

The Clark Fork – Pend Oreille Basin Water Quality Study: A Summary of Findings and a Management Plan was prepared in 1993 as a cooperative effort among the states of Montana, Idaho, and Washington with assistance from the EPA (EPA 1993). This report summarizes three years of water quality research in the Clark Fork-Pend Oreille basin and provides a management plan for protection of the basin's water quality. This report identifies management objectives for the Clark Fork basin, Lake Pend Oreille, and the Pend Oreille basin including an objective to improve Pend Oreille River water quality through macrophyte management and tributary nonpoint source controls. Several actions as related to this objective include:

1. Develop and maintain programs to educate the public on their role in protecting and maintaining water quality.
2. Control Eurasian watermilfoil by education, rotovation, and research into alternative methods.
3. Establish and maintain a water quality monitoring network to monitor effectiveness and trends and to better identify sources of pollutants.

Washington Department of Fish and Wildlife (WDFW)

The Washington Department of Fish and Wildlife (WDFW) has a responsibility to protect, preserve, perpetuate, and manage fish and wildlife resources in Washington State. WDFW has produced two guidance documents regarding the management of native salmonids:

- The Joint WDFW/Tribal Wild Salmonid Policy (WDFW 1997) ; and
- The Bull Trout and Dolly Varden Management Plan (WDFW 2000)

The goals described in these documents are summarized in the following excerpts.

Wild Salmonid Policy

- *Overarching Goal*. The goal of this Wild Salmonid Policy is to protect, restore, and enhance the productivity, production, and diversity of wild salmonids and their ecosystems to sustain ceremonial, subsistence, commercial, and recreational fisheries, non-consumptive fish benefits, and other related cultural and ecological values.
- *Conserving Genetic Diversity*. Genetic diversity within and among stocks will be maintained or increased to encourage local adaptation and sustain and maximize long-term productivity. Conditions will be created that allow natural patterns of genetic diversity and local adaptation to occur and evolve.
- *Ecological Interactions*. 1) Wild salmonid stocks will be maintained at levels that naturally sustain ecosystem processes and diverse indigenous species and their habitats. 2) Healthy populations of other indigenous species will be maintained

within levels that sustain or promote abundant wild salmonid populations and their habitats.

- *Fish Access and Passage*. 1) Provide, restore, and maintain safe and timely pathways to all useable wild salmonid habitat in fresh and marine waters, for salmonids at all life stages. 2) Ensure salmonids are protected from injury or mortality from diversion into artificial channels or conduits (irrigation ditches, turbines, etc.). 3) Ensure natural fish passage barriers are maintained where necessary, to maintain biodiversity among and within salmonid populations and other fish and wildlife.
- *Basin Hydrology and Streamflow*. Maintain or restore the physical processes affecting natural basin hydrology. In addition, manage water use in a manner that would optimize stream flows for salmonid spawning, incubation, rearing, adult residency, and migration, that would address the need for channel-forming and maintenance flows, and that would address the impacts of water withdrawals on estuarine and marine habitats.
- *Water Quality and Sediment Quality, Delivery and Transport.* 1) Provide for water and sediments of a quality that will support productive, harvestable, wild salmonid populations, unimpaired by toxic or deleterious effects of environmental pollutants. 2) Manage watersheds, stream channels, wetlands, and marine areas for natural rates of sediment erosion, deposition, and routing that will support salmonids at all life stages. There should be no net loss of wetlands that are utilized by salmonids or that support salmonid habitat through water quality and stormwater retention. When possible, wetlands supporting salmonids and their habitat should be increased.
- *Riparian Areas and Wetlands*. Functional riparian habitat and associated wetlands are protected and restored on all water bodies that support, or directly or indirectly impact, salmonids and their habitat. There should be no net loss of wetlands that are utilized by salmonids or that support salmonid habitat through water quality and stormwater retention. When possible, wetlands supporting salmonids and their habitat should be increased.
- *Lakes and Reservoirs*. Maintain and restore lake and reservoir habitats that are conducive to wild salmonid passage, rearing, adult residency and spawning. Maintain or restore adequate flows through reservoirs to ensure optimal and timely passage of outmigrant smolts.

Bull Trout and Dolly Varden Management Plan

- *Management Plan Goal*: To restore/maintain the health and diversity of bull trout and Dolly Varden stocks and their habitats to/at self-sustaining levels that would allow recreational utilization within resource protection guidelines.
- *Maintain and Restore Stock Distribution*. The Department will manage native char stocks and their habitat to promote distribution throughout their historic range. Restoration efforts will be accomplished through the development of recovery plans that will address reasons for decline, historic distribution and solutions to restore depressed stocks to healthy levels. The implementation strategy: 1) Habitat

necessary for sustaining critical life history stages of native char including spawning and rearing will be protected or restored through efforts described in the habitat maintenance objectives. 2) The Department will work through processes identified in the habitat maintenance objectives to protect current migratory corridors connecting remote headwater areas and restore historical migration corridors.

- *Reestablish Stocks in Historically Inhabited Areas*. Stocks will be provided mechanisms (e.g., re-establishing migration corridors) that will promote natural recruitment of native char to formerly inhabited areas. In areas where the success of natural recruitment is improbable, supplementation may be employed to seed these areas. Supplementation will be limited to situations where: a) a stock is well below desired levels and it cannot rebuild itself due to some cause other than overfishing; b) a stock is being reintroduced to an area it formerly occupied; and c) the risks of potential stock loss through extinction are greater than the genetic risks due to gene flow or extinction risks due to the supplementation process itself.
- *Conserve Genetic Diversity of Stocks*. Genetic diversity will be maintained within and among stocks to allow local adaptation to occur with changing environmental conditions over the long term.

Washington Department of Ecology (Ecology)

Ecology created the Aquatic Plant Technical Assistance Program in 1994 to provide technical expertise within Ecology and other agencies and the general public regarding aquatic plant ecology, taxonomy, and management. This program has three main goals related to aquatic plants, which are identified below (Parsons 2001).

1. Provide technical assistance and education on aquatic plant identification and management.
2. Evaluate plant community structures and the existence or potential for aquatic plant related problems in selected water bodies.
3. Assist with evaluating Freshwater Aquatic Weed Program grant applications.

Water Resource Inventory Area (WRIA) 62

Numerous agencies and stakeholders formed the Water Resource Inventory Area (WRIA) 62 planning unit in 1998 whose goal is to "develop strategies that will balance competing demands for water, while at the same time addressing local concerns, preserving and enhancing the health of the watershed and considering the economic stability of the watershed." In January of 2005, a Watershed Management Plan for WRIA 62 was completed (Golder Associates 2005). This plan identified the following goal and objective that are related to the management of aquatic plants:

- WQUAL-2: Watershed Planning Implementing Body support of actions that aim to reduce Eurasian watermilfoil and other aquatic nuisance weeds in WRIA 62.

  Objective: Reduce Eurasian watermilfoil and other aquatic nuisance weeds in WRIA 62

Columbia River Subbasin Plans

In 2004, the Northwest Power Planning Council completed the Intermountain Province Subbasin Plan. This plan identifies recommended management actions that will be used to guide the review, selection, and funding of projects in the subbasin (GEI 2004). The management plan objective and strategies developed to achieve this objective as related to aquatic macrophytes in the Pend Oreille River are outlined below.

- Subbasin Objective 1B9: Control the spread (allow 0 acres) of Eurasian Watermilfoil in the subbasin.

  Strategy a: Inventory and map locations of milfoil occurrence.

  Strategy b: Evaluate the impact of extended dewatering and exposure to freezing temperatures on milfoil shoots.

2.3. Study Goals and Objectives

The goal of the Mainstem Aquatic Habitat Modeling Study and its component study efforts is to provide quantitative indices of the effects of existing and alternative Project operational scenarios on aquatic habitats. The objectives of the study are as follows:

1. Map the current aquatic habitat in Boundary Reservoir and tailrace.
2. Select transects to measure and model mainstem Pend Oreille River habitat types.
3. Develop a hydraulic routing model that estimates water surface elevations and average water velocity along modeled transects on an hourly basis under alternative operational scenarios.
4. Develop new, or modify existing, Habitat Suitability Indices for selected target species and lifestages.
5. Develop an integrated mainstem aquatic habitat model that produces a time series of data for a variety of biological metrics under alternative operational scenarios. These metrics include (but are not necessarily limited to):
   - water surface elevation at selected reservoir locations;
   - water velocity within transect subdivisions (cells) over a range of flow and reservoir pool levels;
   - varial zone area (Figures 2.3-1 and 2.3-2);
   - frequency and duration of exposure/inundation of the varial zone at selected reservoir locations (Figures 2.3-1 and 2.3-2); and
   - habitat suitability indices.

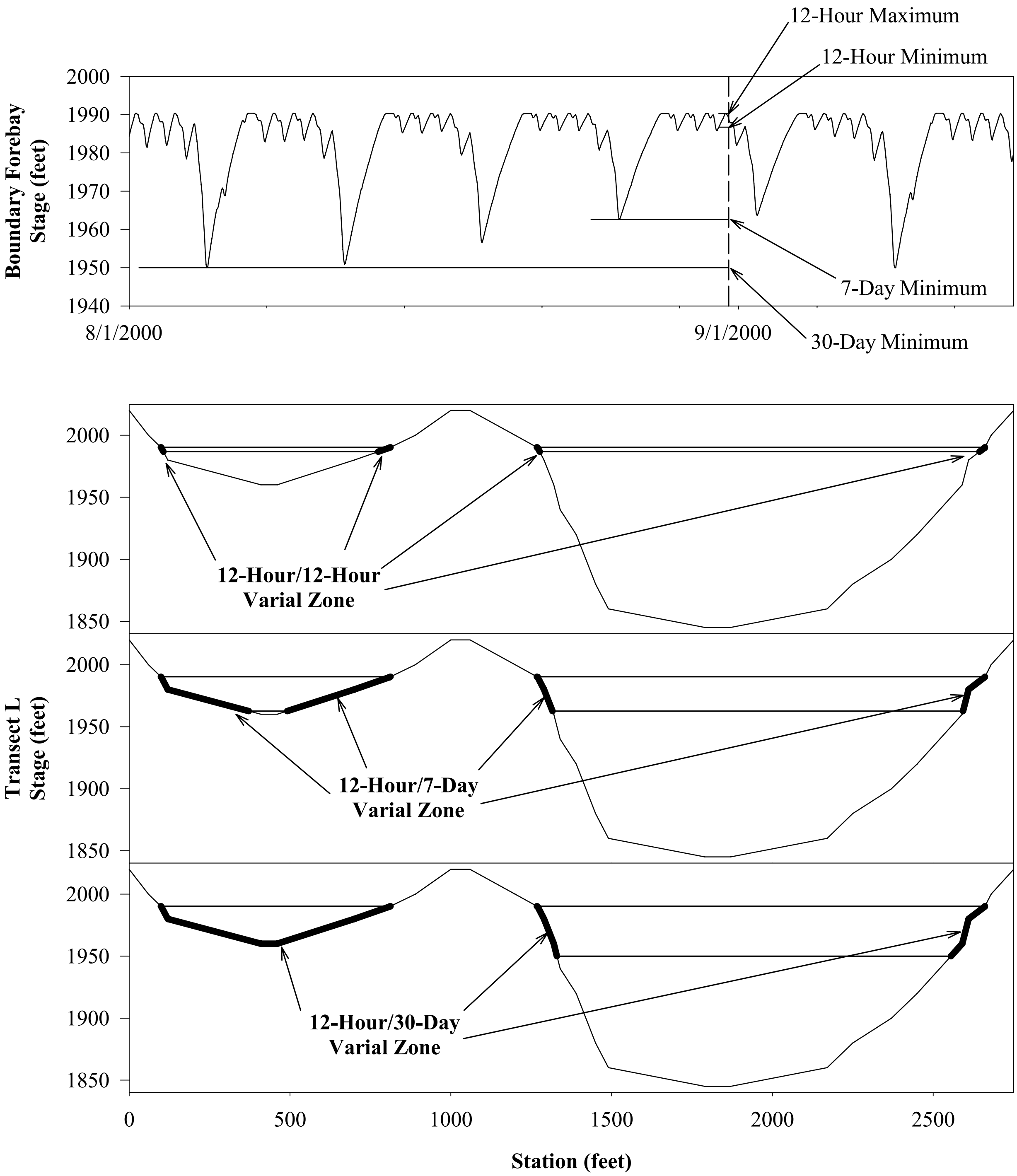

Figure 2.3-1. Illustrative snapshot of mainstem aquatic habitat model output at hypothetical Transect L, downstream of Metaline Falls, for hourly water surface elevation and varial zone area under a hypothetical scenario with maximum pool level fluctuations of up to 40 feet during August 2000. Varial zone stability calculated using 12-hour, 7-day, and 30-day indices.

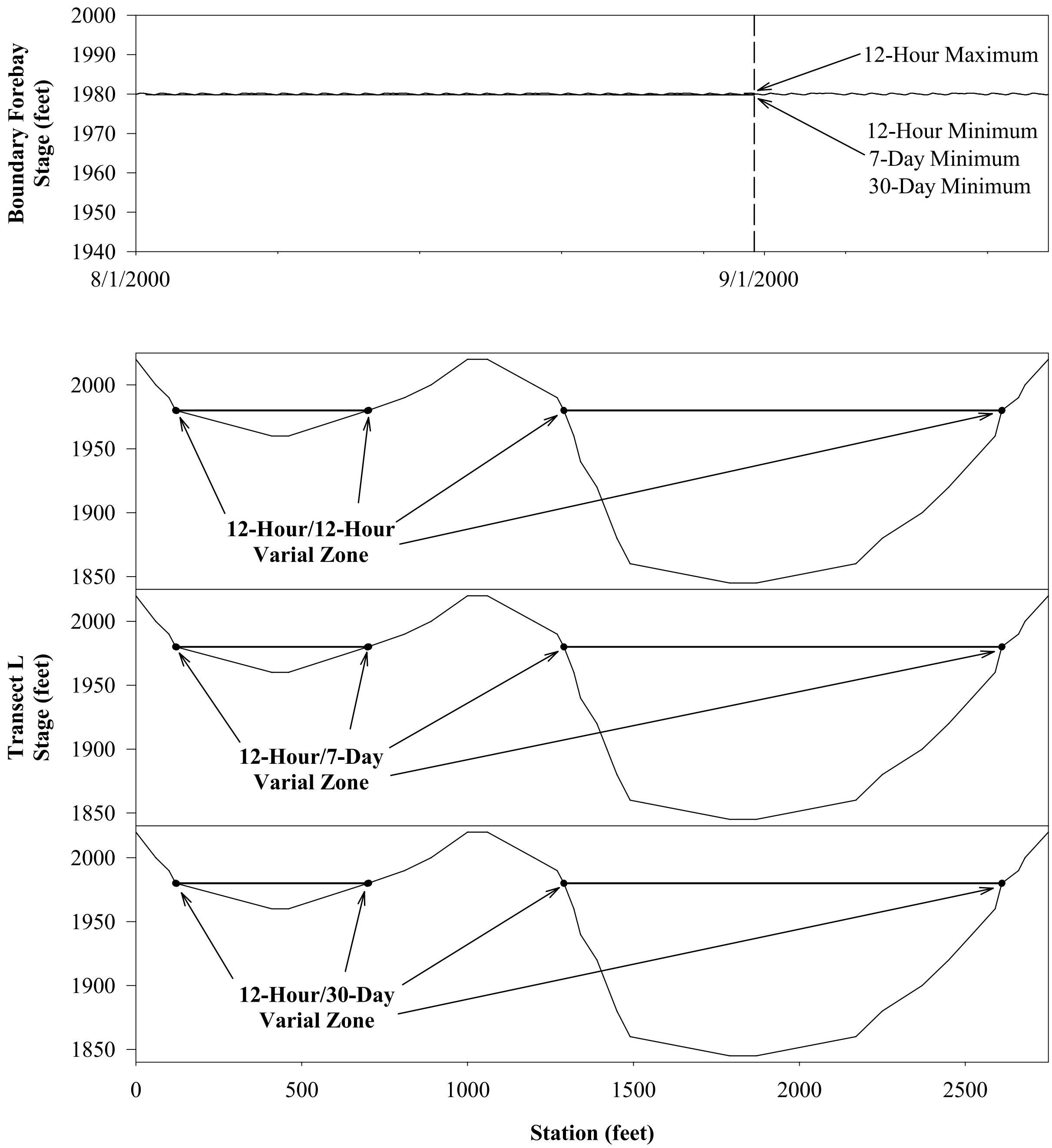

Figure 2.3-2. Illustrative snapshot of mainstem aquatic habitat model output at hypothetical Transect L, downstream of Metaline Falls, for hourly water surface elevation and varial zone area during August 2000 with a relatively stable reservoir pool level during August 2000. Varial zone stability calculated using 12-hour, 7-day, and 30-day indices.

6. Conduct a variety of post-processing comparative analyses derived from the output metrics estimated under the mainstem aquatic habitat model. These include (but are not necessarily limited to):
   - ramping rates;
   - juvenile fish stranding/trapping;
   - fish nest viability;
   - macrophyte distribution and abundance; and
   - distribution and abundance of periphyton and benthic macroinvertebrates under alternative operational scenarios.

2.4. Need for Study

Summary of Existing Information

There is little quantitative information regarding the current distribution and type of aquatic habitats in Boundary Reservoir and the tailrace. Studies by McLellan (2001) and R2 Resource Consultants, Inc. (1998) focused on the collection of fish and zooplankton abundance, distribution, and periodicity information. Information regarding aquatic habitat availability and quality was collected incidentally and was mostly inferred rather than measured. Native salmonid use of aquatic habitats in Boundary Reservoir and its tailrace appears to be limited on a seasonal basis due to high summer water temperatures. Thermal refugia may be present at the mouths of some tributaries (e.g., Slate Creek) during these periods.

Information on channel morphology in the Project area is available from bathymetry data and aerial photographs collected in 2005 and 2006. Bathymetry data collected in 2006 will provide bathymetry information between Box Canyon Dam RM 34.5 and the international border at RM16. Two-foot contours will be generated to an elevation of approximately 1,950 feet NGVD29 (1,954 feet NAVD 88), and 5-foot contours will be generated for depths below this elevation. Bathymetry of Seven Mile Reservoir from Seven Mile Dam to the confluence with the Salmo River has been reported by Klohn Crippen Consultants and ASL Environmental Services (2005). The bathymetry was reportedly derived from 1:50,000 scale Natural Resources Canada NTS maps. SCL has determined that the existing bathymetric data from the U.S.-Canada border to Seven Mile Dam is insufficient for the needs of this study. Hence, this information will be collected in 2007.

Some information on the distribution of macrophytes is reported in section 4.6, Botanical Resources, of the PAD (SCL 2006a). Macrophyte beds in Boundary Reservoir are a habitat feature that provides cover, vertical structure, and substrate for macroinvertebrates and spawning by some fish species. Cover types in the Boundary Project vicinity were delineated on true-color aerial photographs (scales of 1 inch = 1,000 feet and 1 inch = 600 feet) taken in August 2005. Mapping and verification methods are described in the Early Information Development Plan for Cover Type Mapping (Dwerlkotte and McShane 2005). Cover types were field verified in September 2005. A vegetation cover type map (Figure 4.6-1 in the PAD) shows the distribution of macrophytes, which corresponds to the area mapped as Lacustrine Aquatic Bed. This cover type includes shallow water areas that are characterized by the presence of aquatic vegetation, primarily milfoil, coonwort (*Ceratophyllum demersum*), and elodea (*Elodea canadensis*) (SCL 2006a). Eurasian watermilfoil and curly pondweed are found in shallow coves and bays of Boundary Reservoir, and dense mats of macrophytes have been found in side channels near RM 19.5, upstream of Metaline Falls between RM 27 and RM 29, and between the gaging station and Metaline Falls at RM 31–33. A total of 9 aquatic bed species were identified (Table 2.4-1).

Table 2.4-1. Aquatic macrophytes found in the aquatic bed cover type (SCL 2006a). [2]

Common Name	Latin Name	Number of Sites Observed
Coon's tail	*Ceratophyllum demersum*	1
Canadian waterweed	*Elodea Canadensis*	2
Owyhee mudwort	*Limosella acaulis*	1
Water mudwort	*Limosella cf. aquatica*	1
Eurasian watermilfoil	*Myriophyllum spicatum*	2
Variable leaf pondweed	*Potamogeton cf. gramineus*	1
Whitewater crowfoot	*Ranunculus aquatilis*	1
Persistent sepal	*Rorippa calycina*	1
Horned pondweed	*Zannichellia sp.*	1

Need for Additional Information

The Boundary Project is currently operated as a load-following facility with generation shaped to deliver power during peak-load hours. Reservoir forebay pool levels typically fluctuate within a 10-foot range during the summer recreation season and may fluctuate within a 20-foot range during the fall, winter and spring. Daily reservoir level fluctuations may exceed these ranges in response to load demand. Fluctuations in reservoir water surface elevations will cause shallower portions of the Pend Oreille River to alternate between wet and dry conditions on an hourly or daily basis. This cycle of inundation and dewatering may affect the survival and growth of fish, macrophytes, periphyton and benthic macroinvertebrates in channel margin habitats.

As previously indicated, little quantitative information is available regarding the physical habitat characteristics of Boundary Reservoir and its tailrace. Potential effects of existing Project operations on aquatic habitats and biota and potential benefits and impacts of alternative operational scenarios have not been quantitatively analyzed. The mainstem aquatic habitat model will integrate Project operations, physical and hydraulic data, and biological information to quantify potential Project effects. The model will provide an analytical framework for assessing alternative operational scenarios and quantitative metrics that will aid in comparing the

[2] Changes to the list of aquatic macrophytes were made in response to relicensing participant comments (see Attachment 3 of this RSP). Oxeye daisy, common St. Johnsworth, common plantain and American speedwell were dropped from the list of aquatic macrophytes, and the common name Eurasian watermilfoil was used for *Myriophyllum spicatum.*

alternatives. Project effects will be quantified using indices of potential habitat rather than estimates of the number of fish produced or lost under alternative operational scenarios.

2.5. Detailed Description of Study

Study Area

The study area includes all of Boundary Reservoir and portions of the Pend Oreille River mainstem downstream of Boundary Dam that could potentially be affected by Boundary Project operations. The study area is divided into the following four reaches (Figure 1.0-1):

- Upper Reservoir Reach — Box Canyon Dam to Metaline Falls to (RM 34.5 – 26.8)
- Canyon Reach — Metaline Falls to downstream end of Z-Canyon (RM 26.8 – 19.4)
- Forebay Reach — Downstream end of Z-Canyon to Boundary Dam (RM 19.4 – 17.0)
- Tailrace Reach — Boundary Dam downstream to Red Bird Creek confluence with the Pend Oreille River, British Columbia (RM 17.0 – 13.1)

The effects of Boundary Project operations on aquatic habitats below Boundary Dam are influenced by Seven Mile Project operations. At low Seven Mile Reservoir pool levels, riverine habitat is present in the Pend Oreille River downstream to the confluence with Red Bird Creek. At high Seven Mile Reservoir pool levels the riverine habitat above the Red Bird creek confluence becomes reservoir habitat. SCL is proposing to collect data on up to 3.9 miles of the Pend Oreille River channel exposed under low Seven Mile Reservoir pool levels. There are plans by the Columbia Power Corporation to add capacity at the downstream Waneta Project. If the Waneta Project upgrade is approved and the effects on Seven Mile Project operations identified, the downstream extent of the Tailrace Reach may be reduced to reflect the effects of changes in Seven Mile Project operations.[3] SCL will continue discussions regarding the downstream extent of studies during early 2007 as the Technical Consultant finalizes the study implementation details in coordination with SCL and relicensing participants. SCL may limit downstream investigations to the U.S./Canada border.

Description of Study Components

The Mainstem Aquatic Habitat Modeling Study consists of the following components:

- Habitat Mapping
- Hydraulic Routing
- Physical Habitat Model Development
- HSI development, for:

[3] As of October 2006, the Waneta Project turbine capacity upgrade was under environmental review in British Columbia. If implemented, the Waneta Project upgrade could affect the power generation strategy at both the Waneta Project and the Seven Mile Project. If the Waneta Project upgrade is implemented, it is likely that changes to Seven Mile Project operations will increase the frequency and duration of inundation of the Boundary Project tailrace. Since the Waneta Project upgrade is still in development, there is some uncertainty regarding the downstream spatial extent of the effects of Boundary Project operations.

- o fish;
- o macrophytes; and
- o periphyton and benthic macroinvertebrates.

Habitat Mapping

The mainstem aquatic habitat model will be used to evaluate the effects of alternative Boundary Project operational scenarios on aquatic habitats and biota in the Pend Oreille River. One of the initial model development tasks will be the selection of transects. These transects will be representative of habitat conditions based on channel morphology and major habitat features. Transects may also be selected to describe distinct habitat features that are important to aquatic biota, but may not be adequately described by representative transects. In order to select transects, specific information on both channel morphology and other important habitat features within Boundary Reservoir will be needed. This information will allow SCL and relicensing participants to decide on the number and placement of transects to best represent the system within the modeling platform.

The Habitat Mapping study component provides the critical information needed about the distribution of major and distinct habitat features in the study area to select representative transects for the Aquatic Habitat Model and assign appropriate weighting to each selected transect.

Proposed Methodology

The distribution and proportion of major habitat types in the Pend Oreille River from Box Canyon Dam to just above the Salmo River confluence will be identified using analyses of bathymetric data, aerial photography, site-specific biological surveys, and relicensing participants' knowledge of the Project area. The location and distribution of distinct habitat types, including low gradient bars, backwater sloughs, depressions, areas of intense fish spawning activity and macrophyte beds, will also be identified using available information and the results of site-specific surveys. The specific tasks involved in this study component are described below.

Task 1) Channel Typing

Use bathymetric data and aerial mapping techniques to determine the proportion of major channel types by reach and for the total analysis area: the Upper Reservoir Reach, extending from Box Canyon Dam downstream to the Metaline Falls hydraulic feature (6.7 river miles); the Canyon Reach, extending from, and including, Metaline Falls downstream to the mouth of the canyon (8.4 river miles); the Forebay Reach, defined as the Pend Oreille River extending from the mouth of the canyon downstream to Boundary Dam (2.4 river miles); and the Tailrace Reach, extending from Boundary Dam downstream to the confluence of Red Bird Creek (3.9 river miles).

Task 2) Wetted Width Calculations

Using a Geographical Information System (GIS) database to process available bathymetry, calculate the average full pool wetted channel width of the Pend Oreille River from Box Canyon Dam downstream to the confluence of Red Bird Creek. Calculate the percentage of channel length by reach having a width greater than 1.5 times the average channel width of the total analysis area, the length of channel having a width less than 0.5 times the total average, and the length of channel having a width 0.5 to 1.5 time the average channel width or other indices of channel morphology .

Task 3) Wetted Surface Area Calculations

Use the results of the bathymetric survey and the GIS to calculate by reach the total wetted surface area of the Pend Oreille River channel under full pool conditions. Calculate by reach the total wetted surface area having a depth greater than 10 feet, 20 feet, 30 feet, 40 feet, 50 feet, and 100 feet. Develop maps of the Pend Oreille River channel displaying the depth profiles obtained using the bathymetric data.

Task 4) LWD Mapping

Using existing aerial photography, map existing locations of large wood pieces within the full pool surface area of the Pend Oreille River channel. Conduct a field survey of the shorelines of the Pend Oreille River within the analysis area and record the number, volume and type of large woody pieces by reach on an aerial map of the Pend Oreille River (see Large Wood Management Study plan [Study No. 10], for the definition of large wood categories).

Task 5) Aquatic Vegetation Mapping

Using existing aerial photography, map existing beds of aquatic vegetation within the full pool surface area of the Pend Oreille River channel. Conduct field surveys to verify and confirm and, where appropriate, adjust the vegetation maps. Using a stratified sampling scheme, estimate vegetation density, species, and percent of native versus non-native aquatic vegetation. Field surveys will be conducted during a period of peak macrophyte growth.

Task 6) Interviews

Interview relicensing participants, local biologists, anglers, and other personnel familiar with the Project area and identify areas supporting fish spawning and other areas of concentrated biological activity. Record spawning areas by species on aerial maps of the Project area. Field observations of fish spawning sites collected as part of the 2007 Habitat Suitability Information field validation effort will be used to confirm or adjust the location of potential spawning areas.

Task 6) Data Compilation

Compile information on channel width, depth, LWD, macrophytes, concentrated biological activity and channel types to determine the location and distribution of representative and distinct habitat types.

Work Products

The Habitat Mapping study component will include the following work products:

- Map and tabular summary of channel types
- Map and tabular summary of LWD
- Map and tabular summary of aquatic vegetation types
- Tabular summary of wetted width and wetted surface area calculations
- Documentation of interviews

These work products and other results of the aquatic habitat mapping study will be compiled and presented in a study report. The report will include the methodology used to distinguish habitat types, a description of the data collection methods and information collected, and tables summarizing the channel morphology and channel habitat types by river mile.

Schedule

The schedule for completing the Habitat Mapping component of this study is provided in Table 2.5-1.

Table 2.5-1. Schedule for the Habitat Mapping study component.

Activity	2007				2008			
	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q
Study startup	------							
Channel typing		--						
Channel length & surface area calculations		–						
Large woody debris mapping		--------	▲					
Aquatic vegetation mapping			▲					
Fish spawning area mapping		---------						
Prepare draft study report				●				
Distribute draft study report for relicensing participant review					●			
Meet with relicensing participants to review efforts and results					●			
Include final study report in Initial Study Report (ISR) filed with FERC					●			
Hold ISR meeting and file meeting summary with FERC					●			

Hydraulic Routing

Load-following operations at Boundary Project, designed to deliver power during peak-load hours, cause fluctuations of water surface elevations in the forebay of Boundary Reservoir and fluctuations in flow releases to the Boundary Tailrace. Slow moving waves (water surface fluctuations) originating in the forebay of Boundary Reservoir travel upstream through the Pend Oreille River to as far as Box Canyon Dam, and flow fluctuations originating in the tailrace of Boundary Project travel downstream to as far as just above the confluence with the Salmo River. A one-dimensional, unsteady-flow, hydraulic model will be used to analyze the translation and attenuation of water surface elevation and flow fluctuations upstream and downstream from Boundary Dam. The results of the hydraulic model will be used to support the analysis of impacts of Project operations on aquatic habitats in the Pend Oreille River between Box Canyon Dam and the confluence of Red Bird Creek (just upstream of the confluence of the Salmo River with the mainstem Pend Oreille River).

During peak load hours, additional flow is released through Boundary Powerhouse to meet power demands. The forebay water surface elevation in Boundary Reservoir is drawn down to provide the additional flow for peak power generation. During off-peak load hours, flows through the powerhouse are reduced, and Boundary Reservoir is refilled to create available usable storage for the next peak load period. The fluctuations in water surface elevations in the forebay of Boundary Reservoir create waves that travel the 17.5-mile-long distance from the source at Boundary Dam upstream to Box Canyon Dam. These waves attenuate, or dampen, as they travel upstream, and the range of fluctuation of water surface elevation is reduced when they reach Box Canyon Dam. Under certain conditions when the Boundary Reservoir forebay water surface elevations fluctuate below some threshold elevation, the waves do not travel past Metaline Falls, and the reach of the Pend Oreille River between Metaline Falls and Box Canyon Dam is not impacted by downstream fluctuations of water surface elevation at Boundary Dam.

Similarly, fluctuations in flow releases from Boundary Dam create waves that travel downstream through the Pend Oreille River. The distance that these waves travel depends on the water surface elevation maintained in the forebay of Seven Mile Reservoir. When the forebay water surface elevation of Seven Mile Reservoir is at normal maximum, the reservoir extends upstream and inundates the Boundary Dam tailrace. When the forebay water surface elevation of Seven Mile Reservoir is at maximum drawdown, the reservoir is assumed to extend upstream of the confluence of the Salmo River near Red Bird Creek, and the waves created by fluctuating flow releases from Boundary Powerhouse would travel downstream from the Boundary Project tailrace to the confluence with Red Bird Creek.

The waves created by load-following operations at the Boundary Project impact the aquatic habitat of the Pend Oreille River both upstream and downstream from Boundary Dam, especially along the margins of the river that are alternately wetted and dewatered (the varial zone). To analyze the impacts of alternative Project operational scenarios on aquatic habitat, a hydraulic routing model will be used to translate the effects of changes in Boundary Project forebay water surface elevations and tailrace flows associated with Project operations to Pend Oreille River locations extending from Box Canyon Dam downstream to near the confluence with Red Bird Creek.

Proposed Methodology

The U.S. Geological Survey (USGS), SCL, and BC Hydro currently collect hourly hydrologic data in the Pend Oreille River. It is assumed that these data will continue to be collected in 2007 and 2008, and will be available for use in the hydraulic routing model. These data, needed for the hydraulic routing model, consist of the following:

- Hourly flow data from the US Geological Survey for the Pend Oreille River below Box Canyon Dam (Gage No. 12396500).
- Hourly flow data from Seattle City Light for total flow release from Boundary Reservoir (power generation plus spill).
- Hourly water surface elevation data from BC Hydro for the Seven Mile reservoir forebay.

Additional information is needed to develop and calibrate the hydraulic routing model, and to provide a consistent input database to allow for comparison of alternative Project operational scenarios. The additional data required consist of the following:

- Surveys of Boundary Reservoir and the immediate tailrace conducted in 2006 will provide vertical resolution of 2-foot contours for wetted areas down to a depth of approximately 40 feet from the full pool water surface and 5-foot contours below a depth of 40 feet from the full pool water surface for the reach of the Pend Oreille River between Box Canyon Dam and the U.S.-Canada border. SCL has determined that the existing bathymetric data from the U.S.-Canada border to Seven Mile Dam is insufficient for the needs of this study. Hence, this information will be collected in 2007.
- Water surface elevation data (15-minute readings) covering a continuous period encompassing at least one spring and summer will be needed from stage recorders deployed in the Pend Oreille River at the following locations:
  - Just downstream of Box Canyon Dam
  - Just upstream from Metaline Falls
  - Just downstream from Metaline Falls
  - At the downstream end of the Canyon Reach
  - In the Boundary Project forebay
  - In Boundary Project tailrace
  - At the old bridge site upstream from the confluence with the Salmo River
- Water surface elevation data will be needed from the stage recorders deployed at these seven selected sites during 2007 to develop and calibrate the hydraulic routing model. Additional water surface elevation data from the stage recorders will be needed in 2008 to help establish a link between the hydraulic routing model and the mainstem aquatic habitat modeling transects.

- The conversion between vertical elevation references (CGVD28, NGVD29 and NAVD88) will be needed to convert all elevation data to a common datum.
- A time series of hourly flow releases from Box Canyon Dam to the Pend Oreille River will be needed for use as input to the hydraulic routing model. These flow hydrographs will be assumed to be the same for all alternative Boundary Project operational scenarios.
- The effects of alternative operational scenarios on hourly water surface elevations in the Boundary Reservoir forebay and hourly flow releases (power generation plus spill) from Boundary Dam to the Pend Oreille River will be needed from the Boundary Project operations Scenario Tool to be used as input to the hydraulic routing model.
- The potential response of Seven Mile Project operations to changing Boundary Project operations will be needed (either from BC Hydro, or from SCL in coordination from BC Hydro). The specific information needed consists of hourly Seven Mile forebay water surface elevations for each Boundary operational scenario and each hydrologic period of interest.

The specific tasks involved in this study component are described below.

Task 1) Routing Model Construction

A one-dimensional, unsteady-flow, hydraulic routing model will be constructed to allow for the routing of flow and stage fluctuations in the Pend Oreille River from Boundary Dam to Box Canyon Dam and from Boundary Dam to Seven Mile Dam. The routing model will be developed using cross-sectional profile data derived from bathymetric and LIDAR surveys.

Task 2) Model Calibration

The hydraulic routing model will be calibrated to match observed hourly stages obtained from stage recorders by adjusting equivalent channel roughness. The resulting model will reflect indices of wave speed, attenuation, and accretion to translate Boundary Reservoir forebay water surface elevations and tailrace flows to upstream and downstream locations.

Task 3) Evaluate Need for Separate Seasonal Models

The need for separate hydraulic routing models for summer and winter periods will be evaluated. If deemed necessary, separate seasonal-specific hydraulic routing models will be developed to account for the additional hydraulic roughness associated with seasonal growth and die-back of aquatic vegetation.

Task 4) Model Documentation and Executable Model

An executable model and supporting documentation will be prepared that can be used in the development of the mainstem aquatic habitat model and post-processing of operational scenarios developed using the Boundary Project Scenario Tool.

Work Products

Work products will consist of a calibrated executable model and interim and final study reports describing the methods used to develop the routing model, channel cross-section profiles, and details of model calibration. The final study report of the Mainstem Aquatic Habitat Modeling Study will include the final study report of the Hydraulic Routing study component.

Schedule

The schedule for completing the Hydraulic Routing component of this study is provided in Table 2.5-2.

Table 2.5-2. Schedule for the Hydraulic Routing study component.

Activity	2007				2008				2009		
	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q
Technical Consultant study refinement	------										
Assess availability and adequacy of bathymetric data (Box Canyon to Seven Mile Dam)	-------										
Collect bathymetric data for Seven Mile Dam to Boundary Dam		-----									
Construct cross-sections for hydraulic routing model		-------	-------								
Obtain and analyze hourly stage and flow data	-------	-------									
Develop and calibrate flow routing model		------	------	------							
Prepare interim study report (first-year results)				●							
Distribute interim study report					●						
Meet with relicensing participants to review first year efforts and results and discuss plans for any second year efforts					●						
Include interim study report in Initial Study Report (ISR) filed with FERC					●						
Hold ISR meeting and file meeting summary with FERC					●						
Continue to collect water surface elevation data at selected sites to help calibrate the Mainstem Aquatic Habitat Modeling transects					-------	-------	-------				
Prepare "draft" final study report								●			
Distribute "draft" final study report for relicensing participant review								●			
Meet with relicensing participants to review study efforts and results and "cross-over" study results									●		
Include final study report in Updated Study Report (USR) filed with FERC									●		
Hold USR meeting and file meeting summary with FERC									●		

Physical Habitat Model Development

This study component develops the core structure of the mainstem aquatic habitat model. It uses the information or technical analyses performed in other study components as a basis for developing the model structure (e.g., Habitat Mapping) or as part of internal model processes (e.g., Hydraulic Routing and HSI curves).

Proposed Methodology

There are 11 tasks specific to the mainstem aquatic habitat model development and analyses. These tasks are described below.

Task 1) Transect Selection

In coordination with relicensing participants, use the results of the Habitat Mapping study component to select transects within the mainstem Pend Oreille River to describe representative habitat conditions based on channel morphology and major habitat features. As needed, additional habitat transects will be selected to describe distinct habitat features such as localized areas of fish trapping, stranding, and localized spawning that may not be adequately described by transects used to describe representative habitat features. Transects will also be located at some of the water surface elevation recorders (see Hydraulic Routing Model study component above) to assist in calibrating the flow routing model to mainstem habitat transects. For planning purposes, it is assumed 50 transects, distributed as follows, will be required to describe aquatic habitat conditions within the Pend Oreille River:

- Upper Reservoir Reach (Box Canyon Dam downstream to Metaline Falls, 6.7 river miles) — 20 transects.
- Canyon Reach (Metaline Falls downstream to mouth of canyon, 8.4 river miles) — 14 transects.
- Forebay Reach (Mouth of canyon downstream to Boundary Dam, 2.4 river miles) — 4 transects.
- Tailrace Reach (Boundary Dam downstream to Red Bird Creek [just above confluence with the Salmo River], 3.9 river miles) — 12 transects.[4]

Task 2) Relicensing Participant Site Visit

Conduct a site visit with personnel from agencies, tribes and other relicensing participants to confirm/modify habitat transect selection.

Task 3) Substrate and Aquatic Vegetation Characterization

Characterize and map substrate and vegetation along habitat transects to a depth of 40 feet below the full pool water surface during two periods of macrophyte growth. The first should occur

[4] During early 2007, SCL and the Technical Consultant will investigate potential issues associated with conducting cross-boundary studies with the respective US and Canadian border security agencies. SCL will continue discussions regarding the downstream extent of studies with relicensing participants during early 2007 during development of the study implementation details. One option under consideration is to collect detailed bathymetry data of Seven Mile Reservoir in 2007 and to use the bathymetry and LIDAR data to synthesize habitat transects in the Pend Oreille River channel between the US border and the confluence with Red Bird Creek. These synthesized transects would supplement measured habitat transect data collected in the Pend Oreille River channel between Boundary Dam and the US-Canada border.

during a period of abundant macrophyte growth (e.g., late August low-flow conditions). The second should occur during a period of sparse macrophyte growth (e.g., early April). An underwater video camera may be used to characterize and map substrate and macrophytes in water too deep to observe from the surface. Substrate characterization of the channel bed at depths greater than 40 feet will rely on acoustic backscatter collected during the 2006 bathymetric surveys.

Task 4) Velocity and Depth Measurements

Measure velocities, water surface elevation and bottom profile habitat transect alignments under three stable flow conditions and full pool elevations:

- High flows (i.e., above 40,000 cfs). These typically occur in late May or early June.
- Mid-range flows (i.e., about 20,000 cfs). These typically occur in July.
- Low flows (i.e., below about 12,000 cfs). These typically occur in August.

Task 5) Develop Cross-sectional Profiles

Develop cross-sectional profiles for each of the mainstem habitat transects and subdivide transects into cells (n= 20 to 100 cells).

Task 6) Hydraulic Model Integration

Integrate each of the measured mainstem habitat transects into the hydraulic routing model described above to translate changes in Boundary Project forebay water surface elevations and tailrace flows to each of the measured mainstem habitat transects.

Task 7) Calibrate Hydraulic Model

Calibrate the hydraulic routing model to match observed velocities within cells along the habitat transects by adjusting equivalent channel roughness.

Task 8) Downramping Analysis

Calculate the number of hours with downramping rates exceeding 1, 2, 4, 6 and 12 inches per hour associated with each alternative operational scenario and selected hydrologic period. The number of hours of downramping exceeding each criterion will be calculated by month and by annual total for each of the measured mainstem habitat transects. The number of hours of downramping exceeding each criterion will be calculated as a reach-averaged, transect-weighted total for the entire study area from Box Canyon Dam downstream to Red Bird Creek and for the four mainstem Pend Oreille reaches (Upper Reservoir Reach, Canyon Reach, Forebay Reach, and Tailrace Reach).

Task 9) Varial Zone Model

Develop a varial zone habitat model to quantify the magnitude, frequency and duration of the channel area that is exposed to inundation and dewatering. The varial zone analysis is conducted by discrete portions of mainstem transects (i.e., cells) using an hourly time step that considers fluctuations in water surface elevations that occurred before and after the hour of interest. The analysis is conducted by cell and by hour for mainstem transects of interest. The varial zone is defined as the area between the high water surface elevation and the low water surface elevation using a range of time periods to reflect the aquatic species and lifestage of interest. A range of time periods are presented for planning purposes; the selection of time periods to define the upper and lower extent of the varial zone for the Boundary Project will be coordinated with relicensing participants. Information on the rate of colonization, dewatering mortalities and conditions supporting suitable habitats for organisms of interest will be developed as part of the HSI study component.

For planning purposes, the upper end of the varial zone is assumed to be the highest water surface elevation within the previous 12-hour period. In other words, the upper edge of the varial zone extended to the upper wetted channel margin. Three different time scales are used to determine the lower extent of the varial zone. The bottom of the varial zone is based on the minimum reservoir water surface elevation during the previous 12 hours, 7 days, or 30 days. An example of the results of the varial zone analysis for a hypothetical transect under two alternative operational scenarios is presented in Figures 1.0-1 and 1.0-2. The three different varial zone analyses provide the following information on a range of environmental resources and Project effects:

- 12-hr/12-hr time series:[5]
  - Indicator of risk of immediate dewatering mortality due to hourly load-following operations.
  - Indicator of effects of water level changes on aquatic biota such as fry or benthic macroinvertebrate drift that colonize shallow mainstem areas within hours of rewetting of habitats.
  - Results can be used to indicate potential interference of smallmouth bass spawning activity associated with reservoir pool level fluctuations.
- 12-hr/7-day time series:
  - Indicator of risk of dewatering due to daily changes in load-following (weekday versus weekend operations).
  - Indicator of effects of water level changes on periphyton and benthic macroinvertebrate species that have recolonized shallow mainstem areas within days of rewetting of habitats.
- 12-hr/30-day time series:
  - Indicator of risk of dewatering due to seasonal changes in Project inflow associated with storage in upstream reservoirs.
  - Indicator of effects of water level changes on aquatic biota that require weeks to months to establish an assemblage of species.

[5] The varial zone area between the highest water surface elevation in the previous 12 hours and the lowest water surface elevation in the following 12 hours.

The portion of the channel margin below the minimum varial zone will not receive further consideration during the varial zone analysis.

The varial zone will be calculated as the channel area (channel width times assumed channel length) for each habitat transect by month and annual total for each alternative operational scenario and selected hydrologic period. The varial zone area will also be calculated as a reach-averaged, transect-weighted total for each of the four mainstem reaches and as a reach-averaged, transect-weighted total for the entire study area between Box Canyon Dam downstream to the confluence of Red Bird Creek (just above confluence with the Salmo River). The time periods used to define the varial zone will be developed in coordination with relicensing participants as part of the Habitat Suitability Indices Development study component and will be developed to reflect rates of habitat colonization and dewatering-related mortality for the aquatic species and lifestages of interest.

Task 10) Habitat Weighted Usable Area

Translate changes in water surface elevation at each of the measured mainstem habitat transects into changes in depth, velocity, substrate, and cover. Use habitat suitability index (HSI) curves developed for species and lifestages of interest to translate changes in hydraulic conditions to indices of habitat suitability (see the Habitat Suitability Indices Development study component described below). Quantify the area of Pend Oreille River channel containing suitable habitat indices for target species and lifestages of interest for each alternative operational scenario under Boundary Reservoir forebay pool levels at elevations 1,990, 1,980 and 1,970 feet NGVD 29 (1,994, 1,984, and 1,974 feet NAVD 88, respectively).

Task 11) Post-Processing

Use the hydraulic-routing and habitat models to process output from the Boundary Project operations Scenario Tool (see Attachment 1, section 3.2 of this RSP) for each operational scenario and hydrologic period to quantify effects of Boundary Project operations on:

- downramping rates;
- varial zone area;
- effective spawning areas for fish species of interest (i.e., spawning sites remain wetted through egg hatching);
- weighted usable area for fish species and lifestages of interest;
- macrophyte distribution and growth and potential benefits or impacts of changes in abundance; and
- periphyton and benthic macroinvertebrates abundance.

The various indices of Project effects on mainstem aquatic habitats will be summarized and tabulated to allow ready comparison of the effects of an existing operations scenario to alternative operational scenarios. It is anticipated that the varial zone analysis will be used as a primary indicator of the effects of operational scenarios on aquatic habitats in the mainstem Pend Oreille River. Analyses of weighted usable area will be developed for species and lifestages of interest, but the results may be of primary interest in identifying the spatial distribution of potential habitats. Each indicator of environmental effect will be tallied separately, and the relative importance of the effects of Project operations on various aquatic resources may be determined independently by interested parties.

Work Products

An interim study report describing the first year's progress in developing the mainstem aquatic habitat model will be produced. The interim study report will include a summary of the transect selection process and describe their location. The interim study report will also present the results of substrate and aquatic vegetation characterization along the selected transects. It is anticipated that final development of the aquatic habitat model will occur after completion of the subcomponent models and studies at the end of 2008 and that details of the subcomponent model studies will be documented in stand-alone reports or as appendices to the Mainstem Aquatic Habitat Modeling report. A second interim study report describing any field data collected during 2008, the final aquatic habitat model structure, and the initial results of model testing will be produced. Final model runs and post-processing of the output will be documented in a final report to be produced by June 30, 2009.

Schedule

The schedule for completing development of the Mainstem Aquatic Habitat Model is provided in Table 2.5-3.

Table 2.5-3. Schedule for development of the Mainstem Aquatic Habitat Model.

Activity	**2007**				**2008**				**2009**		
	1 Q	**2 Q**	**3 Q**	**4 Q**	**1 Q**	**2 Q**	**3 Q**	**4 Q**	**1 Q**	**2 Q**	**3 Q**
Technical Consultant study refinement	--------										
Habitat Mapping/Transect Selection		---▲ ▲									
Relicensing Participant Site Visit			▲ ▲ ▲								
Hydraulic Routing		--------	--------	--------							
Prepare interim study report (first-year results)				•							
Distribute interim study report					•						
Meet with relicensing participants to review first year efforts and results and discuss plans for any second year efforts					•						
Include interim study report in Initial Study Report (ISR) filed with FERC					•						
Hold ISR meeting and file meeting summary with FERC					•						
HSI Development	--------	▲ ▲	▲ ▲	▲ ▲	▲ ▲	▲ ▲	--------	-----			
Substrate and Vegetation Characterization			▲ ▲ ▲			▲ ▲ ▲					
Collect Velocities and depths			▲ ▲ ▲	▲ ▲ ▲		▲ ▲ ▲	▲ ▲ ▲				
Develop Varial Zone Model				------	------	------	------	-------			
Hydraulic Model Integration and Calibration							------	------			
Prepare 2nd interim study report (second-year results)								•			
Distribute 2nd interim study report for relicensing participant review								•			
Meet with relicensing participants to review study efforts and results and "cross-over" study results									•		
Include 2nd interim study report in Updated Study Report (USR) filed with FERC									•		
Hold USR meeting and file meeting summary with FERC									•		
Downramping Analysis								-------	-------	-------	
Habitat WUA								-------	-------	-------	
Post-Processing								-------	-------	-------	
Prepare and file final study report with License Application											•

Habitat Suitability Indices Development

HSI curves represent an assumed functional relationship between an independent variable, such as depth, velocity, and substrate, and the response of a species life stage to a gradient of the independent variable (suitability), which is expressed over a scale of 0.0 (poor habitat) to 1.0 (best habitat) (Bovee 1982) (Figure 2.5-1). In traditional instream flow studies, HSI curves for depth, velocity, substrate and/or cover are combined in a multiplicative fashion to rate the suitability of discrete areas of a stream for use by a species and lifestage of interest. HSI curves translate hydraulic and channel characteristics into measures of overall habitat suitability in the form of weighted usable area (WUA). Depending on the extent of data available, HSI curves can be developed from the literature, or from physical and hydraulic measurements made in the field in areas used by the species and life stages of interest (Bovee 1986). HSI curves for the Boundary Project will be based on information contained in available literature and validated with site-specific data where it can be obtained.

For use in the mainstem aquatic habitat model, HSI curves will also need to be developed to describe the response of aquatic organisms to cyclic inundation and dewatering. For instance, periphyton (algae growing on substrates) will colonize a site if it contains suitable depth, velocity and substrate, but colonization may not occur until the area has been inundated for a period of time. Conversely, the effects of dewatering of the site on periphyton production will depend on the duration of dewatering and conditions at the time of the dewatering (e.g., hot summer day compared to winter). The following sections describe development of HSI curves for fish, macrophytes, and periphyton and benthic macroinvertebrates.

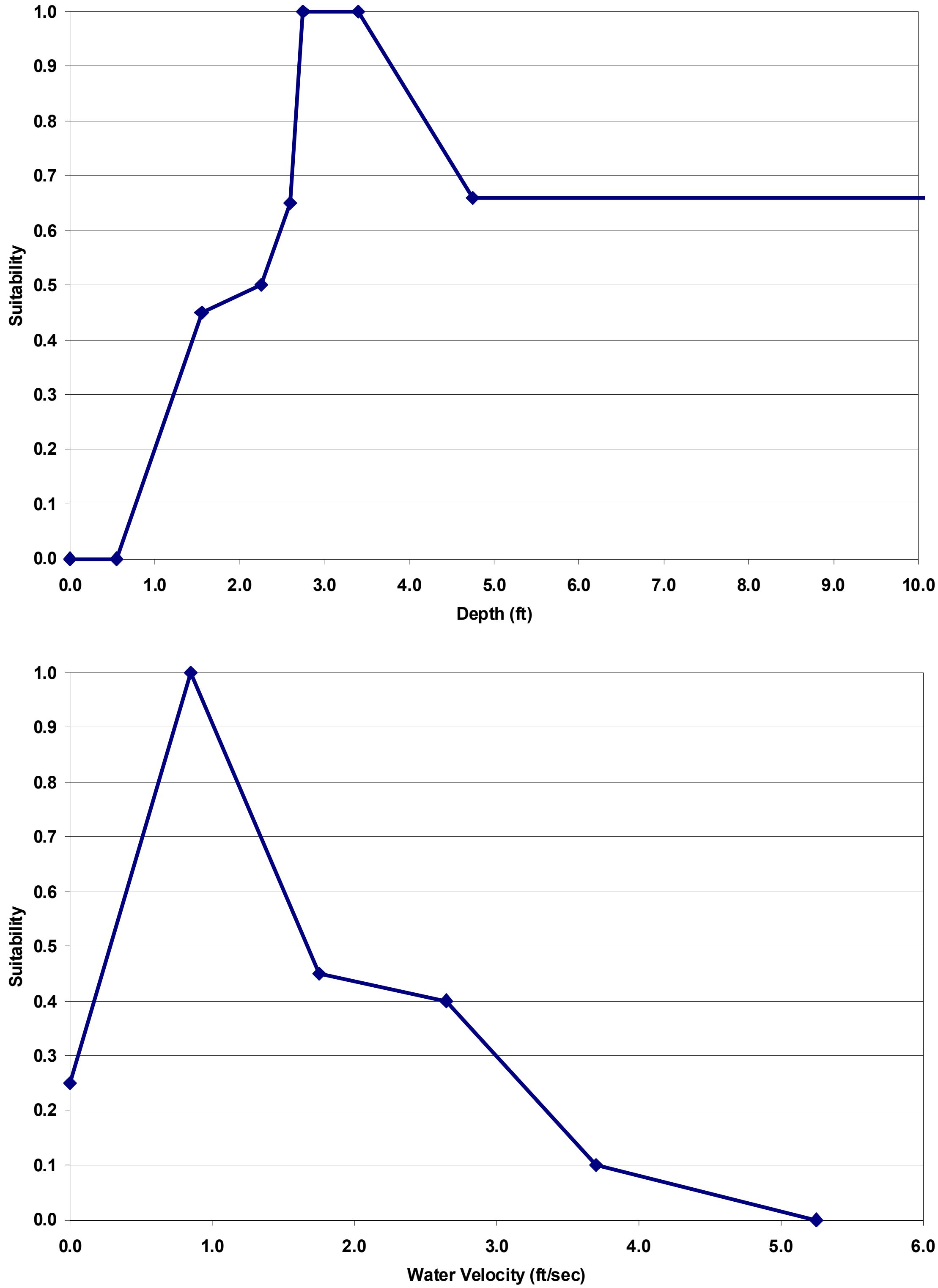

Figure 2.5-1. Example depth (top) and water velocity (bottom) HSI curves for juvenile rainbow trout. Source: WDFW and Ecology (2003).

Fish HSI

The fish community in Boundary Reservoir is dominated by non-salmonids with northern pikeminnow and largescale sucker representing the highest relative abundance based on surveys by McLellan (2001). Salmonids represented about 3.4 percent of the catch, of which about two-thirds of the salmonids were mountain whitefish. From a fisheries management perspective, the important fish species in Boundary Reservoir and the tailrace are the native salmonids (bull trout, westslope cutthroat trout, and mountain whitefish) and a non-native sport fish (smallmouth bass). For the purposes of this study, relicensing participants also tentatively agreed to include a native minnow (redside shiner) [6] as an indicator for prey species. Infrequent observations of reservoir and tributary delta habitat use by native salmonids may increase the reliance on literature-based HSI information. [7] HSI curves developed for fish species and lifestages of interest will be used in the Tributary Delta Modeling Study (see Study No. 8) as well as this Mainstem Aquatic Habitat Modeling Study.

Proposed Methodology

In developing the proposed methodology for this study component, the following assumptions were made:

- Habitat conditions available within the Boundary Project area during the 2007 and 2008 study period may not represent the full range of conditions potentially available under alternative Boundary Project operational scenarios. For some organisms, such as macrophytes or benthic macroinvertebrates, habitat suitability information may not be available, or may require biological surveys to be conducted outside of the Project area.
- A level of effort is described for planning purposes, but details of the sampling program, including selection of sample location, timing, and intensity and data analysis procedures, will be developed in coordination with relicensing participants.

Development of the fish HSI for this study component includes the following six tasks:

Task 1) *Develop Draft HSI Curves*. Develop draft HSI curves for target species and lifestages using available scientific literature. For planning purposes, the species consist of native salmonids, select sport fish species and a native minnow species (Table 2.5-4). Potential sources of information include the Internet, university libraries, peer-reviewed periodicals, and government and industry technical reports. Special emphasis will be given to information

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[6] Peamouth *(Mylocheilus caurinus)* were identified in the PSP as a target species to evaluate the effects of alternate Boundary Project operations on a species potentially preyed upon by native salmonids and larger sportfish. During preparation of the RSP, SCL reviewed the list of target species and proposed changing the prey indicator species from peamouth to redside shiner *(Richardsonius balteatus)*. During 2000, McLellan (2001) captured peamouth ranging in size from 141 to 357 mm, and redside shiners ranging in size from 116 to 146 mm. SCL proposes to substitute redside shiner instead of peamouth since the size range of redside shiner is more indicative of a prey species.

[7] The abbreviation HSI is used in this document to refer to either Habitat Suitability Index (HSI) models or Habitat Suitability Curves (HSC), depending on the context. For the Boundary Project aquatic habitat studies, HSC (i.e., depth, velocity and substrate/cover) and HSI (i.e., light availability, duration of inundation and dewatering) models will be integrated to analyze the effects of alternate operational scenarios (See footnote 1 for additional discussion).

obtained from similar biological and hydrological systems (fish species composition, stream/reservoir size, geographic location, and project configuration and operation). Habitat suitability information will address fish responses to changes in depth, velocity, substrate, cover, macrophyte beds, indices of stranding and trapping (depressions and isolated pools), rates of colonization and stranding and trapping mortality.

Task 2) *Develop a Periodicity Table*. Develop a species and lifestage periodicity table applicable to the Pend Oreille River from Box Canyon Dam downstream to just above the Salmo River confluence using available scientific literature. The periodicity information will be used to define temporal and spatial changes in fish distribution and abundance, identify time periods when young fish are the most susceptible to stranding, and assist in analyses of the results of the aquatic habitat modeling efforts.

Task 3) *Collect Site-Specific Habitat Suitability Information*. Collect site-specific habitat suitability information using HSI-focused biotelemetry and spawning survey field efforts supplemented by information collected while conducting other studies involving fish sampling surveys (Table 2.5-4). Habitat use information (i.e., water depth, velocity, substrate type, and macrophyte density) will be collected at the location of each identified target fish and lifestage. If available, a minimum of 50 habitat use observations will be collected for each target species life stage.

Task 4) *Stranding and Trapping Field Surveys*. Conduct field surveys of potential stranding and trapping areas prior to and immediately following flow fluctuation events. Surveys will be conducted during times of the year when fish are most likely to be susceptible to stranding and trapping (e.g., July–September). For planning purposes, it is assumed that five areas with conditions presenting a high stranding and trapping risk will be surveyed once per month from July through September during 2007 and 2008. Prior to scheduled reductions in reservoir pool levels, electrofishing surveys will be conducted to determine the number, size and species of fish in the targeted areas. During and immediately following a scheduled drop in reservoir pool level, identified stranding and trapping areas will be surveyed to quantify the number, size and species of fish stranded or trapped by the reduction in pool level. When feasible, surveys will be scheduled when pool levels have been relatively constant during the antecedent period.

Task 5) *Habitat Utilization Frequency Histograms*. Develop a histogram (i.e., bar chart) for each of the habitat parameters (e.g., depth, velocity, substrate, cover/ macrophyte use, rate of colonization) using the site-specific field observations. The histogram developed using field observations will then be compared to the literature-based HSI curve to validate applicability of the literature-based HSI curve for aquatic habitat modeling.

Table 2.5-4. Potential data sources for habitat suitability information.

Species and Lifestages of Interest	Literature	Site-Specific Validation Data				
		Biotelemetry	Distribution and Abundance Surveys	Habitat Transect Surveys	Trapping and Stranding Surveys	HSI Spawning Surveys
Bull Trout *(Salvelinus confluentus)*						
▪ adult	P	P	S			
▪ spawning	P	P				
▪ incubation	P					
▪ fry	P					
▪ juvenile	P					
Westslope Cutthroat Trout *(Oncorhynchus clarki lewisi)*						
▪ adult	P	P	S			
▪ spawning	P	P				
▪ incubation	P					
▪ fry	P					
▪ juvenile	P					
Mountain Whitefish (*Prosopium williamsoni*)						
▪ adult	P	P	S			
▪ spawning	P	P	S			
▪ fry	P		S		S	
▪ juvenile	P		S		S	
Columbia Redband Trout (*Oncorhynchus mykiss gairdneri*) (below Boundary Dam)						
▪ adult	P	P	S			
▪ spawning	P	P				
▪ fry	P					
▪ juvenile	P					
Smallmouth Bass (*Micropterus dolomieu*)						
▪ adult	P	P	S			P
▪ spawning	P	P				P
▪ incubation	P					P
▪ fry	P		S		S	
▪ juvenile	P		S		S	
Redside Shiner *(Richardsonius balteatus)*[8]						
▪ adult	P		S		S	
▪ spawning	P		S		S	
▪ fry	P		S		S	
▪ juvenile	P		S		S	
Size / species susceptibility to stranding and trapping						
	P		S		P	

Notes:

P=Primary data sources, S= Secondary data sources

Blank cells indicate few site-specific data points are expected from this source

[8] See previous footnote for a discussion regarding the use of redside shiner as a prey indicator species.

Task 6) *Relicensing Participant and Expert Panel*. Convene a panel of relicensing participants and, if desired, regional experts (agency, tribal, industry and university researchers) to confirm HSI curves for each target species and lifestage. Using a roundtable discussion format, the panel members will review literature-based life history information and site-specific data to develop a final set of HSI curves. These curves will be used in the mainstem and tributary delta aquatic habitat modeling efforts to define the relationship between habitat quantity and quality for each of the target species under alternative operational scenarios.

Work Products

The final work product of this study effort will consist of HSI curves for the target fish species and lifestages. Reports will include an interim study report describing survey methods, results of 2007 monitoring, and discussion of recommendations for 2008 HSI sampling efforts, and a final study report describing survey methods and results of 2007 and 2008 monitoring.

Schedule

The development of fish HSI for this study component is scheduled to begin in early 2007 and end in 2008 (Table 2.5-5). The majority of data collection will occur in the summer of 2007 with the 2008 field season available if additional data collection is required.

Table 2.5-5. Schedule for fish HSI development.

Activity	2007				2008				2009
	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q
Technical Consultant study refinement	-------								
Develop literature-based HSI curves and periodicity		-------							
Field data collection		▲▲	▲▲	▲▲	▲▲	▲▲			
Prepare interim study report (first-year results)				●					
Distribute interim study report					●				
Meet with relicensing participants to review first year efforts and results and discuss plans for any second year efforts					●				
Include interim study report in Initial Study Report (ISR) filed with FERC					●				
Hold ISR meeting and file meeting summary with FERC					●				
Develop final HSI curves and periodicity							-------	--	
Prepare "draft" final study report								●	
Distribute "draft" final study report for relicensing participant review								●	
Meet with relicensing participants to review study efforts and results and "cross-over" study results									●
Include final study report in Updated Study Report (USR) filed with FERC									●
Hold USR meeting and file meeting summary with FERC									●

Macrophyte HSI

Macrophytes are emergent, submergent, or floating aquatic plants growing in or near the water. Macrophytes can be beneficial to lakes and reservoir systems because they provide cover for fish and substrate for aquatic invertebrates, but the overabundance of macrophytes can become problematic by interfering with recreational activities, affecting the water quality and enhancing internal nutrient loading from the sediments. Macrophyte growth has become an increasing problem in Boundary Reservoir because the shallow water areas of the reservoir system are conducive to the growth of macrophytes. Non-native invasive species, such as Eurasian watermilfoil (*Myriophyllum spicatum*) and curly pondweed (*Potamogeton crispus*), have spread in the shallow, low-velocity areas throughout the Pend Oreille River system (EPA 1993, Pelletier and Coots 1990). Eurasian watermilfoil and curly pondweed are found in shallow coves and bays of Boundary Reservoir, and dense mats of macrophytes have been found in side channels upstream of Peewee Creek near RM 19.5, upstream of Metaline Falls between RM 27 and RM 29, and between the gaging station and Metaline Falls at RM 31–33. The distribution of macrophytes in Boundary Reservoir corresponds to the area mapped as Lacustrine Aquatic Bed in the vegetation cover type map presented in the PAD (Figure 4.6-1; SCL 2006a). This cover type includes shallow water areas, that are characterized by the presence of aquatic vegetation, primarily milfoil, coonwort, and elodea.

Eurasian watermilfoil grows in still to flowing waters, can tolerate salinities of up to 15 parts per thousand (ppt) and pH values from 5.4 to 11, and has been found abundant across a broad range of alkalinity (WSNWCB [undated]; Madsen 1998). Milfoil forms dense mats of vegetation on the water surface, which reduces light penetration and can displace native species of aquatic vegetation (CWS 2003). Its growth begins in early spring, often earlier than other aquatic plants, as temperatures reach 15˚C, and it blooms from June through August (WSNWCB [undated]). A light compensation point of only 1–2 percent enables watermilfoil to photosynthesize in deeper water than other rooted plants (Engel 1995). Milfoil can disperse by fragmentation of plant parts (Hamel 1990). Each fragment can grow roots and develop into a new plant, allowing it to disperse quickly and aggressively. In the late summer and fall the plants become brittle and naturally break apart, promoting colonization of other areas.

In addition to Eurasian watermilfoil, a reconnaissance level survey of Boundary Reservoir in 2005 indicated the presence of another non-native invasive species of macrophyte, curly pondweed, in the Project vicinity (C. McShane, EDAW, personal communication, 2005). Curly pondweed also begins growth in early spring and spreads by vegetative turions or seeds (WSNWCB 2004). Typically, peak biomass is reached in late spring or early summer and decline begins in summer in response to increasing water temperatures. Before decline, the plants grow turions or buds that survive in a dormant state until winter or early spring. Little information is available regarding the distribution of curly pondweed in the Pend Oreille River.

Aquatic macrophyte biomass has been found to be greatest in the littoral regions of the Pend Oreille River at depths of less than 10 feet (Falter et al. 1991). Little to no growth has been found at depths greater than 18 feet. Maximum macrophyte biomass in the mainstem occurs in the latter part of July and in August (Pelletier and Coots 1990). The dense growth of milfoil slows water velocities and allows nutrients and sediments to precipitate out of the water column (EPA 1993).

Many factors influence the growth of aquatic macrophytes such as shading, toxicity, turbidity, water temperature, and gradient, but the main factors are depth, water column velocity, nutrients, and substrate. In general, submerged macrophytes have been found to grow to a depth of two to three times the Secchi depth (Nichols 2001). However, a study by Canfield et al. (1985) found the depth of colonization by macrophytes to be slightly more than the Secchi depth. This study developed the following regression model between the maximum depth of plant colonization (MDC, meters) and Secchi depth (meters): $\text{Log MDC} = 0.62\log SD + 0.26$ (Canfield et al. 1985) (Figure 2.5-2). The depth of colonization will vary depending on the species present. Growth of milfoil has been found to be poor in shallow water of less than 3.28 feet (1 meter) (Smith and Barko 1990). Abundant milfoil growth appears between depths of 1.6 to 11.5 feet (CWS 2003), but some growth has been found at depths as high as 16.4 feet (Pend Oreille County 2003).

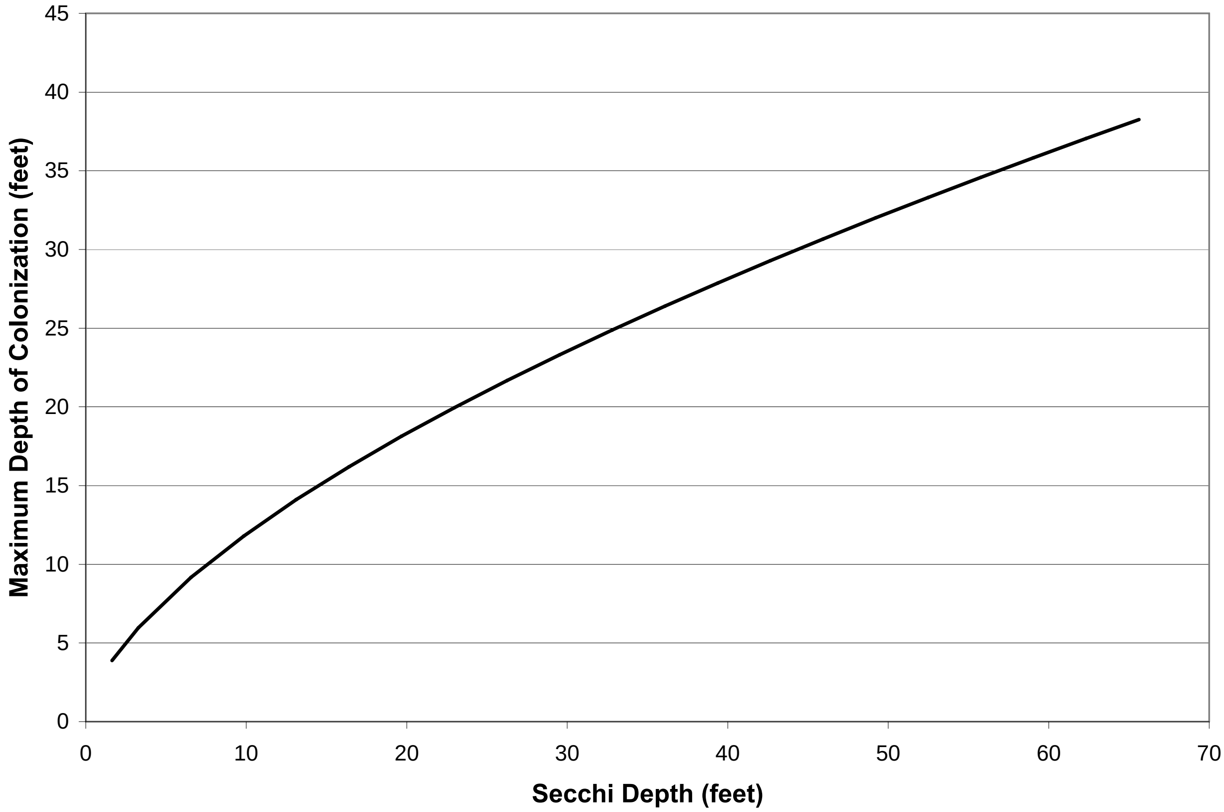

Figure 2.5-2. Regression model relationship developed by Canfield et al. (1985) between Secchi depth and the maximum depth of colonization.

Water column velocity also influences the growth and abundance of aquatic macrophytes. In general, abundant macrophyte growth occurs in areas exposed to slow velocities with growth declining when velocities increase. One study found that at velocities less than 0.2 m/s (0.66 ft/s) 75 percent of the reach was occupied by aquatic vegetation, but that percentage decreased to only 10 percent in areas with velocities greater than 0.9 m/s (2.95 ft/s) (Henriques 1987). In a different study, data from 29 transects for five hydrologically stable streams were compiled and a curve developed for habitat preference as a function of mean water velocity. Habitat preference was analyzed for *Elodea canadensis*, *Myriophyllum triphyllum*, *Potamogeton cheesemanii*, and *Ranunculus trichophyllus*. This study found habitat preference to be lowest in velocities less than 0.05 m/s (0.16 ft/s), to increase steadily until approximately 0.4 m/s (1.3 ft/s), and to decrease slightly until 0.6 m/s (1.97 ft/s) (Riis and Biggs 2003). In addition, this study found a threshold velocity of 0.8 m/s (2.6 ft/s) above which no macrophyte growth occurred. The above studies represent the type of information available in the literature, but additional understanding is necessary in order to evaluate the applicability to species within Boundary Reservoir.

Another factor influencing the growth of macrophytes is the availability of nutrients. Aquatic macrophytes can either utilize water column nutrients or absorb nutrients from the sediments (Davis and Brinson 1980). A study by Bole and Allan (1978) found that milfoil first utilizes phosphorus from the sediment until the water column concentration reaches a threshold value above which the uptake from the water column increases. Studies like these suggest that sediment nutrition dominates over water column concentrations in influencing macrophyte growth (Welch 1992). As such, substrate is also an important factor influencing the growth and abundance of macrophytes. Studies have found milfoil to grow best on fine-textured inorganic sediments (WSNWCB [undated]; Smith and Barko 1990) and relatively poorly on highly organic sediments (>20 percent organic content) or coarse substrates (WSNWCB [undated]; Smith and Barko 1990; Pend Oreille County 2003). In addition, growth of milfoil in full sediment (undiluted with sand) has been found to be nearly 5 times greater than growth in full sand and high water concentrations of nutrients (Welch 1992).

Another factor present within Boundary Reservoir that may also inhibit macrophyte growth is the frequency of dewatering or inundation. On other lakes and reservoirs, water level manipulation has been used effectively to manage macrophyte growth. However, the effectiveness of drawdown is dependent on several factors such as the degree of desiccation, the composition of the substrate, the species present, and the air temperature (WSNWCB [undated]). Lowering the water level in winter exposes sediments to freezing and loss of water, while dewatering during the summer causes desiccation and exposure to high temperatures; both conditions can kill plants (WSNWCB [undated]). The length of exposure required to cause death varies within the literature and little information is available regarding the impacts of short-term dewatering. Several studies found that exposure duration of as little as 3–4 days is sufficient to kill plants (CWS 2003; WSNWCB [undated]), whereas others suggest that only prolonged (one month or more) exposure is sufficient to achieve macrophyte control (Cooke 1980). Milfoil is particularly resistant to exposure and may require three or more weeks of exposure to achieve control (Cooke 1980). In addition, some studies suggest that some species, such as milfoil, may be enhanced by water level drawdown by creating favorable habitat conditions where they can out-compete other macrophytes (Smith and Barko 1990; WSNWCB [undated]).

Proposed Methodology

The proposed method to assess the impact of alternative Project operational scenarios on the growth and distribution of macrophytes within Boundary Reservoir is to develop and field validate HSI curves. These curves will then be used in the Mainstem Aquatic Habitat and Tributary Delta Aquatic Habitat modeling to evaluate the potential distribution of macrophytes under alternative operational scenarios. The work effort for this study has been divided into the following seven tasks:

Task 1) *Literature Review*. Conduct a literature review to develop seasonal periodicity and HSI curves for macrophyte growth within the Pend Oreille River. HSI curves will be developed for macrophyte growth as a function of depth, velocity, substrate, and frequency of inundation and dewatering (rates of macrophyte colonization and dewatering mortality). Available information on the duration and severity of freezing and desiccation necessary to retard growth will be compiled to assist in the evaluation of reservoir drawdown as a potential opportunity for control of invasive macrophytes.

Task 2) *Aquatic Plant Field Surveys*. Conduct field surveys of aquatic plant distribution and abundance data along depth, velocity, and substrate gradients extending to the depth of the euphotic zone [9] in established macrophyte beds exposed to a range of inundation and dewatering conditions. Final selection of macrophyte HSI study sites will be determined following completion of the habitat mapping exercise described previously. It is likely that sites representative of a low range of pool level fluctuation will not be available in the reach downstream of Box Canyon Dam. Consequently, field data collection efforts may be extended to the Box Canyon Reservoir to represent habitat suitability under the range of reservoir pool level fluctuations associated with run-of-river conditions. Field surveys will consist of measurements of macrophyte abundance, depth, velocity, substrate, and frequency of inundation and dewatering. Field surveys will be conducted during peak macrophyte growth periods (i.e., August or September). Where possible, HSI field surveys will be integrated into ongoing mainstem habitat transect measurement efforts (see Physical Aquatic Habitat Model Development described above) or other macrophyte study efforts. For planning purposes, macrophyte bed measurement sites may be above or below Box Canyon Dam, across from the town of Metaline, and in the divided channel across from the Lime Creek confluence.

Task 3) *Validate HSI curves for depth, velocity, substrate, and frequency of inundation*. Use literature-based information from Task 1 and field data from Task 2 to validate HSI curves for depth, velocity, substrate, and frequency of inundation as a function of macrophyte abundance. To do this, a histogram (i.e., bar chart) will be developed for each of the habitat parameters (e.g., depth, velocity, substrate, frequency of inundation and dewatering) using the site-specific field observations. The histogram developed using field observations will then be compared to the literature-based HSI curve to validate applicability of the literature-based HSI curve for aquatic habitat modeling. In order to validate literature-based habitat suitability information with site-specific observations, it will be assumed that all suitable habitats within the Pend Oreille River have been colonized by aquatic macrophytes. Areas above or below Box Canyon, across from the town of Metaline, and in the divided channel across from the Lime Creek confluence are exposed to a range of pool level fluctuations. Measurements of macrophyte density in these areas will be correlated to the frequency of inundation and dewatering associated with antecedent Boundary Project operations or Box Canyon Project operations (for data collected in Box Canyon Reservoir). Data collection in Box Canyon Reservoir is proposed to validate portions of the draft HSI curves with a low amount of pool level fluctuation that are not observable under current operations in Boundary Reservoir.

[9] Text was added to this sentence to extend the field surveys to the depth of the euphotic zone. SCL's commitment to survey aquatic vegetation to the depth of the euphotic zone was described in the Task 3 of the section on Physical Habitat Model Development in the PSP. That detail was not included in the description of Aquatic Plant Field Surveys in the PSP but had been added to the RSP in response to relicensing participant comments.

Task 4) *Develop HSI information for pH and DO*. Use water quality and macrophyte abundance data available from the Evaluation of the Relationship of pH and DO to Macrophytes in Boundary Reservoir (Study No. 6) to develop HSI information for pH and dissolved oxygen as a function of macrophyte abundance. This information will be used to help interpret the effects of aquatic macrophyte density and distribution on aquatic biota.

Task 5) *Confirm macrophyte HSI curves*. Convene a panel of relicensing participants and, if desired, regional experts (agency, tribal, industry and university researchers) to confirm macrophyte HSI curves. Using a roundtable discussion format, the panel members will review literature-based life history information and site-specific data to develop a final set of HSI curves.

Task 6) *Provide finalized information to Aquatic Habitat Models*. Provide finalized HSI curves, periodicity, and colonization information for use in conjunction with the mainstem physical habitat model described above and for use in the Tributary Delta Habitat Modeling Study (Study No. 8). Estimates of macrophyte distribution and abundance under alternative Boundary Project operational scenarios will be used to evaluate the effects of operations on changes in aquatic habitats, and will also be used to evaluate the efficacy of operational measures to control invasive macrophytes.

Lowering water levels in the winter can cause Eurasian watermilfoil plant buds to freeze, which reduces growth the following summer. Lowering water levels in summer can expose sediments to desiccation, which can also kill some aquatic plants. Because of the limited ability of the Project to affect reservoir drawdown upstream of Metaline Falls (see the Hydraulic Routing component of this study plan), drawdown periods sufficient to fully desiccate or freeze nonnative macrophytes may not be achievable in the areas of greatest watermilfoil infestation. The results of the mainstem and tributary delta habitat modeling studies can be used to identify the magnitude and duration of potential reservoir drawdown and the areas of macrophyte infestation that can be affected by Project operations. The results of these analyses will be used to develop an Aquatic Macrophyte Management Plan, which SCL will submit as part of its Application for 401 Water Quality Certification (see Study No. 5).

Task 7) *Provide necessary information to the Productivity Assessment Study*. Provide macrophyte abundance, distribution and productivity data developed in this study component for use in the Productivity Assessment (Study No. 11), where the information can be used to evaluate the potential need and opportunities for macrophyte management.

Work Products

Work products will include an interim study report describing survey methods, results of 2007 monitoring, and discussion of recommendations for 2008 HSI sampling efforts, and a final study report describing survey methods and results of 2007 and 2008 monitoring. The final work product of this study effort will consist of HSI curves for macrophytes as a function of depth, velocity, substrate, and frequency of inundation.

Schedule

The development of macrophyte HSI for this study component is scheduled to begin in early 2007 and end in 2008 (Table 2.5-6). The majority of data collection will occur in the summer of 2007, with the 2008 field season available if additional data collection is required.

Table 2.5-6. Schedule for macrophyte HSI development.

Activity	2007				2008				2009
	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q
Technical Consultant study refinement	--------								
Develop literature-based HSI curves and periodicity		--------	----						
Field Data Collection			▲▲				▲▲		
Prepare interim study report (first-year results)				●					
Distribute interim study report					●				
Meet with relicensing participants to review first year efforts and results and discuss plans for any second year efforts					●				
Include interim study report in Initial Study Report (ISR) filed with FERC					●				
Hold ISR meeting and file meeting summary with FERC					●				
Develop Final HSI Curves and periodicity							--------	--	
Prepare "draft" final study report								●	
Distribute "draft" final study report for relicensing participant review								●	
Meet with relicensing participants to review study efforts and results and "cross-over" study results									●
Include final study report in Updated Study Report (USR) filed with FERC									●
Hold USR meeting and file meeting summary with FERC									●

Periphyton and Benthic Macroinvertebrate HSI

Periphyton and benthic macroinvertebrates (BMI) are organisms that live on the bottom of a river or lake, or on substrates attached to the bottom such as logs or plants. Periphyton are a complex matrix of algae and bacteria that are primary producers (see Productivity Assessment, Study No. 11). Primary production forms the basis of the food chain and refers to the rate of biomass formation of organisms that photosynthesize. Periphyton use energy from the sun and nutrients for growth, and in turn, are fed upon by BMI and some fish. The BMI community is an assemblage of organisms, large enough to be seen by the unaided eye, that are involved in the recycling of nutrients and the decomposition of organic materials such as leaves, and thus facilitate the transfer of energy from organic matter resources to fish and other larger organisms

(Hershey and Lamberti 2001; Hauer and Resh 1996; Reice and Wohlenberg 1993; Klemm et al. 1990).

The littoral habitat of lakes, reservoirs, and large rivers is the bottom area along the shoreline where the level of light penetration is sufficient for photosynthesis (Wright and Szluha 1980; Wetzel 2001). This area usually supports larger and more diverse populations of periphyton and BMI than deeper water habitats (Wright and Szluha 1980; Ward 1992; Thorp and Covich 2001; Wetzel 2001). The vegetation and substrate heterogeneity of the littoral habitat provide an abundance of microhabitats supplying food and shelter, which in turn enhances invertebrate production (Wright and Szluha 1980; Gerritsen et al. 1998).

As described above, the varial zone typically encompasses some or all of the littoral zone. If the magnitude and frequency of water level fluctuations is low, the varial zone can be highly productive. However, as the magnitude and frequency of water level fluctuations increase, the abundance and diversity of periphyton and BMI is reduced in the varial zone (Fisher and LaVoy 1972; Ward 1992). Several studies have reported that load-following flow releases associated with hydropower production can substantially reduce the species diversity and abundance of periphyton and BMI both above and below hydropower projects (Brusven et al. 1974; Gislason 1985; Perry and Perry 1986; Troelstrup and Hergenrader 1990; Blinn et al. 1995; DeVries et al. 2001; Grzybkowska and Dukowska 2002) and within reservoirs subject to drawdown (Fillion 1967; Paterson and Fernando 1969; Kaster and Jacobi 1978; May et al. 1988; Chisholm et al. 1989; Furey et al. 2006).

Fisher and LaVoy (1972) examined BMI communities along a sand/gravel bar below a hydroelectric dam on the Connecticut River in Massachusetts. Fluctuations of approximately 3.3 feet at the bar completely submerged it during high flows, and exposed much of it during low flows. Four zones were established along a transect running from high (Zone 1, exposed 70 percent of the summer) to low (Zone 4, constantly submerged) water marks. Results indicated reduced diversity, biomass, densities, and taxa richness in Zones 1 and 2. Metric values and community compositions of Zone 4 did not differ significantly from Zone 3, which was exposed for 13 percent of the summer, suggesting that the benthic community established at those levels was adapted to brief exposure periods.

Blinn et al. (1995) determined that discharge fluctuations during the summer and winter influenced the benthic community in the Colorado River downstream of Glen Canyon Dam, Arizona. The annual mean biomass of macroinvertebrates in a continuously inundated section of the channel was more than four times the biomass of macroinvertebrates in the proximal varial zone. Algal communities showed a 50 percent reduction in biomass after two days of repeated 12-hour exposures, and more than 70 percent reductions in biomass after five days (Blinn et al. 1995). Gislason (1985) concluded that the effects of power peaking adversely influenced insect density along the margins of the Skagit River, Washington. Under fluctuating flows, insect density increased in the direction from shallow to deep water, and density decreased with increasing number of hours of dewatering prior to sampling. Diversity appeared to increase with water depth, and decrease with increased duration of dewatering.

Studies on the lower Flathead River have demonstrated that BMI production in the varial zone is severely limited due to daily dewatering (Perry and Perry 1986; Hauer and Stanford 1991; DeVries et al. 2001). DeVries et al. (2001) also found that benthic macroinvertebrate density and taxa richness in margin areas of the lower Flathead River was significantly lower relative to the community in mid-channel areas. The benthic fauna in margin areas contained a much higher percentage of snails, aquatic earthworms, and chironomids than mid-channel habitats. Chironomids and oligochaetes are often the taxa collected in significant numbers in these frequently exposed zones (Fisher and LaVoy 1972; Brusven et al. 1974; Gislason 1985; Perry and Perry 1986; Troelstrup and Hergenrader 1990; Blinn et al. 1995; DeVries et al. 2001; Grzybkowska and Dukowska 2002; Furey et al. 2006). These organisms are often able to survive or take advantage of water-level fluctuations by burrowing deep into the substrates (Fillion 1967; Paterson and Fernando 1969; Kaster and Jacobi 1978), or by possessing life history strategies that facilitate colonization of and survival in disturbed habitats such as varial zones (Furey et al. 2006).

Little fishery or limnological research had been conducted on Boundary Reservoir. Basic water quality and periphyton data were collected at the Metaline Falls Bridge and at the mouth of the Z Canyon in October 1962 by the Washington State Pollution Control Commission (Pine and Clemetson 1962 as cited in McLellan 2001). In 2000, the Washington Department of Fish and Game (WDFG) conducted a baseline fisheries assessment of the reservoir and its tributaries that included, among other studies, periphyton and benthic macroinvertebrates sampling of the reservoir during a period from August through October (McLellan 2001). Periphyton was sampled during the late summer at two stations: in the forebay of Boundary Dam and at the Metaline Falls Bridge. Periphyton was sampled with two DuraSampler periphyton samplers floated at the reservoir surface at each station. Estimates of chlorophyll *a*, density, and bio-volume were made for each sample. Sixteen species of periphyton were identified from samples collected from Boundary Reservoir. Mean density of periphyton in Boundary Reservoir was estimated at $258/cm^2$ (± 325), with higher densities at the Boundary Dam forebay. Mean biovolume of periphyton was 130 mm^3/cm^2 (± 143). McLellan (2001) found that periphyton production, according to periphyton chlorophyll *a* values, was greater than phytoplankton production.

Benthic macroinvertebrates were collected with Hester-Dendy round plate samplers ($0.13m^2$). A set of three samplers was placed in both the forebay of Boundary Dam and at the Metaline Falls Bridge. The samplers were deployed during two separate periods, designated as “summer” and “fall” samples, for 4–5 weeks per period. Samplers were dominated by cladoceran zooplankton, snails, and chironomid larvae during the two periods. McLellan (2001) concluded that secondary aquatic productivity of macroinvertebrates was relatively low in Boundary Reservoir compared to other northwest reservoirs and lakes. However, the study also cautioned that its conclusions were based on a limited number of macroinvertebrate samples from Boundary Reservoir.

Additional information on benthic macroinvertebrates has been collected upstream in the Pend Oreille River in Box Canyon Reservoir. During 1988, 1989, and 1990, quantitative BMI sampling was conducted in Box Canyon Reservoir using a Ponar dredge to collect three grabs in soft substrates at each of 11 study sites (Ashe and Scholz 1992). Samples were collected in

March, April, June, July, September, and October during 1988 and 1989. In 1990, samples were only collected in April, July, and September. Chironomids were the most abundant organisms collected in benthic samples during all three years of the study (Ashe and Scholz 1992). Oligochaeta, Talitridae, and Sphaeriidae were also prominent organisms in the benthos during the study. Additional BMI sampling was conducted in the tributaries and sloughs of the Pend Oreille River within the Box Canyon Reservoir, as well as a feeding habits study for target fish species.

Proposed Methodology

In developing the proposed methodology for this study component, the following assumptions were made:

- Habitat conditions available within the Boundary Project area during the 2007 and 2008 study period may not represent the full range of conditions potentially available under alternative Boundary Project operational scenarios. In order to describe the response of periphyton and benthic macroinvertebrates to specific environmental conditions associated with the range of pool level fluctuations, biological surveys may need to be conducted upstream or downstream of Boundary Reservoir.
- A level of effort is described for planning purposes but details of the sampling program, including selection of specific sampling transects, timing, methodology, and data analysis procedures will be developed by the Technical Consultant in coordination with SCL and relicensing participants.

Development of the periphyton and benthic macroinvertebrate HSI for this study component encompasses the following six tasks: [10]

Task 1) *Literature-based Benthic HSI Curves*. Develop literature-based draft HSI curves for BMI and periphyton communities. Because BMI and periphyton communities are comprised of numerous taxa, the HSI curves will be developed for commonly used benthic metrics (biomass, chlorophyll *a* [periphyton], density, diversity, or dominant taxa) selected to summarize and describe the communities. [11] Habitat suitability information will address BMI and periphyton responses to changes in depth, velocity, substrate, rates of colonization and frequency of inundation and dewatering. Potential sources of information include the Internet, university libraries, peer-reviewed periodicals, and government and industry technical reports. Special emphasis will be given to information obtained from similar hydrological systems (stream/reservoir size, geographic location, and project configuration and operation).

[10] In response to relicensing participant comments and in discussion with the Technical Consultant, SCL modified the sampling strategy for development of periphyton and benthic macroinvertebrate HSI information. SCL's responses to comments are summarized in Attachment 3 of this RSP. Additional specifics of the study components will be developed in early 2007 when the Technical Consultant finalizes the study implementation details in coordination with SCL and relicensing participants.

[11] The list of potential metrics was modified based upon discussions with the Technical Consultant.

Task 2) Benthic Communities on Hard Substrates.

Task 2a) Shoreline Sites. Collect site-specific habitat suitability information for BMI and periphyton communities using artificial substrate sampling to approximate hard substrate surfaces for the colonization of BMI and periphyton. For planning purposes, artificial substrates for BMI sampling are assumed to consist of small rock baskets (e.g., Whitlock-Vibert boxes), and artificial substrates for periphyton sampling are assumed to consist of unglazed tiles. Artificial substrates will be preconditioned prior to deployment by being placed for 4 weeks in Boundary Reservoir and then air-dried. Where possible, sampling sites will be located along mainstem habitat transects measured for the Physical Aquatic Habitat Model Development study component described above. The sampling design will include three treatments representing the range of depths and inundation/exposure periods likely to occur under different operating scenarios (Table 2.5-7). The three treatments include relatively large pool level fluctuations, moderate pool level fluctuations, and low pool level fluctuations. Each site will be sampled using fixed sampling units placed along the channel bed.

The sampling units will be installed along the shoreline, with units deployed at depth intervals ranging from full pool to the euphotic depth (Table 2.5-8) under maximum expected reservoir drawdown for the sample period. The sampling units will be in fixed positions, so some units will be dewatered and inundated repeatedly, thereby describing the response of organisms to fluctuating reservoir water surface elevations at that site. Sampling will be conducted at a site below Metaline Falls in either the Canyon Reach or Forebay Reach to describe the response of BMI and periphyton to the effects of pool level fluctuations in that reach. Artificial substrate sampling will also be conducted at a site in the Upper Reservoir Reach and in Box Canyon Reservoir to describe the response to a smaller range of pool level fluctuation. Artificial substrate sampling will take place during spring, summer, autumn, and winter for 8-week periods. For planning purposes, artificial substrates are assumed to be deployed on April 5, July 7, September 12 and December 8 and retrieved 8 weeks later on May 31, September 1, November 7 and February 2, respectively.

Refinements of the sampling strategy may be developed by the Technical Consultant in the first quarter of 2007 in coordination with SCL and relicensing participants, provided the refinements satisfy the primary sampling objectives.

Task 2b) Vertical Face Sites. The WDFW requested that Task 2 be modified to include hard substrate sampling on a vertical face. To address this concern, SCL will sample hard substrate for BMI and periphyton on a vertical face under two treatment conditions including high pool level fluctuations found in the Forebay or Canyon Reach of Boundary Reservoir and low pool level fluctuations found in Box Canyon Reservoir. Similar to Task 2a, artificial substrate sampling will take place at 6 depths (3 replicates each) ranging from full pool to the euphotic depth during spring, summer, autumn, and winter for 8-week periods (Table 2.5-9). For planning purposes, artificial substrates are assumed to be deployed on April 5, July 7, September 12 and December 8 and retrieved 8 weeks later on May 31, September 1, November 7 and February 2, respectively.

Table 2.5-7. Task 2a. Hard substrate sampling at fixed shoreline sites.

Date	Macroinvertebrates (e.g., baskets)				Periphyton (e.g., plates)			
	Treatments	Depths	Replicates	# samples	Treatments	Depths	Replicates	# samples
April	3	6	3	54	3	6	3	54
July	3	6	3	54	3	6	3	54
Sept	3	6	3	54	3	6	3	54
Dec	3	6	3	54	3	6	3	54
Total				**216**				**216**
Treatment/Site								
A) High fluctuation - Downstream of Metaline Falls								
B) Moderate fluctuation - Upstream of Metaline Falls								
C) Low fluctuation - Box Canyon Reservoir								

Table 2.5-8. Estimated monthly euphotic depth of Boundary Reservoir based on Secchi disk readings and extrapolations of turbidity readings.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estimated Euphotic Depth (feet)	34.5	34.5	27.1	19.7	15.7*	16.7*	28.5*	44.3*	39.4*	34.5*	34.5	34.5

* Estimated euphotic depth based on three times the Secchi disk readings reported by McLellan (2001).

Table 2.5-9. Task 2b. Hard substrate sampling at fixed vertical face sites.

Macroinvertebrates (e.g., baskets)					Periphyton (e.g., plates)			
Date	Treatments	Depths	Replicates	# samples	Treatments	Depths	Replicates	# samples
April	2	6	3	36	2	6	3	36
July	2	6	3	36	2	6	3	36
Sept	2	6	3	36	2	6	3	36
Dec	2	6	3	36	2	6	3	36
Total				144				144
Treatment/Site								
A) High fluctuation - Forebay or Canyon Reach								
B) Low fluctuation - Box Canyon Reservoir								

Task 3) *Benthic Communities on Soft Substrates*. Collect site-specific habitat suitability information for BMI communities on soft substrates (i.e., fine sediments) using substrate-appropriate sampling methodologies to collect BMIs. [12] Similar to Task 2, three treatments are proposed that represent the range of pool level fluctuations to be considered during scenario modeling of different operation strategies. Sampling will be conducted at one site in either the Canyon Reach or Forebay Reach to describe the effects of pool level fluctuations in that reach (large fluctuation treatment), one site in the Upper Reservoir Reach to describe a smaller range of pool level fluctuation (moderate fluctuation treatment), and at one site/treatment within the lower Box Canyon Reservoir to describe the effects of a minimum pool level fluctuation scenario. Where possible, sampling sites in Boundary Reservoir will be located along mainstem habitat transects measured for the Physical Aquatic Habitat Model Development study component described above. Samples will be collected at incremental depths ranging from full pool to the euphotic depth under maximum expected reservoir drawdown for the sample period. Three to five soft substrate samples will be collected per depth strata on each shoreline (Table 2.5-10).

Table 2.5-10. Task 3 – Macroinvertebrate sampling on soft substrates.

Date	Treatments	Depths	Replicates	# samples
May	3	6	3	54
Sept	3	6	3	54
Nov	3	6	3	54
Feb	3	6	3	54
Total				**216**
Treament/Site.				
A) High fluctuation - Downstream of Metaline Falls				
B) Moderate fluctuation - Upstream of Metaline Falls				
C) Low fluctuation - Box Canyon Reservoir				

Task 4) *Benthic Colonization Rates*. Conduct a field study to estimate potential BMI and periphyton colonization rates for different seasons within Boundary Reservoir. For summer and winter periods, sets of three to five preconditioned artificial substrates will be deployed incrementally for set periods of colonization time (e.g., 8, 6, 4, 2, and 1 weeks) and then pulled simultaneously at the conclusion of the colonization period (see Tables 2.5-11 to 2.5-13).

[12] Following discussion with the Technical Consultant, sampling of periphyton on soft substrates was dropped because quantitative sampling would be difficult and would require the use of SCUBA. Furthermore, it was concluded that the response of periphyton on hard substrates to the effects of different treatments (pool level fluctuations) could be extrapolated to periphyton production on soft substrate.

Artificial substrates will be deployed at three depths at fixed sites along the channel bed of Box Canyon Reservoir at an elevation within the euphotic zone where they will remain wetted through the incubation period. Besides their use for HSI curve development, results of the colonization studies will also be used to adjust, if necessary, deployment times for artificial substrates in Task 3.

Table 2.5-11. Potential deployment and retrieval schedule for artificial substrates from selected sites during two seasonal periods of colonization.

Season	Colonization Period	Deployment Date	Retrieval Date
Summer	8 weeks	July 7	September 1
	6 weeks	July 21	September 1
	4 weeks	August 4	September 1
	2 weeks	August 18	September 1
	1 week	August 25	September 1
Winter	8 weeks	December 8	February 2
	6 weeks	December 22	February 2
	4 weeks	January 5	February 2
	2 weeks	January 19	February 2
	1 week	January 26	February 2

Table 2.5-12. Task 4 – Benthic macroinvertebrate colonization.

Date	Treatments	Sites	Depths	replicates	# samples
7-Jul	1	1	3	3	9
21-Jul	1	1	3	3	9
4-Aug	1	1	3	3	9
18-Aug	1	1	3	3	9
25-Aug	1	1	3	3	9
8-Dec	1	1	3	3	9
22-Dec	1	1	3	3	9
5-Jan	1	1	3	3	9
19-Jan	1	1	3	3	9
26-Jan	1	1	3	3	9
Total					90
Treament/Site.					
A) Low fluctuation - Box Canyon Reservoir					

Table 2.5-13. Task 4 – Periphyton colonization.

Date	Treatments	Sites	Depths	replicates	# samples
7-Jul	1	1	3	3	9
21-Jul	1	1	3	3	9
4-Aug	1	1	3	3	9
18-Aug	1	1	3	3	9
25-Aug	1	1	3	3	9
8-Dec	1	1	3	3	9
22-Dec	1	1	3	3	9
5-Jan	1	1	3	3	9
19-Jan	1	1	3	3	9
26-Jan	1	1	3	3	9
Total					90
Treament/Site.					
A) Low fluctuation - Box Canyon Reservoir					

Task 5) *Validation of Benthic HSI Curves*. Develop a histogram (i.e., bar chart) for each of the habitat parameters (e.g., depth, velocity, substrate, frequency of dewatering) using the site-specific field observations. The histogram developed using field observations will then be compared to the literature-based HSI curve to validate applicability of the literature-based HSI curve for aquatic habitat modeling.

Task 6) *Finalize Benthic HSI Information*. Convene a panel of relicensing participants and, if desired, regional experts (agency, tribal, industry and university researchers) to confirm HSI curves for each benthic metric. Using a roundtable discussion format, the panel members will review literature-based benthic community information and site-specific data to develop a final set of HSI curves. These curves will be used in the aquatic habitat modeling study to define the relationship between habitat quantity and quality for each of the selected benthic metrics under various operational scenarios.

Work Products

The final work product of this study effort will consist of HSI curves for target metrics for use in this Mainstem Aquatic Habitat Modeling Study and in the Tributary Delta Habitat Modeling Study (Study No. 8). Information developed during this study effort will also be used to support the Aquatic Productivity Study (Study No. 11). This study effort will produce two year-end study reports. The interim study report will describe survey methods, results of 2007 efforts, and a discussion of recommendations for 2008 HSI sampling efforts. The final study report will describe survey methods and the results of 2007 and 2008 efforts.

Schedule

The schedule for development of periphyton and benthic macroinvertebrate HSI as part of this study component is shown in Table 2.5-14. During the first quarter of 2007, the Technical Consultant will make refinements to the study as needed, in coordination with SCL and relicensing participants. Research, sampling, and sample analysis will take place throughout the remainder of 2007. Sampling efforts will be completed by the first quarter of 2008, with continued analysis and research continuing through the third quarter.

Table 2.5-14. Schedule for periphyton and benthic macroinvertebrate HSI development.

Activity	2007				2008				2009
	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q
Technical Consultant study refinement	------								
Develop literature-based HSI curves and periodicity		------	------						
Hard Substrate Sampling		▲▲	▲ ▲	▲▲	▲				
Soft Substrate Sampling		▲	▲	▲	▲				
Colonization Rate Study			▲▲▲	▲	▲▲				
Prepare interim study report (first-year results)				●					
Distribute interim study report					●				
Meet with relicensing participants to review first year efforts and results and discuss plans for any second year efforts					●				
Include interim study report in Initial Study Report (ISR) filed with FERC					●				
Hold ISR meeting and file meeting summary with FERC					●				
Develop final HSI curves and periodicity							--------	--	
Prepare "draft" final study report								●	
Distribute "draft" final study report for relicensing participant review								●	
Meet with relicensing participants to review study efforts and results and "cross-over" study results									●
Include final study report in Updated Study Report (USR) filed with FERC									●
Hold USR meeting and file meeting summary with FERC									●

2.6. Composite Schedule

The schedule for completing all components of the Mainstem Aquatic Habitat Model is provided in Table 2.6-1.

Table 2.6-1. Schedule for development of all components of the Mainstem Aquatic Habitat Model.

Activity	2007				2008				2009		
	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q
Technical Consultant study refinement	-------										
Habitat Mapping: LWD / macrophyte		▲ ▲	▲								
Mainstem Transect Selection		--	-- ▲								
Relicensing Participant Site Visit			▲ ▲								
Hydraulic Routing: data collection and reporting		------	------	----●	------	------	----■				
Hydraulic Routing: develop executable model			-------	-------							
HSI Fish, Macrophyte, Periphyton and BMI: Develop literature -based curves		-------	-------								
Prepare interim study reports (first-year results)				●							
Distribute interim study reports					●						
Meet with relicensing participants to review first year efforts and results and discuss plans for second year efforts					●						
Include interim study reports in Initial Study Report (ISR) filed with FERC					●						
Hold ISR meeting and file meeting summary with FERC					●						
HSI Fish, Macrophyte, Periphyton and BMI: Field data collection	-------	▲ ▲	▲ ▲	▲ ▲	▲ ▲	▲ ▲	▲ ▲				
HSI Fish, Macrophyte, Periphyton and BMI: Develop final curves/periodicity							-------	---■			
Substrate and Vegetation Characterization			▲ ▲			▲ ▲					
Collect Velocities and depths			▲ ▲	▲ ▲		▲ ▲	▲ ▲				
Develop Varial Zone Model				------	------	------	------	-------			
Hydraulic Model Integration and Calibration							------	------			
Downramping Analysis								-------	-------	-------	
Habitat WUA								-------	-------	-------	
Alternate Scenario Post-Processing								-------	-------	-------	
Prepare “draft” final study reports								●			
Distribute “draft” final study reports for relicensing participant review								●			
Meet with relicensing participants to review study efforts and results and “cross-over” study results									●		
Include final study reports in Updated Study Report (USR) filed with FERC									●		
Hold USR meeting and file meeting summary with FERC									●		

2.7. Consistency with Generally Accepted Scientific Practice

Habitat Mapping. Studies regarding habitat mapping and the distribution and abundance of aquatic macrophytes and large woody debris are commonly conducted at many hydroelectric projects as part of FERC licensing (e.g., Watershed GeoDynamics 2005, R2 Resource Consultants 2003, R2 Resource Consultants 2004). Mapping surveys will utilize protocols similar to those performed at other hydroelectric projects. Aquatic mapping data collection efforts will follow Ecology identification manuals (Ecology 2001).

Hydraulic Routing. One-dimensional unsteady flow hydraulic models are commonly used to route flow and stage fluctuations through rivers and reservoirs. Examples of public-domain computer models used to perform these types of processes include FEQ (USGS 1997), FLDWAV (U.S. National Weather Service 1998), UNET (U.S. Army Corps of Engineers 2001), and HEC-RAS (U.S. Army Corps of Engineers 2002a, 2002b, and 2002c). The HEC-RAS model has proven to be very robust under mixed flow conditions (subcritical and supercritical), as will be expected in the vicinity of Metaline Falls of the Pend Oreille River. The HEC-RAS model also has the capability of automatically varying Manning's "n" with stage through the use of the equivalent roughness option. Another feature of HEC-RAS is the capability of varying Manning's "n" on a seasonal basis. The need for this capability may arise in reaches of the Pend Oreille River where macrophytes grow during the summer and then die off during the rest of the year. The robust performance and flexibility of HEC-RAS make this model the appropriate choice for routing stage fluctuations through Boundary Reservoir from the forebay of Boundary Dam to Box Canyon Dam.

Mainstem Aquatic Habitat Model Development. Physical habitat models are often used to evaluate alternative instream flow regimes in rivers (e.g., the Physical Habitat Simulation [PHABSIM] modeling approach developed by the U.S. Geological Survey; Bovee 1998, Waddle 2001). The proposed approach for assessing the effects of different operational scenarios on habitat in the mainstem is analogous to the PHABSIM approach in that hydraulic modeling is translated to indices of habitat quality and availability. One of the major differences between PHABSIM and the proposed approach is the implementation of hydraulic models and quantitative evaluations of dewatering and inundation to quantify the environmental effects of reservoir water surface elevation fluctuations. This study uses HEC-RAS modeling to obtain water surface elevations, water depths and velocities, which is more appropriate for the hydraulic conditions in the Boundary reservoir study area, while PHABSIM uses a variety of water surface elevation and hydraulic simulation programs more appropriate for modeling riverine flow conditions. The proposed modeling approach is consistent with the use of physical habitat models used at other hydroelectric projects to assess the effects of alternative operational scenarios on aquatic habitat.

HSI Development. HSI curves have been utilized by natural resources scientists for over two decades to assess the effects of habitat changes on biota. HSI curves were developed by the USFWS for use with fish and wildlife (see http://www.nwrc.usgs.gov/wdb/pub/hsi), but their usage has also included periphyton and wetland tree habitats (e.g., Tarboton et al. 2004). The proposed method for the development and verification of HSI curves is analogous to the methods described for fish in Bovee (1986) and USFWS (1981). Aquatic plant data collection efforts will follow Washington State sampling protocols and identification manuals (Parsons 2001; Ecology

2001). The sampling devices proposed for collecting BMI are consistent with the devices described in Rabeni (1996). Artificial substrates (Hester-Dendy multi-plate samplers) were used previously in Boundary Reservoir by McLellan (2001). The proposed fish sampling and observation methods are consistent with those described in Murphy and Willis (1996). The proposed use of an expert panel to develop and verify fish, macrophyte, periphyton and benthic macroinvertebrate HSI curves is modified from that described by Crance (1987).

2.8. Consultation with Agencies, Tribes, and Other Stakeholders

Input regarding the Mainstem Aquatic Habitat Modeling Study was provided by relicensing participants during workgroup meetings. Workgroup meetings were held in Spokane, Washington, on May 23, 2006, and August 14, 2006, and in Metaline Falls, Washington, on June 27, 2006. During the May workgroup meeting, outlines for the development of Aquatic Habitat Modeling, the Fish HSI, and Macrophyte HSI components of the study plan were presented and discussed with relicensing participants. At the June workgroup meeting, the Habitat Mapping and Periphyton and Benthic Macroinvertebrate study components were presented and discussed with relicensing participants. At the August workgroup meeting, an overview of the aquatic habitat modeling study was presented and discussed with relicensing participants. The proposed Aquatic Habitat Modeling study plan was developed from the outline and relicensing participant comments. Comments provided by relicensing participants on the review outlines for this study plan are summarized in the PSP Attachment 4-1 (SCL 2006b) and can also be found in meeting summaries available on SCL's relicensing website (http://www.seattle.gov/light/news/issues/bndryRelic/).

In the PAD/Scoping comment letter filed by the USFWS (2006), the USFWS endorsed the Mainstem Aquatic Habitat Modeling outline and the various HSI study components presented at the workgroup meetings. WDFW provided additional comments on the periphyton and benthic macroinvertebrate aspect of habitat suitability information in a letter to SCL dated August 28, 2006 (included in the PSP Attachment 4-1). In that letter, WDFW requested that the number of sample sites be increased to adequately characterize and account for the variability in substrate types and water velocities found in the range of habitats available in Boundary Reservoir. As described in the study plan, fixed artificial substrates are proposed to isolate and identify the effects of pool level fluctuations on periphyton and benthic macroinvertebrates. SCL understands that there may be differences in the response of organisms depending on the substrate type and water velocity, but believes that the proposed sampling program is sufficient to support development of HSI curves. The HSI curves will be used as part of the mainstem habitat modeling effort to calculate an index of the effects of Project operations on periphyton and benthic macroinvertebrates. The HSI information will not be used to calculate productivity, which will be addressed in the Productivity Assessment (see Study No. 11).

In its PAD/Scoping comment letter (USFS 2006), the USFS submitted a request for a study titled Effects of Current Operations (Ramping) and Alternative Operations on Aquatic Habitat and Biota. In this letter, the USFS requested that a model utilizing habitat suitability curves be developed to quantify the amount of habitat available to salmonids at full pool versus various stages of reservoir drawdown. They also requested that areas presenting a risk of stranding and trapping be surveyed following downramp events, and substrate sampling occur at 1-hour, 2-hour, 4-hour and 8-hour intervals from the start of a downramp event. SCL's proposed mainstem aquatic habitat model, as described in this study plan, was designed to provide the information requested by the USFS. Surveys of areas presenting a risk of stranding/trapping are proposed prior to and following a downramp event in Task 4 of the HSI:Fish study component, and analyses of substrates are designed for hourly intervals. In a follow-up conference call on September 8, 2006 (PSP Attachment 4-1), USFS staff indicated that there was general agreement on the proposed aquatic habitat modeling and ramping rate study outlines presented at the workgroup meetings and that the hourly intervals were provided as an example rather than an explicit study request.

PAD/Scoping comments (USFS 2006), the USFS also submitted a request for an Aquatic Plant Management Control Study. SCL is not proposing to conduct a separate study, as explained in the PSP section 3.6 (SCL 2006b). However, the Mainstem Aquatic Habitat Modeling Study will provide information on the expected distribution and abundance of aquatic macrophytes under alternative Project operational scenarios. Alternative Project operations to be evaluated may include scenarios designed to control the growth of aquatic macrophytes through reservoir drawdown. The results of these analyses will be used in development of an Aquatic Macrophyte Management Plan that SCL will submit as part of its License Application and its Application for 401 Water Quality Certification with the Washington Department of Ecology.

The modified Mainstem Aquatic Habitat Modeling Study plan was included in the PSP that was filed with FERC on October 16, 2006. Since filing the PSP, SCL has continued to work with relicensing participants on its proposed study plans. In response to comments provided during an October 10 meeting with staff from SCL, WDFW, and Kalispel Tribe, comments made during the November 15 study plan meeting, and comments filed with FERC by the USFS (2007) and WDFW (2007), SCL has further modified the plan for the habitat modeling. (SCL's responses to comments are summarized in Attachment 3 and consultation documentation is included in Attachment 4 of this RSP.) Modifications included adding clarification, additional supporting rationale, and additional detail to address agency and tribal comments. Where differences remain between study requests and study elements, SCL has so noted in Attachment 3 of this RSP. Additional specifics of the study components will be developed in early 2007 as the Technical Consultant finalizes the study implementation details in coordination with SCL and relicensing participants (Attachment 1, section 2.2 of this RSP).

2.9. Progress Reports, Information Sharing, and Technical Review

Relicensing participants will have opportunities for study coordination through regularly scheduled meetings, reports and, as needed, technical subcommittee meetings. Reports are planned for distribution in early 2008 and 2009 for each of the Mainstem Aquatic Habitat Model study components. Prior to release of the Initial and Updated Study Reports (which will include the results of this study), SCL will meet with relicensing participants to discuss the study results, as described in Attachment 1, section 2.3 of this RSP. Relicensing participants will also have the option to participate in site visits during transect selection and participate on panels as part of the HSI curve development process. Workgroup meetings are planned to occur on a quarterly basis, and workgroup subcommittees will meet or have teleconferences as needed.

2.10. Anticipated Level of Effort and Cost

Habitat Mapping. Based on a review of study costs associated with similar efforts conducted at other hydropower projects, the estimated cost to implement this effort at the Boundary Project ranges from $100,000 to $140,000; estimated study costs are subject to review and revision as additional details are developed. To obtain efficiencies in the overall relicensing work effort, portions of this study will be conducted in conjunction with the Large Woody Management Study (Study No. 10).

Hydraulic Routing. The estimated cost to implement this effort and develop a routing model of the Pend Oreille River from Seven Mile Dam to Box Canyon Dam ranges from $160,000 to $200,000; estimated study costs are subject to review and revision as additional details are developed. This level of effort assumes that adequate bathymetric and LIDAR data are available.

Physical Habitat Model Development. Based on a review of study costs associated with similar efforts conducted at other hydropower projects, the estimated cost to implement this effort at the Boundary Project ranges from $500,000 to $575,000. Estimated study costs do not include habitat mapping, development of the hydraulic routing model, HSI information, or development and processing of Scenario Tool output. Estimated study costs are subject to review and revision as additional details are developed.

Fish HSI Development. Based on a review of study costs associated with similar efforts conducted at other hydropower projects, the estimated cost to implement this effort at the Boundary Project ranges from $80,000 to $120,000. The majority of the field survey efforts will be conducted under the Fish Distribution, Timing and Abundance Study (Study No. 9).

Macrophyte HSI Development. Based on a review of study costs associated with similar efforts conducted at other hydropower projects, the estimated cost to implement this effort at the Boundary Project ranges from $72,000 to $108,000.

Periphyton and Benthic Macroinvertebrates HSI Development. Based on a review of study costs associated with similar efforts conducted at other hydropower projects, the estimated cost to implement this effort at the Boundary Project ranges from $160,000 to $240,000. Estimated study costs are subject to review and revision as additional details are developed.

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