Revised Study Plan

Boundary Hydroelectric Project (FERC No. 2144)

Study No. 8
Sediment Transport and Boundary Reservoir Tributary Delta Habitats

Seattle City Light

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TABLE OF CONTENTS

List of Tables

List of Figures

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Study No. 8 – Sediment Transport and Boundary Reservoir Tributary Delta Habitats

1.0 INTRODUCTION

Deltas are depositional features that form where flowing water, such as tributary streams, enter a static water body such as a lake or reservoir. Where tributary streams enter a flowing body of water, such as a larger river, sediments may be deposited at the confluence, forming a delta, or the tributary sediments may be transported downstream by mainstem river currents. The proportion of tributary sediments that is deposited as a delta or transported downstream is influenced by the volume and particle size distribution of the sediments, tributary and mainstem river flows and, in the case of the Boundary Project (Project), the water surface elevation of the reservoir.

Tributary deltas are transition areas between the tributaries and reservoir that, depending upon their physical characteristics, provide a variety of ecological functions. Fish may congregate at the tributary confluence to feed on aquatic organisms transported downstream in the tributary flow, may use the deltas as temperature refugia, or may stage in delta habitats prior to spawning runs; fry and juvenile fish may rear in complex habitats associated with the deltas; and the influx of tributary water may provide protection from dewatering associated with reservoir pool level fluctuations. Physical characteristics that influence these functions include water depth, velocity and temperature; substrate size; cover (large woody debris and other structures); nutrients in the form of leaf and needle litter; and the frequency and magnitude of disturbance.

There are 28 tributaries that drain to Boundary Reservoir (Table 1.0-1); including 13 unnamed drainages. Most of the tributaries are very small, and may not contain measurable surface flow during late summer months. However, some tributaries to the Boundary Reservoir represent potential year-round habitat for native salmonids. Portions of tributary deltas may also be present in the varial zone, and therefore are potentially affected by fluctuations in pool levels. This study examines the potential effects of Project operations on the quantity and quality of tributary delta habitat and potential changes in tributary delta morphology under future Project operations. Because they represent potential high aquatic resource value areas and have a source of inflow separate from the mainstem Pend Oreille River, the delta areas of major tributaries will require a modeling approach specific to their physical characteristics.

This study complements, but is separate from, the Mainstem Aquatic Habitat Modeling Study described in Attachment 2, Study No. 7 of this RSP. Three interrelated modeling components are needed to evaluate the effects of Boundary Project operations on delta habitats. Physical habitat modeling of major tributary deltas, analogous to the mainstem aquatic habitat model described in Study No. 7, will translate depth, velocity, substrate, and cover suitability indices to estimates of weighted usable area (WUA). The latter two sediment modeling exercises are needed to determine if, and how, tributary delta morphology might change over the potential 50-year term of a new FERC license for the Project.

Table 1.0-1. Adfluvial habitat and known sport fish present in tributaries that drain into Boundary Reservoir.

Stream Name	Pend Oreille River Mile	Length of Adfluvial Habitat (Feet)	Known Sport Fish Present[1]
Unnamed No. 1	18.1	82[2]	
Pewee Creek	19.0	0[3]	CTT, EBT
Unnamed No. 2	19.1	129[2]	
Lime Creek	20.5	6,746[3]	EBT
Everett Creek	22.8	60[2]	
Whiskey Gulch	22.9	547[2]	
Slate Creek	23.1	3,474[3]	EBT, CTT, RBT
Beaver Creek	25.2	0[3]	
Threemile Creek	25.2	0[3]	EBT, RBT
Unnamed No. 3	26.4	58[2]	
Flume Creek	26.8	1,626[3]	EBT
Sullivan Creek	27.9	21,729[3]	EBT, CTT, RBT, MWF, PWF, BNT, BLT, KOK, BBT
Unnamed No. 4	28.1	77[2]	
Linton Creek	28.5	19,159[2]	
Unnamed No. 5	28.9	130[2]	
Unnamed No. 6	29.1	955[2]	
Pocahontas Creek	29.5	16,480[2]	CTT, RBT
Unnamed No. 7	29.7	53[2]	
Unnamed No. 8	31.3	66[2]	
Wolf Creek	31.4	236[2]	
Sweet Creek\Lunch Creek	32.0	3,202[3]	EBT, CTT, RBT, MWF, BNT, BLT
Unnamed No. 9	32.3	67[2]	
Sand Creek	32.6	1,498[3]	EBT, CTT, RBT
Lost Creek	33.1	165[2]	CTT
Unnamed No. 10	33.6	99[2]	
Unnamed No. 11	33.8	78[2]	
Unnamed No. 12	34.1	102[2]	
Unnamed No. 13	34.5	4,184[4]	

Notes:

1 Blanks indicate nonfish-bearing stream or not surveyed. EBT=eastern brook trout; CTT= cutthroat trout; RBT= rainbow trout; MWF= mountain whitefish; PWF= pygmy whitefish; BNT= brown trout; BLT= bull trout; KOK= kokanee; BBT= burbot. Sources: USFS (2006a); McLellan (2001); FERC (1998).

2 The length of adfluvial habitat is the distance from the mouth of the stream to the lowermost stream segment in the Salmonscape Geographic Information System (WDFW 2002) with a gradient greater than 20% and does not consider the quality of the adfluvial habitat for sustaining fish.

3 The length of adfluvial habitat is the distance from the mouth of the stream to the lowermost migration barrier identified by McLellan (2001) and does not consider the quality of the adfluvial habitat for sustaining fish.

4 The length of adfluvial habitat was based on the Salmonscape Geographic Information System (WDFW 2002); however, during a September 20, 2006 site visit, a natural fish migration barrier (>15-ft high) was observed near the reservoir margin of Unnamed tributary No. 13.

2.0 STUDY PLAN ELEMENTS

2.1. Nexus Between Project Operations and Effects on Resources

The Boundary Project is operated in a load-following mode that results in daily fluctuations in pool level, as described in section 1.3.5 of the Proposed Study Plan (PSP; SCL 2006b). As noted in PSP section 1.3.5, the change in bathymetry and narrowing of the Pend Oreille River at the Metaline Fall hydraulic feature may result in significant differences in both the range of daily water surface fluctuations and the rate of change above and below Metaline Falls (i.e., range and rate both appear to be reduced above as compared to below Metaline Falls).

Tributary deltas generally form in shallow shoreline areas if the local reservoir sediment transport capacity is insufficient to mobilize sediment delivered from the tributary. Portions of tributary deltas could occur within the varial zone, which ranges between the minimum and maximum pool level. Project operations have the potential to affect the morphology of tributary deltas primarily within the Boundary Reservoir drawdown zone. These potential effects may have related effects on the quality and quantity of tributary delta habitats.

2.2. Agency Resource Management Goals

A description of relevant agency management goals is provided in the Mainstem Aquatic Habitat Modeling Study (see Study No. 7, section 2.2).

2.3. Study Goals and Objectives

The goal of this study is to evaluate the effects of current and alternative Project operations on aquatic habitats in the deltas of major tributary streams within the Boundary Reservoir drawdown zone. The objectives of the study are to: 1) collect physical and hydraulic site information; 2) evaluate changes in delta morphology and characteristics over the potential term of the new FERC license; 3) develop models of delta habitats at the mouths of major tributaries that reflect potential changes in delta morphology; and 4) prepare quantitative comparisons of delta fish habitats under alternative operational scenarios.

2.4. Need for Study

Summary of Existing Information

Very little information is available regarding the physical characteristics of tributary deltas in Boundary Reservoir. Fish surveys have suggested that some tributary deltas (e.g., Slate Creek) may provide thermal refugia for native salmonids when mainstem river temperatures become too warm. Aerial photography suggests that some of the tributaries have readily identifiable deltas (e.g., Sullivan Creek and Sweet Creek) while others deposit tributary sediments into deep portions of the reservoir or do not transport sufficient sediment to the mouth of the tributary to develop a delta. Scour and deposition in the mainstem may also affect the development of deltas at the mouth of tributaries.

In preparation for relicensing studies, Seattle City Light (SCL) has obtained high-resolution topographic and bathymetric data for Boundary Reservoir and its vicinity. This information will be critical for identifying and selecting potential transects to describe delta habitats in the study.

Need for Additional Information

Information on the type of aquatic habitats available within deltas located at tributary mouths is needed to evaluate the effects of Boundary Project operations on these potential high resource value habitats. As noted, this study is separate from, but complementary to, the Mainstem Aquatic Habitat Model Study (Study No. 7).

2.5. Detailed Description of Study

Study Area

The study area encompasses delta areas and the lower reaches of major tributaries draining to Boundary Reservoir. For planning purposes, it is assumed that six to eight tributaries will be studied in detail; these include Sand Creek, Sweet Creek, Sullivan Creek, Slate Creek (Washington), Flume Creek, and Pewee Creek. Final selection of tributary deltas to be studied will occur in coordination with relicensing participants.

Description of Study Components

This study includes three interrelated components: Tributary Delta Habitat Modeling, Tributary Delta Sediment Processes, and Mainstem Sediment Transport.

Tributary Delta Habitat Modeling

The size and morphology of a tributary delta and its importance as aquatic habitat over the duration of the new FERC license depends upon a number of factors. Among these, some of the more important include:

- the volume and size distribution of sediment transported by the tributary to its mouth;
- the capacity of the tributary to transport sediment to its mouth;
- the reservoir bathymetry at the tributary mouth;
- the capacity of the mainstem Pend Oreille River to transport sediment delivered by the tributary;
- Boundary Project Operations that affect mainstem sediment transport capacity; and
- fish species and life stage habitat response to water depth, velocity, and substrate.

This study component proposes a physical habitat modeling approach supported by field measurements of physical characteristics at selected tributary mouths and deltas. A conceptual work plan for the study is provided in Figure 2.5-1. Three important parameters in the habitat models will be water depth, water velocity, and substrate composition. Consequently, potential changes in delta morphology need to be addressed during model development.

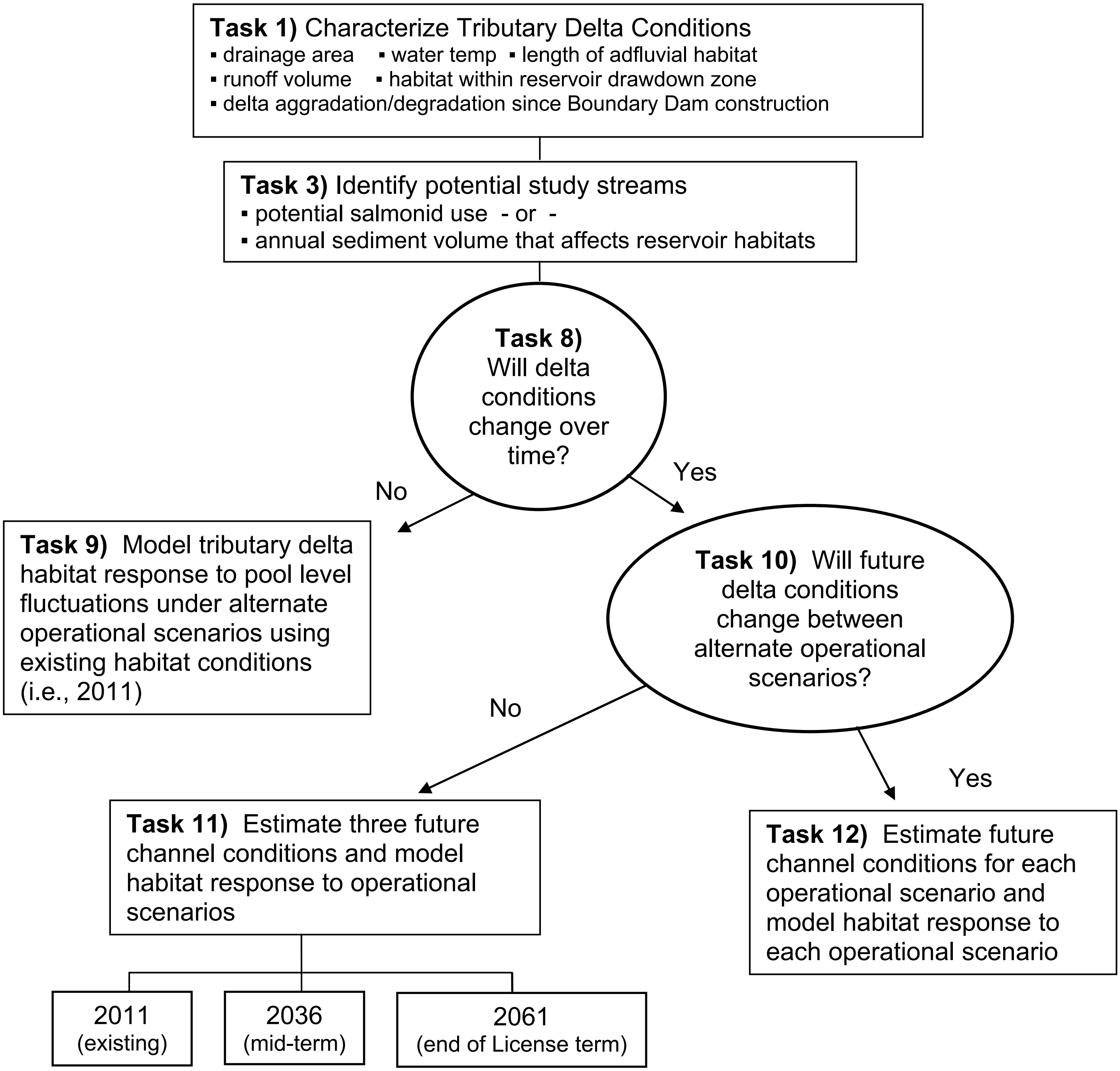

Figure 2.5-1. Conceptual work plan for tributary delta habitats in the Boundary Reservoir drawdown zone. Numeral designations refer to tasks described in the study methodology.

As described below in more detail, the study efforts will characterize tributaries based on the size of the delta and potential effects of current and alternative Project operations on changes in delta morphology over the potential 50-year license term. Tributaries will be categorized by type based on the following characteristics:

Type 1) Tributaries that do not have significant deltas, or where tributary sediments are deposited well below the reservoir water level fluctuation zone (these will be dropped from further study because there is no effect by Project operations);

Type 2) Tributaries that have significant deltas, but the existing size and morphology is not expected to change substantially over the term of a new FERC license;

Type 3) Tributaries that have significant deltas that are expected to change substantially over the course a new FERC license, but these changes are independent of operational scenario; and

Type 4) Tributaries that have significant deltas that are expected to change substantially over the course of a new FERC license, and these changes are influenced by alternative operational scenarios.

The work effort for this study component has been divided into 13 tasks. Tasks 4, 9, and 11 are decision points for categorizing tributaries into one of the four types based upon the results of preceding tasks. The physical habitat model development tasks (Tasks 10, 12, and 13) will vary depending on the tributary type. Task 1 includes the analysis of effects of alternative operational scenarios on tributary habitats, which will be conducted in 2009 as part of an overall Mainstem Habitat Modeling and Scenarios Analysis.

Several assumptions were identified during development of the methodology. If the assumptions are false, the study may fail to meet one or more of its objectives or may require substantial changes to the methodology:

- Bathymetry will be available for Boundary Reservoir.
- Topographic maps and/or GIS coverage will be available for all tributary watersheds.
- Tributary flow records will be available from the U.S. Geological Survey, or will be synthesized as part of the Mainstem Sediment Transport study component.
- The Scenario Tool will be used to determine effects of various operating scenarios on hourly water surface elevations in the Boundary Reservoir forebay.
- A hydraulic unsteady flow model will be developed to translate hourly reservoir water surface elevations to the tributary mouths (see Hydraulic Routing Model study component of the Mainstem Aquatic Habitat Modeling Study, Study No. 7)
- Information on fish use of habitats at tributary mouths will be developed as part of the Fish Distribution, Timing and Abundance Study (Study No. 9).

Proposed Methodology

The 13 tasks for the Tributary Delta Habitat Modeling study component are described in more detail below.

Task 1) Characterize Tributary Delta Conditions

Characterize the following hydrologic and physical conditions of tributaries draining to Boundary Reservoir:

- Drainage area — Based upon available watershed topography (GIS or maps).
- Runoff volume — see Mainstem Sediment Transport study component.
- Water temperature — Based upon existing available data and supplemented by ongoing monitoring efforts.
- Drawdown zone habitat length — Based upon bathymetric maps and aerial photos, estimate the drawdown zone habitat length at each confluence with Boundary Reservoir.
- Length of adfluvial fish habitat — Based upon available existing information.
- Evidence of significant delta aggradation or degradation since construction of Boundary Dam — Based upon bathymetric maps, aerial photos, local interviews and on-site inspection during delta reconnaissance.

Task 2) Tributary Delta Reconnaissance

General. Conduct a reconnaissance-level site visit to each tributary delta. Visually assess the morphological conditions at each tributary confluence with Boundary Reservoir including any observations of fish use, macrophyte growth, substrate types, large woody debris and other structures associated with potential fish use of the area. Examine each tributary delta for evidence of significant delta aggradation or degradation since Boundary Dam construction. Photograph each tributary mouth and delta from at least three common viewpoints.

Cultural Resource Features. The Cultural Resources Workgroup noted that a correlation has been observed between certain topographic features and the potential for prehistoric archaeological deposits (e.g., prehistoric weirs and Native American fishing features). During the reconnaissance of the tributary deltas, researchers will observe and record the presence of any of the following features:

- *Fire-cracked rock (FCR)* — Should researchers, in the examination of parallel sloughs, identify an interior perpendicular "barb" that cannot be accounted for by natural landform development processes, the survey team shall examine the inundated margins of the barb for any indication of cultural deposits (e.g., fire-cracked rock [FCR]). Fire-cracked rock can be readily identified and differentiated from naturally occurring gravel substrates in the Pend Oreille valley in that it typically has at least one, more typically three, angular and crenulated facet(s) in an environment where naturally deposited gravels should have a water smooth and rounded cross sectional profile. The site of these observations and collections shall be marked on aerial photographs and the GPS coordinates will be recorded and provided to the Cultural Resources Workgroup. A simple description of the observations will also be recorded at the time of such discoveries; each description will include the relative density of FCR (estimate number of rocks per square meter) and best estimate of the FCR scatter's size in both length and width.

- *FCR clusters* — Should clusters of FCR, on either the out-board or in-board meander scars in inundated tributary alluvial fans, be observed within the margins of the tributary's main channel, the survey team is to make notation of their presence, estimate their relative density, and provide an estimate of their dimensions. These observations are to be marked on aerial photographs and the GPS coordinates recorded and the data provided to the Cultural Resources Workgroup.

Task 3) Identify Potential Study Streams

Use the results from Tasks 1, 2, and tributary sediment yield and flow estimates from the Mainstem Sediment Transport study component to identify six to eight study streams that provide potential high aquatic resource values, or that potentially contribute sufficient sediment volume to affect reservoir habitats. Tributaries that enter the reservoir where the shoreline water depth is deep enough to fully submerge the delta sediment deposits under all Project operations may be eliminated from further analyses. Final selection of tributaries to be modeled using site-specific data will be coordinated with relicensing participants.

Task 4) Delta Water Temperature Monitoring

During the summer and early fall of 2007 and 2008, deploy anchored thermographs along the bed of the thalweg of selected tributaries to assess the effects of fluctuating reservoir pool levels on tributary water temperatures. Locations should include one in the tributary upstream of the reservoir fluctuation zone, one in the mainstem Pend Oreille River, and one to three locations in the varial zone. Use a constant reading temperature and depth probe during deployment of temperature recorders to identify suitable locations. Record these locations relative to the longitudinal profile of the tributary delta. Prior to deployment, the temperature recorders will be calibrated according to the manufacturer's specifications, and for verification, calibration curves will be developed using a certified thermometer over the range of water temperature expected in the field (about 10–25°C). Recording intervals should be set to every 30 minutes or less. Water temperatures will be recorded during July through October 2007; the thermographs will be inspected and the data will be downloaded each month.

Task 5) Physical Habitat Data Collection

Collect physical habitat data along longitudinal and cross-sectional transects, to be located in the lower reaches and deltas of the selected representative tributaries, as follows:

- Identify the sediment deposition zone from the tributary and collect a longitudinal bottom profile along the thalweg from the lowest pool elevation to at least two times the stream bankfull width above the deposition zone (except Pewee Creek, where if included in the study, data will only be collected in the deposition zone).

- Collect cross-sectional information perpendicular to the tributary and delta stream course to describe physical and hydraulic conditions upstream, within, and if applicable, downstream of the sediment deposition zone extending to the low reservoir pool water surface elevation. Tributary deposition zones are expected to begin upstream of the full pool water surface elevation but may not extend down to the water surface elevation at the low reservoir drawdown levels. Transect selection will be coordinated with the relicensing participants; however, for planning purposes, it is assumed that 8 to 14 transects will be established, including the following locations:
    - tributary channel between the lowermost end of the deposition zone and the low reservoir pool water surface elevation (2–3 transects depending on length and complexity of the channel);
    - lowermost end of the deposition zone (1 transect);
    - within the deposition zone (2–5 transects);
    - uppermost end of the deposition zone (1 transect); and
    - upstream of the deposition zone extending into the tributary channel (2–4 transects).
- Each cross-sectional transect in the depositional zone should be a minimum of two bankfull widths in length or the width of the depositional zone, whichever is longer, while those upstream of the depositional zone should be a minimum of one bankfull width. Information to be collected under low reservoir pool level conditions includes:
    - bed profile (all elevations to be tied into a common benchmark with a known elevation);
    - crossing location from the longitudinal transect;
    - Wolman pebble count (minimum of 100 particles);
    - mean column water velocity, water surface elevation, and flow direction relative to the transect alignment at each vertical (minimum of 20 verticals per transect under high tributary inflow);
    - embeddedness at three locations along each transect (25 percent, 50 percent, and 75 percent of transect);
    - macrophyte density;
    - substrate; and
    - cover (for fish).
- The flow at each tributary will be measured at one transect and water surface elevations measured at all transects under medium and low tributary flow conditions when the reservoir pool level is low.

- Identify, measure (including base elevation), and describe any large woody debris or other structures that could affect localized scour during periods when the Boundary Reservoir pool level is at a lower elevation.
- Photo-document measured transects and structures observed.

Task 6) Future Tributary Sediment Supply

The sediment supplied by each tributary to the delta will be determined as part of Task 2 of the Mainstem Sediment Transport component of this study. A time series of daily sediment supply will be determined on a grain-size specific basis for each tributary for the time period from 1987 to 2004 (considered representative of long-term future hydrologic conditions).

Task 7) Mainstem Sediment Transport Capacity

Use the HEC-RAS model developed for the Pend Oreille River (as part of the Hydraulic Routing Model component of the Mainstem Aquatic Habitat Modeling Study, described in Study No. 7) to determine the hydraulic transport capacity of the mainstem to transport sediment from the toe of the tributary delta. Each tributary delta will grow until some balance is reached between the sediment delivered by the tributary and the capacity of the mainstem to transport sediment from the toe of the tributary delta. The timeline for this balance to be reached will be estimated for each tributary.

Task 8) Identify Type 2 Tributaries

Identify whether the size and morphology of each tributary delta within the reservoir drawdown zone are expected to change over the next 50 years (potential term of a new license) (Figure 2.5-1). Tributaries that are not expected to change are Type 2 Tributaries (see the Tributary Delta Sediment Processes component of this study).

Task 9) Develop Type 2 Physical Habitat Models

If tributary delta conditions within the reservoir drawdown zone are not expected to change over the next 50 years, construct a transect-based habitat model to evaluate effects of alternative Project operational scenarios (e.g., Scenario 1, Scenario 2, etc.) on tributary habitats within the reservoir drawdown zone (Figure 2.5-1) (one multi-transect-based model per tributary to characterize effects of alternative operational scenarios on aquatic habitats). For each model, the following steps will be taken:

- Translate changes in water surface elevation at each of the measured delta habitat transects into changes in depth, velocity, substrate, and cover.
- Use HSI information[1] developed for species and lifestages of interest to translate changes in hydraulic conditions to indices of habitat suitability (see Mainstem Aquatic Habitat Modeling Study, Study No. 7).

[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

- Using the longitudinal profile of the tributary delta, identify any potential barriers to fish migration.
- As the reservoir pool level rises, tributary delta habitats will be inundated, transforming stream habitat into reservoir habitat. The analysis of hourly reservoir water surface elevations produced by the Hydraulic Routing Model component of the Aquatic Habitat Modeling Study (Study No. 7) will allow the changes in indices of habitat area and habitat quality to be quantified and the results used to evaluate fluctuations in reservoir pool levels under alternative Boundary operational scenarios.

Task 10) Identify Type 3 and 4 Tributaries

If the size and morphology of the tributary delta are expected to significantly change over the potential 50-year term of a new license (i.e., net aggradation or degradation), identify whether the size and morphology is expected to change in response to alternative operational scenarios. Seasonal flow records from the Salmo River indicate that high flows (and tributary sediment transport) typically occur during the snowmelt season (May and June). The forebay in Boundary Reservoir is typically maintained at or near full pool level when there are high flows during May and June; thus, changes in tributary delta morphology may occur over time but may not be influenced by alternative operational scenarios (see Figure 2.5-1). If morphological changes in a tributary delta are expected to be the same under each alternative operational scenario, it is considered to be a Type 3 delta with model development occurring under Task 12. Type 3 deltas will be identified as part of Task 2 of the Delta Sediment Processes component of this study. Alternatively, if changes in tributary delta morphology are scenario-specific, the tributary delta is considered a Type 4 delta and model development will occur under Task 13.

Task 11) Develop Type 3 Physical Habitat Models

If changes in tributary delta morphology are not operation scenario-specific, construct a transect-based habitat model for each target tributary for three time periods: existing, mid-license term (i.e., 2036) and end of the potential new license period (i.e., 2061). One transect-based model per tributary per time period (each with a different delta morphology) will be developed to characterize effects of each alternative operational scenario for a total of three transect-based models per tributary (Table 2.5-1). Similar to the Type 2 tributaries, each of the three models per tributary will translate changes in water surface elevation at each of the measured delta habitat transects into changes in depth, velocity, substrate, and cover, and use HSI curves to translate changes in hydraulic conditions to indices of habitat suitability.

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.

Task 12) Develop Type 4 Physical Habitat Models

If the size and morphology of the tributary delta (deposition zone) are expected to significantly change over the next 50 years and alternative operational scenarios are expected to affect the size and shape of tributary morphology, a transect-based habitat model will be constructed for each target tributary under existing, mid-license term (i.e., 2036) and end of the potential new license period (i.e., 2061) for each scenario, resulting in three transect-based models being constructed for each scenario and tributary (Table 2.5-1). Similar to the Type 2 tributaries, each of the three models per tributary per scenario will translate changes in water surface elevation at each of the measured delta habitat transects into changes in depth, velocity, substrate, and cover, and use HSI curves to translate changes in hydraulic conditions to indices of habitat suitability.

Table 2.5-1. Number of habitat models needed per tributary delta for each of the four types.

Tributary Type	Description	Number of Models per Tributary
Type 1	No significant delta present, or delta is below minimum reservoir pool water surface elevation	Not modeled[1]
Type 2	Delta morphology not expected to significantly change over next 50 years	1
Type 3	Delta morphology expected to change, but delta morphology is not significantly influenced by alternative operational scenarios	3 Models[2]
Type 4	Delta morphology expected to change, and delta morphology will be significantly influenced by alternative operational scenarios	Up to 3 Models[2] per operational scenario

Notes:

1 Dropped from detailed study

2 Separate models developed to describe morphology anticipated in Year 2011, 2036, and 2061.

Task 13) Run Physical Habitat Models

Evaluate the response of tributary habitat conditions to alternative operational scenarios. Use the Scenario Tool (see Attachment 1, section 3.2 of this RSP) to predict Boundary forebay water surface elevations under alternative operational scenarios. The mainstem hydraulics routing model will then be used to translate those water surface elevations to water surface elevations at each tributary mouth. The tributary habitat models will then be used to evaluate changes in habitat conditions under each scenario (Figure 2.5-2).

Analysis of effects of alternative operational scenarios on tributary habitats will be conducted in 2009 as part of the Scenarios Analysis and in combination with analysis of the Mainstem Aquatic Habitat Modeling Study (Study No. 7).

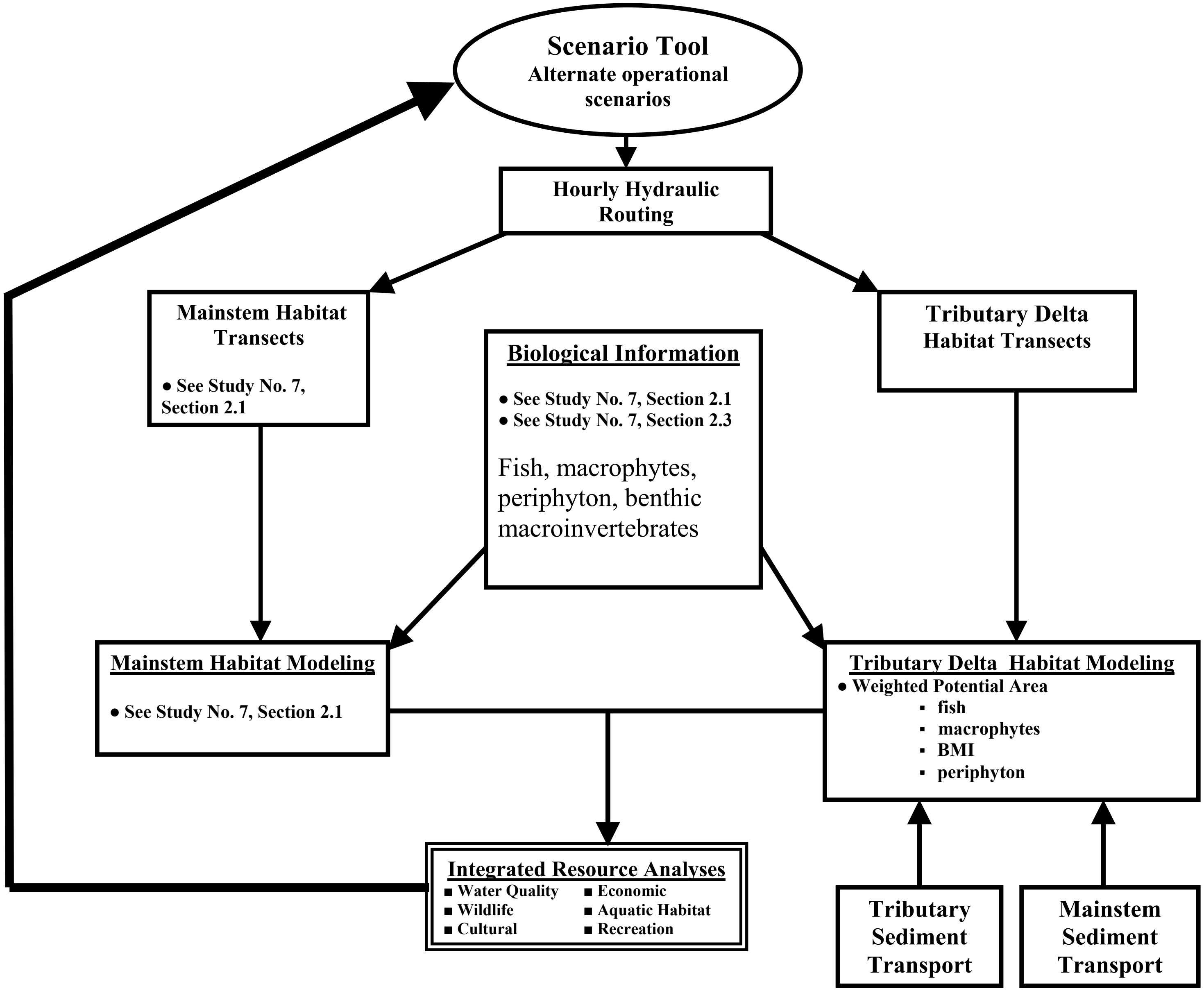

Figure 2.5-2. Conceptual workflow for integration of tributary modeling results into the Scenario Tool (see Attachment 1, section 3.2).

Work Products

Work products will consist of: an interim study report describing survey methods, results of 2007 data collection, and if needed, discussion of recommendations for supplemental 2008 delta surveys, and; a final study report describing survey methods and results of fieldwork and analysis.

Schedule

The schedule for completing the Tributary Delta Habitat Modeling component of this study is provided in Table 2.5-2.

Table 2.5-2. Schedule for the Tributary Delta Habitat Modeling 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	--------										
Characterize tributary delta conditions		-									
Identify study streams		--									
Estimate total sediment supply from Mainstem and Delta Sediment Transport Studies		------	---------								
Temperature collection			▲▲								
Tributary delta surveys			▲▲	▲▲							
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					●						
Quantify changes in tributary delta morphology under alternative operational scenarios using the mainstem HEC-RAS model					-----						
Determine if tributary morphology is expected to change over time					---------						
Construct habitat models for tributaries where scenarios do not affect morphology						------	---------				
Construct habitat models for tributaries where scenarios affect morphology								-----	----------	----	

Table 2.5-2, continued…

Use hydraulic routing model and tributary habitat models to quantify effects of operational scenarios								-----	----------	-----	
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									•		

Tributary Delta Sediment Processes

The erosion, transport, and accumulation of sediment within select tributary deltas of the Pend Oreille River may affect aquatic habitats by altering channel morphology and the size and distribution of channel substrates. This study effort will evaluate the effects of Project operations on the delta morphology of major tributaries within the Pend Oreille River from Box Canyon Dam downstream to Boundary Dam. The net change in the volume of sediment deposited on the tributary deltas will be estimated and potential zones of erosion and accumulation of sediment within the deltas will be delineated.

The construction of a dam and impoundment of water in a river can impact the morphology and sediment transport regime of tributaries to the reservoir. As the tributary enters the reservoir, the coarser portion of the total sediment load, referred to as bed-material load, settles out on the topset slope of the delta, as illustrated in Figure 2.5-3. Bed-material load generally consists of relatively coarse substrate (cobbles, gravel, and sand). The finer portion of the total sediment load, referred to as wash load (because it is generally "washed" through a river without depositing), is transported further into the reservoir, where some of it will accumulate on the reservoir bottom and the remainder will be passed through the reservoir. The wash load generally consists of relatively fine sediment (clay and silt).

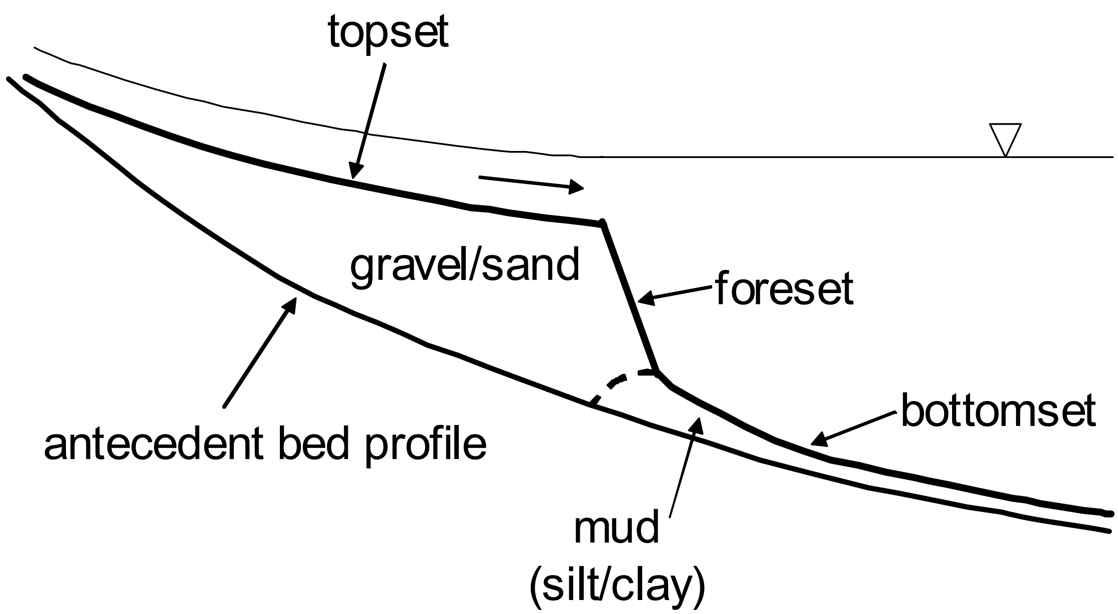

Figure 2.5-3. Conceptual longitudinal profile of tributary delta morphology (from Parker 2004).

The wash load will be suspended in the water column when it reaches the end of the topset slope. If this sediment-laden mixture is heavier than the water in the reservoir, then it will plunge downward and form a turbidity current that flows along the bottom of the reservoir (Fan and Morris 1992). Otherwise, it will generally disperse and mix with the water in the reservoir.

As the delta accumulates sediment, the leading edge of the delta (foreset slope shown in Figure 2.5-3), will advance further into the reservoir. If the delta is confined within a narrow canyon, then it will advance forward in one direction. Otherwise, the tributary will intermittently avulse, and the accumulated sediment will spread laterally and form a delta fan (Parker et al. 1998a and 1998b, Sun et al. 2002, and Kostic and Parker 2003a and 2003b).

The sediment accumulated within tributary deltas may also be eroded by several different potential mechanisms. These erosional processes include the following:

- Direct erosion from the main current of the Pend Oreille River. If the leading edge of the topset slope advances far enough into the reservoir to where it is exposed to the main current of the Pend Oreille River, then bed material transported by the tributary will become available for transport by the Pend Oreille River.
- Headcutting erosion in the tributary channel when the water surface elevation in the reservoir drops below the tributary delta channel (Morris and Fan 1997). This process will rework the sediment that had previously accumulated on the topset slope of the delta and transport it further into the reservoir.
- Shoreline erosion of the leading edge of the tributary delta associated with fluctuations of water surface elevation in the reservoir.

Thus, both accumulation and erosion of sediment may shape the morphology of the tributary delta. The sediment transport regime of the tributary deltas will also be linked with fluvial processes in the mainstem Pend Oreille River (see Mainstem Sediment Transport study component). The wash load in the tributaries (clay and silt) will be available for transport by the mainstem Pend Oreille River. Depending on how far the topset slope of the tributary delta has advanced into the reservoir, the bed-material load (sand, gravel, and cobbles) may also become available for transport by the Pend Oreille River.

The tributary delta sediment processes study will provide morphological information to be used in the Tributary Delta Habitat Modeling study component. The tributary delta sediment processes study will estimate whether the morphology of each delta is expected to change over the next 50 years (potential term of a new license) and whether any expected changes are expected to depend on various operational scenarios. If changes to tributary delta morphology are expected, then the predicted delta morphology will be estimated for use in the tributary delta habitat study for mid-license term (i.e., 2036) and end of the potential new license period (i.e., 2061) for each alternative operational scenario.

Proposed Methodology

In developing the methodology for the Tributary Sediment Processes component of this study, a summary of existing information needed to conduct the study was compiled, a list of additional information needed to conduct the study was prepared, and underlying assumptions of the study were defined. The following available existing information will be needed to conduct this study:

- Bathymetry of the Pend Oreille River from Box Canyon Dam to Boundary Dam (USGS 1938), based on surveys conducted in 1934 by the U.S. Geological Survey (USGS) in cooperation with the Washington Department of Conservation and Development. The contour interval of the land surface adjacent to the river was 20 feet. Thalweg profile elevations were determined at intervals ranging from 1 to 20 feet.
- Bathymetry of the Pend Oreille River from Metaline Falls to the proposed Boundary Dam transect site (SCL 1957) based on surveys conducted in 1956 by Northern Pacific Mapping Services, Inc. Contour intervals on these maps were 20 feet.
- Topographic maps and GIS coverage of the entire drainage basin of the Pend Oreille River upstream from Boundary Dam, including portions that extend into Canada.
- At least a 30-year period of daily flow records (1967 through 2006) will be needed from the following gage sites: the USGS gage for the Priest River near the confluence with the Pend Oreille River (USGS Gage 12395000); and from the Water Survey of Canada gage for the Salmo River near Salmo (Gage No. 08NE074).
- Daily flow records covering a shorter period of time (1994 through 2005) will be needed from the USGS for Sullivan Creek at Metaline Falls (Gage No. 12398000).

The additional data required to conduct the tributary delta sediment study consist of the following:

- Study stream selection will be coordinated with relicensing participants as part of the Tributary Delta Habitat Modeling study component.
- The results from a cumulative total of 48 to 132 Wolman pebble count surveys Wolman (1954) of surface layer delta sediment deposits from 6 to 8 tributaries of the Pend Oreille River between Box Canyon Dam and Boundary Dam will be needed (see Tributary Delta Habitat Modeling study component).
- Current bathymetry of the Pend Oreille River (including tributary delta zones) from Box Canyon Dam downstream to Boundary Dam will be needed with 2-foot contours in areas less than 40 feet deep below normal full pool level and 5-foot contours in areas greater than 40 feet deep.
- Bathymetric changes of the tributary delta morphology from 1967 to 2006 will be determined as part the Mainstem Sediment Transport study component.
- Tributary delta cross-section profiles will be surveyed and a HEC-RAS (U.S. Army Corps of Engineers 2002a, 2002b, and 2002c) hydraulic model will be developed for each tributary delta as part of the Tributary Delta Habitat Modeling study component.
- A time series of daily flows and daily sediment loads will be developed for each tributary from 1987 to 2004 as part of the Mainstem Sediment Transport study component.
- 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 will be available as output from the Scenario Tool (Attachment 1, section 3.2).
- The effects of hourly Project operations on hourly hydraulic conditions (depth, velocity, and shear stress) in the Pend Oreille River extending from Box Canyon Dam to just above the Salmo River confluence will be available from the hydraulic unsteady flow routing model (Mainstem Aquatic Habitat Modeling Study, Study No. 7).

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

- Seasonal and daily runoff patterns from ungaged tributaries to the Pend Oreille River between Box Canyon Dam and Boundary Dam will be assumed to be similar to seasonal and daily runoff from the Priest River and the Salmo River.
- The magnitude of seasonal and daily runoff patterns from ungaged tributaries to the Pend Oreille River between Box Canyon Dam and Boundary Dam will be assumed to be proportional to tributary drainage area.
- Average annual sediment input to the Pend Oreille River between Box Canyon Dam and Boundary Dam from tributary streams is assumed to be proportional to tributary drainage area (downstream from any major lakes or reservoirs within each tributary).
- Daily sediment input to the Pend Oreille River between Box Canyon Dam and Boundary Dam from tributary streams is assumed to depend on the magnitude of the daily flow in the tributary streams.

The sediment processes associated with tributary deltas can be complex, especially if the delta spreads laterally as it forms when it enters a reservoir. Tributary delta sediment processes have attracted the recent attention of various researchers (Parker et al. 1998a and 1998b, Sun et al. 2002, and Kostic and Parker 2003a and 2003b). Current knowledge of the physical processes associated with tributary delta morphology is sufficient to develop a simplified model to analyze the effects of Project operations on the sediment processes of the Pend Oreille River tributary deltas. A model will be developed to estimate potential changes to tributary delta morphology based on estimates of daily flow and sediment supply to each tributary mouth, and hourly water surface elevations in the mainstem Pend Oreille River from the Hydraulic Routing Model. In developing this model, the following assumptions, will be made to estimate the effects of Project operations on tributary delta habitats:

- The morphology of the delta will be assumed to change by accumulating sediment along both the topset slope and the foreset slope of the delta surface as a result of bed material accumulation.
- Accumulation of bed-material load within the tributary channel of the delta will be assumed to match the accumulation of bed material load on the delta floodplain surface, so that the current shape and alignment of the tributary channel across the topset slope of the delta remains constant. In other words, the effects of channel avulsion on the alignment of the tributary channel will be ignored, but the effects of channel avulsion on long-term accumulation of sediment on the delta surface will be accounted for.
- Bed-material load will be assumed to accumulate uniformly across the entire surface of the foreset slope, so that the front edge of the delta maintains a similar shape as it advances towards the mainstem Pend Oreille River channel. When the front edge of the delta reaches the mainstem, the bed-material load delivered by the tributary will become a source of sediment to the mainstem, and no more sediment will accumulate on the front edge of the delta.
- The density of sediment deposits will be assumed to be constant as sediment accumulates on the delta. In other words, the effects of consolidation of sediment deposits associated with the increasing weight of overburden sediment deposits will not be considered.

A phased approach will be used in the tributary delta sediment processes study to provide morphological information to be used for each tributary selected in the tributary habitat study. The proposed phased approach is outlined in the three tasks described below.

Task 1) Phase 1, Evaluate Potential Delta Change

Determine if the tributary delta morphology is expected to change over the next 50 years (potential term of a new license). If no changes are expected, then the current morphology of the tributary may be used directly for habitat evaluations.

Task 2) Phase 2, Predict Delta Change Common to All Scenarios

If the tributary delta morphology is expected to change, then determine whether the change in morphology is expected to differ among alternative operational scenarios. If changes to tributary delta morphology are not expected to be scenario-specific, then the predicted delta morphology will be estimated for use in the tributary delta habitat study for mid-license term (i.e., 2036) and at the end of the potential new license period (i.e., 2061).

Task 3) Phase 3, Predict Delta Change Associated with Specific Scenarios

If changes to tributary delta morphology are expected to differ among operational scenarios, then the predicted delta morphology will be estimated for use in the tributary delta habitat study for mid-license term (i.e., 2036) and at the end of the potential new license period (i.e., 2061) for each alternative operational scenario.

If the topset slope of the tributary delta is predicted to advance into the reservoir, where it would become exposed to the main current of the Pend Oreille River, then the quantity of bed material delivered by the tributary to the mainstem would be estimated for use in the Mainstem Sediment Transport study component.

Work Products

Work products will consist of a site-specific model for each selected tributary delta, and interim and final study reports describing the methods and results of the determination of potential changes in tributary delta morphology at mid-license term (2036) and at the end of the potential new license term (2061).

Schedule

The schedule for completing the Tributary Delta Sediment Processes component of this study is provided in Table 2.5-3.

Table 2.5-3. Schedule for the Tributary Delta Sediment Processes 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	--------										
Compile information		-------	------	-------							
Determine if tributary delta morphology is expected to change over time					--------						
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					●						
Predict estimated future tributary delta morphology for 2036 and 2061 for tributaries where morphology is not expected to depend on potential alternative operational scenarios.						-------	------				
Predict estimated future tributary delta morphology for 2036 and 2061 for tributaries where morphology is expected to depend on various alternative operational scenarios.								-------	------	-------	
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									●		

Mainstem Sediment Transport

The erosion, transport, and accumulation of sediment within the mainstem Pend Oreille River may affect aquatic habitats by altering channel morphology and the size and distribution of channel substrates. This study effort will evaluate the effects of Project operations on channel morphology within the Pend Oreille River from Box Canyon Dam downstream to just above the confluence of the Salmo River. The net change in the volume of sediment deposited within the study reach will be estimated, and zones of erosion and accumulation of sediment within the study reach will be delineated. Existing Conditions, as described by bathymetry data collected in 2006, will be compared to conditions over the potential term of a new license.

The construction of a dam and impoundment of water can impact the channel morphology and sediment transport regime in both the upstream and downstream directions. Upstream from the dam, some of the incoming sediment will be trapped as it enters the reservoir, and the remainder of the sediment will be passed downstream. The ratio of the weight of sediment trapped in the reservoir divided by the total weight of incoming sediment is referred to as the "trapping efficiency" of the reservoir. The sediment trapped in the reservoir will be coarser than the sediment passed downstream. The sediment deposited in the reservoir will generally be sorted longitudinally with the coarser sediments accumulating further upstream from the dam, and the finer sediments accumulating closer to the dam.

Downstream from the dam, the sediment transport regime will be impacted by two confounding processes: reduced supply of sediment to the river just downstream from the dam; and altered flow regime. Just below the dam, the substrate may become coarser and the channel may become incised. Further downstream from the dam, these processes will diminish and possibly reverse, as the river receives additional sediment from downstream tributary sources.

In addition to potential impacts to the mainstem channel morphology and substrate texture, there may also be potential impacts to tributary channel morphology and substrate texture in the vicinity of the confluence of tributaries with the mainstem river channel. Upstream from the dam, delta formation and accumulation of fine sediments may be the result. Downstream from the dam, tributaries may become perched above the incised mainstem channel and the substrate of the tributary may coarsen. The response of the tributaries, which are linked to processes that occur in the mainstem, will be the focus of the Tributary Delta Sediment Processes study component.

Proposed Methodology

In developing the methodology for the mainstem sediment transport study a summary of existing information needed to conduct the study was compiled, a list of additional information that may be needed to conduct the study was prepared, and underlying assumptions of the study were defined. The following available existing information will be needed to conduct this study:

- Bathymetry of the Pend Oreille River from Box Canyon Dam to the international border (USGS 1938), based on surveys conducted in 1934 by the USGS in cooperation with the Washington Department of Conservation and Development. The contour interval of the land surface adjacent to the river was 20 feet. Thalweg profile elevations were determined at intervals ranging from 1 to 20 feet.
- Bathymetry of the Pend Oreille River from Metaline Falls to the proposed Boundary Dam site (SCL 1957) based on surveys conducted in 1956 by Northern Pacific Mapping Services, Inc. Contour intervals on these maps were 20 feet.

- Topographic maps and GIS coverage of the entire drainage basin of the Pend Oreille River upstream from the confluence with the Salmo River, including portions that extend into Canada.
- At least a 30-year period of daily flow records (1967 through 2006) will be available from the USGS for the Priest River near the confluence with the Pend Oreille River (USGS Gage 12395000; and from the Water Survey of Canada for the Salmo River near Salmo (Gage No. 08NE074).
- Daily flow records covering a shorter period of time (1994 through 2005) are available from the USGS for Sullivan Creek at Metaline Falls (Gage No. 12398000).

In addition to the information listed above, additional information may be needed to develop and calibrate the mainstem sediment transport model. This information would be developed by other relicensing study efforts in 2007 and 2008 and includes the following:

- Bathymetry of the Pend Oreille River from the international border to the location of Seven Mile Dam. 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 US-Canada border to Seven Mile Dam is insufficient for the needs of this study. Hence, this information will be collected in 2007.
- Bathymetry of the Pend Oreille River from Box Canyon Dam downstream to the International Border will be needed with 2-foot contours in areas less than 40 feet deep below normal full pool level and 5-foot contours in areas greater than 40 feet deep. Bathymetry of Boundary Reservoir was surveyed during 2006, and the final processed datasets will be available in early 2007.
- The effects of alternative operational scenarios on hourly water surface elevations in Boundary Reservoir forebay and hourly flow releases (power generation plus spill) from Boundary Dam will be obtained from the Scenario Tool (Attachment 1, section 3.2).
- The effects of hourly Project operations on hourly hydraulic conditions (depth, velocity, and shear stress) in the Pend Oreille River extending from Box Canyon Dam to just above the Salmo River confluence will be needed from the hydraulic unsteady flow routing model (see Mainstem Aquatic Habitat Modeling Study , Study No. 7)
- The results from a cumulative total of 48 to 132 Wolman pebble count surveys Wolman (1954) of surface layer delta sediment deposits from six to eight tributaries of the Pend Oreille River between Box Canyon Dam and just upstream of the Salmo River confluence will be obtained from the Tributary Delta Habitats Modeling study component.
- Mainstem substrate grain size composition along transects of the Pend Oreille River between Box Canyon Dam and just upstream of the Salmo River confluence will be obtained from the Mainstem Aquatic Habitat Modeling Study (Study No. 7).

The following assumptions were made when developing the list of tasks to be conducted as part of this study component:

- The effects of the Boundary Project extend downstream in the Pend Oreille River to the confluence of Red Bird Creek, which enters on the left bank just above the confluence of the Pend Oreille River and the Salmo River. Future changes in Seven Mile Project operations may alter the downstream influence of the Boundary Project (refer to section 4.5.5.1.2 in the PAD [SCL 2006a] for additional detail).
- Lake Pend Oreille and Priest Lake (combined drainage area ~ 24,500 mi^2) are assumed to trap the entire incoming bed-material load (cobbles, gravel, and sand).
- Albeni Falls Dam is assumed to pass all of the incoming bed load and suspended load to the Pend Oreille River between Lake Pend Oreille and Albeni Falls Dam. Bed load is defined as the coarser portion of total sediment load that moves on or near the streambed by rolling, sliding, or saltating (i.e., bouncing). Suspended load is defined as the finer portion of total sediment load that is transported while suspended above the streambed. The primary source of bed load in the reach above Albeni Falls is assumed to be the Priest River (with effective drainage area limited to the portion downstream from Priest Lake).
- Box Canyon Dam is assumed to pass all of the incoming bed load and suspended load to the Pend Oreille River between Albeni Falls Dam and Box Canyon Dam.
- The grain size distributions of surface layer delta sediment deposits from sampled tributaries will be assumed to be representative of grain size distributions of the bed load from unsampled tributaries of the Pend Oreille River between Lake Pend Oreille and just upstream of the Salmo River confluence.
- Seasonal and daily runoff patterns from ungaged tributaries to the Pend Oreille River between Lake Pend Oreille and just upstream of the Salmo River confluence will be assumed to be similar to seasonal and daily runoff from the Priest River and the Salmo River.
- The magnitude of seasonal and daily runoff patterns from ungaged tributaries to the Pend Oreille River between Lake Pend Oreille and just upstream of the Salmo River confluence will be assumed to be proportional to tributary drainage area.
- Average annual sediment input to the Pend Oreille River between Lake Pend Oreille and just upstream of the Salmo River confluence from tributary streams is assumed to be proportional to tributary drainage area (downstream from any major lakes or reservoirs within each tributary).
- Daily sediment input to the Pend Oreille River between Lake Pend Oreille and just upstream of the Salmo River confluence from tributary streams is assumed to depend on the magnitude of the daily flow in the tributary streams.

The focus of this study will be on predicting erosion, transport, and accumulation of sediments in the mainstem Pend Oreille River over the potential 50-year term of a new license. The first major task will be to examine patterns of erosion and accumulation of sediment in the river from 1967 to 2006 to serve as a guide for predicting future process patterns.

The second major task will be to estimate future input of sediment to the Pend Oreille River. Sediment supply to the study reach can come from the following sources:

- Releases from Box Canyon Dam (to be estimated in this study);
- Tributary input (to be estimated in this study); and
- Shoreline erosion (to be estimated in Erosion Study, Study No. 1).

The third major task will be to develop a sediment routing model to route sediment input from the various sources through the study reach, and to track where sediment is eroded and accumulated. The model will be calibrated to reproduce the historical patterns of erosion and accumulation (from 1967 to 2006). Historical supply of sediment will be assumed to be similar to estimated future inputs. A one-dimensional hydraulic model (see Hydraulic Routing Model study component, Study No. 7) will be used to help determine sediment transport capacity, based on historical flow releases from Box Canyon Dam, historical reservoir levels in the forebay of Boundary Project, historical flow releases from Boundary Dam to the Pend Oreille River, and historical reservoir levels in the forebay of the Seven Mile Project.

The fourth major task will be to predict future patterns of erosion and accumulation of sediment in the Pend Oreille River over the potential duration of the new license. These four tasks are described in more detail below.

Task 1) Delineate Zones of Erosion and Accumulation of Sediment from 1967 to 2006

The results of bathymetry and/or topographic surveys conducted prior to Project construction will be compared to current (i.e., 2006) bathymetry to delineate zones of erosion and accumulation of sediment in the Pend Oreille River between Box Canyon Dam and just upstream of the confluence with the Salmo River between 1967 and 2006. The volumetric change in zones where erosion and accumulation of sediment has occurred will be estimated.

Task 2) Characterize Sediment Supply

The average annual sediment supply to the Pend Oreille River from Box Canyon Dam and from tributaries to the Pend Oreille River between Box Canyon Dam and just upstream of the Salmo River confluence will be estimated. The average annual total sediment supply will be subdivided into components based on grain size (clay, silt, sand, gravel, and cobble). Guidelines established by the U.S. Bureau of Reclamation (USBR 1987) will be used to estimate bed load (gravel and cobble) as a portion of suspended load (clay, silt, and sand). The silt, sand, and gravel components will be further subdivided into size classes based on the phi classification scale (Lane 1947). Techniques used to estimate average annual sediment supply will include at least one watershed-based method and one method based on evaluating changes in reservoir bathymetry.

The sediment supply to the study reach will be estimated using watershed-based methods such as USGS (1962), Dendy and Bolton (1976), or U.S. Bureau of Reclamation (1987). These methods are used to estimate sediment yield from a watershed on an average annual basis (tons per square mile per year). The results developed using the watershed-based methods will be compared with available literature and discussed with local land and water management agencies.

The reservoir trapping efficiency of Boundary Reservoir will be calculated using methods such as Churchill (1948), Brune (1953), Borland (1971), and the modified Brune curve method (Linsley et al. 1986). The volume of sediment accumulated in Boundary Reservoir from 1967 to 2006 will be estimated using the information determined in the first major task. The density of the accumulated reservoir deposits will be estimated using methods developed by the U.S. Bureau of Reclamation (1987). Densities estimated using these methods typically range from about 80 to 90 pounds per cubic foot. The reservoir sedimentation volume, reservoir sediment density, and the reservoir trapping efficiency will be used to estimate the average annual quantity (tons) of sediment supplied to the reservoir over the term of the existing FERC license.

The previously described sediment supply estimates will be reviewed, and an appropriate average annual sediment supply (tons per year) will be selected to be used for evaluating all future sediment processes. The total average annual sediment supply to the Pend Oreille River from releases from Box Canyon Dam and from tributary sources will be apportioned on the basis of drainage area.

A sediment supply versus flow rating curve will be developed for flow releases from Box Canyon Dam and from the tributary sources for each of the grain size fractions. The sediment supply-rating curve will be assumed to have the following form:

$$Q_s = a(Q - Q_c)^b$$

where Q_s is the sediment transport rate in acre-feet per year, Q is the flow discharge rate in cfs, and Q_c is a critical flow rate to mobilize sediment. A value of 2.0 will be used for the exponent b, as recommended by the U.S. Army Corps of Engineers (1995). The coefficient "a" will be determined by applying the rating curve to 1967 to 2006 daily flows to match the average annual sediment supply. The critical flow, Q_c, for silt and clay will be assumed to be zero. A critical flow will be estimated for sand, gravel, and cobbles by applying the HEC-RAS model developed for each tributary to determine how much flow it would take to mobilize the substrate in each of the tributaries. A critical flow for sand, gravel, and cobbles will be estimated for flow releases from Box Canyon Dam from discussions with operators of Box Canyon Dam.

A time series of daily flows from tributaries (from 1967 to 2006) to the Pend Oreille River between Box Canyon Dam and the confluence with the Salmo River will be developed using flow records from the Priest River and the Salmo River as a guide. A time series of daily sediment supply (from 1967 to 2006) to the Pend Oreille River from Box Canyon Dam and from tributaries to the Pend Oreille River between Box Canyon Dam to just above the Salmo River confluence will be developed for each of the grain size classifications previously discussed.

The estimated sediment supply to the Pend Oreille River from Box Canyon Dam and tributary sources will be combined with estimates of shoreline erosion (see Erosion Study, Study No. 1) to determine a time series (1987 to 2004) of total sediment input to Boundary Reservoir. The average annual volume of sediment input from Box Canyon Dam and tributary streams estimated for the period 1987 to 2004 will be assumed to represent average annual sediment input under future conditions.

Task 3) Develop and Calibrate Sediment Routing Model

One-dimensional sediment transport models are commonly used to analyze the erosion, transport, and accumulation of sediment in rivers and reservoirs. Examples of public-domain computer models used to analyze these types of processes include HEC-6 (U.S. Army Corps of Engineers 1993), EFDC1D (EPA 2001), and GSTAR-1D (USBR 2006). These models, as well as other available models will be reviewed for applicability to the study reach of the Pend Oreille River, where the stage and flow can vary on an hourly basis. If an appropriate model can be found from among those currently available, then that model will be utilized for this study. Otherwise a simplistic, site-specific, one-dimensional sediment transport model will be developed for this study.

The study reach will be subdivided into sediment routing cells to include and correspond with habitat transects (see Mainstem Aquatic Habitat Modeling Study, Study No. 7). The sediment routing model will be developed and calibrated to match historical sediment accumulation patterns within the reservoir. Flow and reservoir forebay pool level records from 1967 to 2006 will be used to calculate hourly velocity, depth, and shear stress within each sediment routing cell using the hydraulic routing model (see Hydraulic Routing Model study component, Study No. 7). Model calibration will consist of selecting appropriate methods for bed load (gravel and cobble) and bed-material load (sand, gravel, and cobble) to match historical accumulation patterns. The difference between the bed-material load and the bed load will consist of the sand portion of the bed-material load. Sediment transport methods to be considered for the sediment routing model will include but not be limited to the following:

- Bed load — Meyer-Peter and Muller (1948) and Parker (1990a and 1990b); and
- Bed-material load — Engelund and Hansen (1972), Ackers and White (1973), Yang (1973, 1979, and 1984), and Wilcock and Crow (2003).

Task 4) Predict Future Patterns of Erosion and Accumulation

The calibrated sediment routing model will be used to predict erosion and accumulation of sediment and effects on channel morphology under the existing operations scenario. Potential changes in channel morphology, areas of continued sediment erosion and deposition will be identified and used to interpret the results of other studies, such as the Macrophyte study component of the Mainstem Aquatic Habitat Modeling Study (Study No. 7).

Work Products

Work products will consist of an interim study report describing the estimation of sediment supply to the Pend Oreille River between Box Canyon Dam and Boundary Dam and a final study report describing development and calibration of the sediment routing model.

Schedule

The schedule for completing the Mainstem Sediment Transport component of this study is provided in Table 2.5-4.

Table 2.5-4. Schedule for the Mainstem Sediment Transport 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	--------										
Determine historical patterns of mainstem sediment erosion and accumulation		-------									
Estimate daily time series by size fraction of sediment supplied to the Pend Oreille River between Box Canyon Dam and Boundary Dam.		-----	------								
Develop and calibrate the sediment 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					●						
Use sediment routing model to predict future patterns of mainstem sediment erosion and accumulation						-----	------	-----			
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. Consistency with Generally Accepted Scientific Practice

Tributary Delta Habitat Modeling: 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 USGS; Bovee 1998, Waddle 2001). The proposed approach for assessing the effects of alternative operational scenarios on habitat in the tributary deltas (and mainstem) is analogous to the PHABSIM approach in that hydraulic modeling is translated to indices of habitat availability using HSI information. Indeed, much of the HSI information to be used in the tributary delta study will be drawn directly from, or modified from, HSI information used in the mainstem habitat modeling approach (Study No. 7). One of the major differences between PHABSIM and the proposed approach is the incorporation of hydraulic models and quantitative evaluations of dewatering and inundation analogous to Habitat Evaluation Procedures (USFWS 1980) . The study uses HEC-RAS and tributary flow modeling to obtain water depths and velocities, which is more appropriate for the hydraulic conditions in the study area, while PHABSIM uses a variety of water surface elevation and hydraulic simulation programs more appropriate for modeling riverine flow conditions. The proposed custom 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.

Tributary Delta Sediment Processes: The sediment processes associated with tributary deltas can be very complex, especially if the delta spreads laterally as it forms when it enters a reservoir. Tributary delta sediment processes have attracted the recent attention of various researchers (Parker et al. 1998a and 1998b, Sun et al. 2002, and Kostic and Parker 2003a and 2003b). However, currently available “off-the-shelf” models may have to be adapted to analyze the sediment processes associated with the Pend Oreille River tributary deltas. Current knowledge of the physical processes associated with tributary delta morphology is sufficient to develop simplistic site-specific models to analyze the effects of Project operations on the tributary deltas.

Mainstem Sediment Transport: One-dimensional sediment transport models are commonly used to analyze the erosion, transport, and accumulation of sediment in rivers and reservoirs. Examples of public-domain computer models used to analyze these types of processes include HEC-6 (U.S. Army Corps of Engineers 1993), EFDC1D (EPA 2001), and GSTAR-1D (USBR 2006). Each model has its own unique strengths and limitations. These models, as well as other available models, will be reviewed for applicability to the study reach of the Pend Oreille River, where the stage and flow can vary on an hourly basis. If an appropriate model can be found from among those currently available, then that model will be utilized for this study. Otherwise a simplistic, one-dimensional, site-specific sediment transport model will be developed for this study.

2.7. Consultation with Agencies, Tribes, and Other Stakeholders

Tributary Delta Habitat Modeling: Input regarding the Tributary Delta Habitat component of the Sediment Transport and Boundary Reservoir Tributary Delta Habitats study was provided by relicensing participants during a workgroup meeting held in Spokane, Washington, on May 23, 2006. During the workgroup meeting, an outline for the Tributary Delta Habitat Modeling Study was presented and discussed with relicensing participants. Comments provided by relicensing participants on this review outline 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/).

Tributary Delta Sediment Processes: Input regarding the Delta Sediment Processes component of the Sediment Transport and Boundary Reservoir Tributary Delta Habitats study was provided by relicensing participants during workgroup meetings held in Spokane, Washington on May 23, 2006, and on August 14, 2006. During the May workgroup meeting, an outline for the Tributary Delta Sediment Processes was presented and discussed with relicensing participants. During the August meeting, the linkage between the Tributary Delta Sediment Processes study and the Mainstem Sediment Transport study was presented and discussed. Comments provided by relicensing participants regarding this study component 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/).

Mainstem Sediment Transport: Input regarding the Mainstem Sediment Transport component of the Sediment Transport and Boundary Reservoir Tributary Delta Habitats study was provided by relicensing participants during workgroup meetings held in Metaline Falls, Washington, on June 27, 2006, and in Spokane, Washington on August 14, 2006. During the June workgroup meeting, background on the issues associated with mainstem sediment transport was presented and discussed with relicensing participants. During the August workgroup meeting, an outline for the Mainstem Sediment Processes was presented and discussed with relicensing participants. Comments provided by relicensing participants regarding this study component 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 its PAD/Scoping comment letter (USFWS 2006), the USFWS endorsed the Tributary Delta Habitats and Mainstem Sediment Transport study outlines presented at the workgroup meetings. In a letter to SCL dated August 28, 2006 (included in the PSP Attachment 4-1; SCL 2006b), WDFW reiterated the importance of tributary delta habitats and indicated that they could not find an electronic version of the Tributary Delta study outline that had been presented at the May 23, 2006 workgroup meeting. An electronic version of the study outline was subsequently provided to WDFW.

The USFS did not specifically reference the tributary delta and sediment transport study outlines in its PAD/Scoping comment letter (USFS 2006b). However, in a follow-up conference call on September 8, 2006 (see PSP Attachment 4-1; SCL 2006b), USFS staff indicated that there was general agreement on the study outlines. The Tributary Delta and Sediment Transport Study plan, as modified to address relicensing participant comments, 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. Comments made during the November 15 study plan meeting and comments filed with the FERC by the USFS (2007) were supportive of the proposed study. SCL has made minor modifications to the Tributary Delta and Sediment Transport Study plan to address a USFS comment and to add clarification and detail. (SCL’s responses to comments are summarized in Attachment 3 and consultation documentation is included in Attachment 4 of this RSP.) Additional specifics will be developed in early 2007 when the Technical Consultant finalizes the study implementation details in coordination with SCL and relicensing participants (Attachment 1, section 2.2 of this RSP).

2.8. 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 three components of this study. 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 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.

2.9. Anticipated Level of Effort and Cost

Based on a review of study costs associated with similar efforts conducted at other hydropower projects, the estimated total cost to implement the three components of this effort (Tributary Delta Habitat Modeling, Tributary Delta Sediment Processes, and Mainstem Sediment Transport) at the Boundary Project ranges from $475,000 to $600,000; estimated study costs are subject to review and revision as additional details are developed.

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