Revised Study Plan
Boundary Hydroelectric Project (FERC No. 2144)

Study No. 12
Fish Entrainment and Habitat Connectivity Study

Seattle City Light

February 2007

TABLE OF CONTENTS

1.0 Introduction 1

2.0 Study Plan Elements 7

2.1. Nexus Between Project Operations and Effects on Resources 7

2.2. Agency Resource Management Goals 7

2.3. Study Goals and Objectives 7

2.4. Need for Study 8

2.5. Detailed Description of Study 10

2.6. Consistency with Generally Accepted Scientific Practice 18

2.7. Consultation with Agencies, Tribes, and Other Stakeholders 18

2.8. Progress Reports, Information Sharing, and Technical Review 20

2.9. Anticipated Level of Effort and Cost 20

3.0 Literature Cited 21

List of Tables

Table 1.0-1. Monthly 10 and 50 percent exceedance flows in the Pend Oreille River below the Boundary Project, hourly flow record 1987 to 2004 (R2 Resource Consultants 2006a). 5

Table 1.0-2. Proposed timeline for the Boundary Project fish entrainment and connectivity program. 6

Table 2.4-1. Estimated ranges of fish mortality for existing downstream passage routes (R2 Resource Consultants 2006b) 9

Table 2.5-1. Schedule for conducting the Turbine Entrainment study component. 15

Table 2.5-2. Schedule for conducting the Spillway Entrainment study component. 18

List of Figures

Figure 1.0-1. Aerial overview of Boundary Dam and associated facilities. 2

Figure 1.0-2. Potential entrainment paths through the Project include the intakes to the six penstocks, Spillways 1 and 2 and the skimmer gate. The seven sluiceways are not shown in this figure. 3

[This page intentionally left blank.]

Study No. 12 – Fish Entrainment and Habitat Connectivity Study

1.0 INTRODUCTION

The Boundary Project (Project) is designed to store Pend Oreille River water behind the 340-foot-high Boundary Dam and release it through six large turbines. When flow in the Pend Oreille River exceeds the capacity of the turbines, water is released through spillway or sluiceway structures built into the dam. Fish moving downstream through the Pend Oreille River may pass through the dam along with the flow (hence the term entrainment), and be exposed to potential injury or mortality during downstream passage. Fish attempting to move upstream through the Pend Oreille River are blocked by Boundary Dam, essentially preventing the connection between fish and aquatic habitats downstream and upstream of the dam.

Boundary Dam was built without facilities designed to pass fish or provide connectivity between upstream and downstream habitats. Grand Coulee and Chief Joseph dams, both federal power facilities, block anadromous fish migration more than 200 miles downstream of Boundary Dam, and the height (340 feet) and large flow volume (average annual flow of 26,480 cfs [SCL 2006a]) at Boundary Dam presents significant challenges to structural options to protect fish passing the dam. In recent years, declines in native resident fish populations, such as bull trout, have placed increased focus on resident fish migration. Primary concerns at the Boundary Project center on three native fish species found at the Project: bull trout, westslope cutthroat trout and mountain whitefish.

Similar to most other salmonids, bull trout and westslope cutthroat trout are known for their ability to return to natal streams for spawning, an aspect of their life history that contributes to genetic isolation and adaptation to local environmental conditions. Migration barriers are clearly an isolating mechanism for local populations. Types of barriers are waterfalls, landslides, water withdrawals, road crossings, and dams. A local population that lives above a barrier can only contribute individuals (and their genes) in a downstream direction. If that local population is extirpated then there is virtually no opportunity for the local population to become re-established unless other local populations are present farther upstream or there is human intervention.

Although there are no anadromous fish at the Boundary Project, resident fish moving downstream may pass through or over Project facilities at Boundary Dam. There are four potential pathways through which fish can pass downstream through Boundary Dam water intakes. These are the turbines, spillways, sluiceways, and the skimmer gate. Entrainment can potentially cause direct injury or mortality of fish through strike, shear, grinding, turbulence, cavitation, pressure changes, or gas bubble disease from supersaturated total dissolved gas (TDG) levels. In addition, injured fish could incur delayed mortality through predation.

The number of fish susceptible to entrainment into Project facilities depends on many inter-related physical and biological factors including entrainment route, flow and spill levels, reservoir pool level, hydroelectric production levels, time of year, and the abundance, distribution, behavior, and life history of the species of interest. The likelihood that fish would

pass through a particular pathway is a function of which pathways are open and passing flow, what percentage of the overall river flow each pathway is passing at the time, the relative depth of the pathway entrance in the water column, and the time of year relative to the fish species and its movement patterns both laterally in the river and vertically in the water column. In conjunction with physical factors, biotic factors also influence fish species susceptibility to entrainment. These include diurnal and/or seasonal movement patterns, fish size, swimming speed, life history requirements, relative size of the population, and density-dependent influences.

Boundary Dam is configured with six deep water turbine intakes 30 feet wide by 34 feet high (horseshoe-shaped in cross section) located at an invert elevation of 1,903 feet NGVD 29 (1,907 feet NAVD 88) in the Boundary Project forebay (Figure 1.0-1). The forebay channel (190 feet wide at the trash rack and 500 feet long) is located along the left abutment of the dam. A trash rack structure spans the channel approximately 200 feet from the nearest turbine intake. The forebay channel was excavated during Project construction and resembles a large, short canal. Fish may enter the Boundary Project forebay channel due to migratory behavior, density dependent movements, or drift in the river currents.

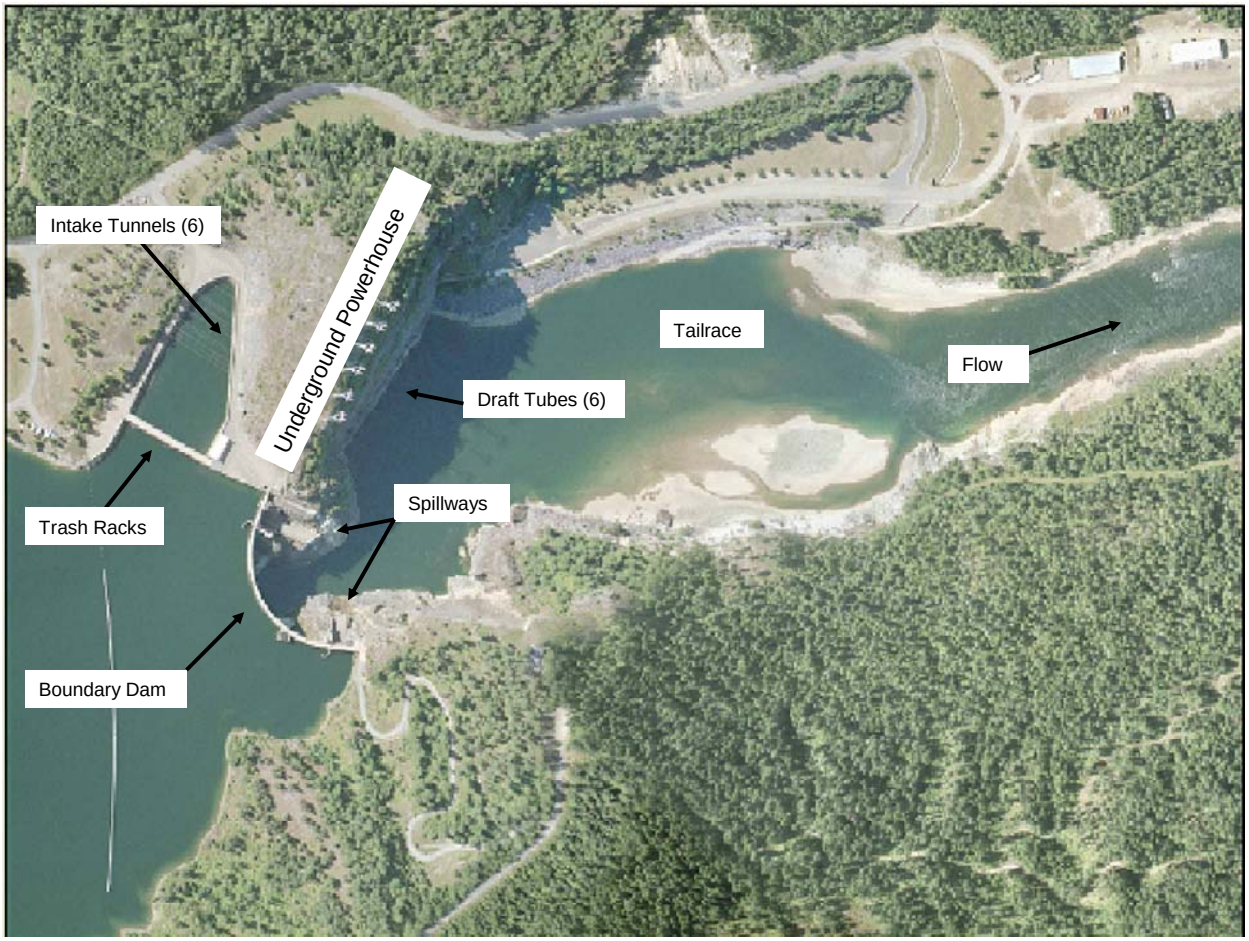

Figure 1.0-1. Aerial overview of Boundary Dam and associated facilities.

Boundary Dam has two spillways, one on either side of the main arch dam section (Figure 1.0-2). Both spill gates are bottom-opening Tainter gates 50 feet high by 45-feet wide. When fully closed, the top of the gates are at an elevation of 1,990 feet NGVD 29 (1,994 feet NAVD 88), which corresponds to the normal maximum pool elevation of Boundary Reservoir in the forebay. The spillway chutes do not extend all the way to the tailwater. Spillway 1, on the left bank looking downstream, extends 197 feet horizontally downstream from the crest. The end of the spillway chute has a flip bucket with a radius of 35 feet that causes the discharge to be released at an upward angle of about 21 degrees at an elevation of 1,904.6 feet. Spillway 2, on the right bank, is a shorter chute, extending 93.9 feet horizontally downstream of the crest, and does not include a flip bucket. Flow is discharged from this spillway at a downward angle of about 5.7 degrees. The flow then plunges into a pool in the tailrace.

Figure 1.0-2. Potential entrainment paths through the Project include the intakes to the six penstocks, Spillways 1 and 2 and the skimmer gate. The seven sluiceways are not shown in this figure.

Boundary Dam includes seven sluiceways located at about mid-height of the dam that discharge into the plunge pool below the dam. The sluiceways are generally used to supplement the spill flow during extreme high-flow events. The sluiceways are submerged on the upstream side of

the dam and are rectangular in shape, with a reducing area in the downstream direction through the dam. At the discharge end, on the downstream face of the dam, the sluiceways are 21 feet high by 17 feet wide. The flow capacity of each of the seven sluiceways is approximately 35,000 cfs with the forebay at normal full pool. The invert of the sluiceway outlet is at elevation 1,791.5 feet NGVD 29 (1,795.5 feet NAVD 88). The sluice gates are either fully open or fully closed, and cannot be throttled.

A surface-oriented gate is located adjacent to Spillway 1 on the left bank looking downstream (see Figure 1.0-2). The gate is 26 feet wide by 8 feet tall with an invert at elevation 1,982.0 feet NGVD 29 (1,986 feet NAVD 88). The flow capacity of the skimmer gate fully lowered is estimated to be approximately 1,800 cfs with the forebay at elevation 1,990.0 NGVD 29 (1,994.0 feet NAVD 88). Use of the skimmer gate was discontinued in the 1980s.

The Boundary Project is operated using a load-following strategy (see section 3.4 in the Boundary Project Pre-Application Document [PAD]; SCL 2006a). The Project has a maximum turbine flow capacity of 55,000 cfs, which is more than twice the average annual flow of the Pend Oreille River near Boundary Dam (SCL 2006a). Flow releases through the Boundary Project spillways are typically much less frequent than at non-peaking hydroelectric projects. Based on an analysis of hourly flow records, spill events are most likely to occur during the April through July period (Table 1.0-1). During power production, fish passing downstream in the Pend Oreille River may encounter water velocities in the turbine intakes that are greater than their ability to avoid. Water velocities in the turbine intake tunnels exceed 10 feet per second at maximum turbine flow capacity.

When powerhouse flows reach capacity (i.e., 55,000 cfs) during higher flow or flood conditions, the spillway gates are opened to pass flows downstream. The spillways are used until half their discharge capacity (total of approximately 54,000 cfs) is reached, then the sluiceway gates are opened to accommodate additional flow, with the sluice gates closest to the center of the dam opened first to reduce the possibility of eroding the abutments on the downstream side of the dam. Consequently, the sluiceways are usually not utilized until river flows exceed 109,000 cfs.

Table 1.0-1. Monthly 10 and 50 percent exceedance flows in the Pend Oreille River below the Boundary Project, hourly flow record 1987 to 2004 (R2 Resource Consultants 2006a).

Month	10% Exceedance (cfs)	50% Exceedance
January	32,725	16,100
February	33,488	15,400
March	37,792	18,700
April	51,403	26,050
May	72,069	36,700
June	88,668	41,250
July	47,521	22,200
August	26,906	12,300
September	21,310	14,650
October	26,330	21,500
November	27,200	20,250
December	25,490	17,100

The Fish Entrainment and Habitat Connectivity Study will address both turbine and spillway entrainment. Beyond the study phase, development of a Connectivity Management Plan component is proposed to evaluate the results of this study in the overall context of relicensing study results and to identify an appropriate response to the information. Relicensing studies addressing fish movement, tributary access, aquatic habitats, aquatic productivity, entrainment, and total dissolved gas will be used to ascertain those effects that have a nexus to current and future Project facilities and operations, and identify Project-induced impacts to fish and aquatic resources. Seattle City Light (SCL) anticipates that the Connectivity Management Plan will be developed in 2009, using the results of these relicensing studies. The plan will be developed in coordination with relicensing participants and will identify a comprehensive set of protection, mitigation, and enhancement (PME) measures for consideration in the FERC and related regulatory processes, as deemed appropriate. Potential connectivity measures may take the form of structural, operation, habitat, production, or other methods. These PME measures will be evaluated with relicensing participants, and will help in the development of Section 18 and Section 4(e) terms and conditions, including implementation schedules.

The overall process for addressing entrainment and habitat connectivity issues, as well as defining potential management responses during the relicensing process, is presented in Table 1.0-2. This table illustrates how fish and aquatic resources will be evaluated during the period extending from the implementation of studies through preparation of the Preliminary License Proposal (PLP) and Final License Application (FLA).

Table 1.0-2. Proposed timeline for the Boundary Project fish entrainment and connectivity program.

	2007	2008	2009	2010	2011	2012
Integrated Licensing Process	Conduct Studies	Conduct Studies	License Application	EIS Review	License Issued	
Fish and Aquatic Studies	Proposed Studies / Study Elements: ▫ Turbine entrainment ▫ Spillway entrainment ▫ Forebay fish timing, abundance and movements ▫ Genetics ▫ Tailrace fish timing, abundance and movements ▫ Habitat distribution ▫ Water quality	Continue Studies	Continue Selected Studies Connectivity Management Plan ▫ Structural options ▫ Habitat options ▫ Production options ▫ Other options	Continue Selected Studies	Continue Selected Studies	
Post-Licensing Process					Develop Implementation Plans	Begin Plan Implementation

2.0 STUDY PLAN ELEMENTS

2.1. Nexus Between Project Operations and Effects on Resources

If fish pass downstream through Boundary Dam facilities, they are exposed to potential injury and mortality. Depending upon the route, the risk of entrainment and the magnitude of injury and mortality can vary considerably. Operating conditions such as river flow, generating level, and pool level can affect what routes are available and the susceptibility of fish to entrainment.

2.2. Agency Resource Management Goals

General agency management goals are described in the Mainstem Aquatic Habitat Modeling Study (see Study No. 7, section 2.2). In addition, regulatory agencies have also developed the following goals, objectives, or action items related specifically to fish protection at water control facilities:

- USFWS — Identify barriers or sites of entrainment for bull trout and implement tasks to provide passage and eliminate entrainment (USFWS 2002).
- USFWS — 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.
- WDFW — 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 (WDFW 1997).

2.3. Study Goals and Objectives

The goal of the Fish Entrainment and Habitat Connectivity Study is to estimate the number, size, species, and timing of fish that may be entrained within the Boundary Project turbine intakes and spillways. The limited frequency, duration of use, and flow conditions associated with the use of the sluiceways, and the discontinued use of the skimmer gate, reduces the need to quantify the number of fish potentially entrained though these pathways (R2 Resource Consultants 2006b). For this reason, the assessment of the potential impact of fish entrainment at the Boundary Project will focus on entrainment through the turbine and spillway pathways. Study results will be used to quantify the effects of Boundary Project operations on hourly, daily, diel, and seasonal entrainment of fish within Boundary Reservoir. Study results will be used to evaluate the potential benefit and efficacy of fish protection measures and opportunities to establish connectivity between habitat and populations upstream and downstream of Boundary Dam.

2.4. Need for Study

Summary of Existing Information

An understanding of the abundance, distribution, and periodicity of fish in Boundary Reservoir is important for determining what species may be vulnerable to entrainment. However, few studies have been conducted in Boundary Reservoir. The most comprehensive surveys, conducted by McLellan (2001), occurred seasonally (spring, summer, and fall) during 2000 and consisted of electrofishing and gillnet sampling throughout the reservoir. Based upon these collections, Boundary Reservoir appears to be dominated by non-salmonids such as northern pikeminnow and largescale sucker (see Table 2.4-1, in the Fish Distribution, Timing and Abundance Study [Study No. 9]). McLellan (2001) concluded that most fish in Boundary Reservoir used the littoral (shallow) zone, while few fish used the pelagic zone (deep water).

Appendix E in McLellan (2001) reported the results of their surveys by species, season, and reservoir section, but no discussion of spatial (by section) or temporal distribution patterns was included in the body of the report. The data tables suggest that catch rates were generally higher in the summer and fall relative to the spring surveys. Electrofishing surveys generally had higher capture rates in the Upper Reservoir (Sections 3 and 4) compared to the Canyon and Forebay Reaches (Sections 1 and 2), while horizontal gillnet catch rates were variable with no strong patterns discernable among the different sections. McLellan (2001) reported that high flows occurred during the spring surveys. Seasonal differences in catch per unit effort may have been the result of spring high flows or fish activity levels, which may have affected capture efficiency rather than actual changes in fish abundance or distribution. Apparent spatial differences in capture rates for electrofishing surveys may have occurred because the Upper Reservoir Reach is relatively shallow, which is likely to result in higher electrofishing efficiency compared to the deeper Canyon and Forebay Reaches. Overall, the available information from McLellan (2001) is inadequate to draw strong conclusions concerning spatial and temporal patterns of reservoir use by the fish community, but is useful in describing relative abundance of the different fish species residing in the reservoir. A study is proposed to supplement the available information on fish distribution, abundance, and periodicity (see Study No. 9).

Nearby hydroelectric projects include the Waneta Project at RM 0.5, the Seven Mile Project at RM 6.0, and the Box Canyon Project at RM 34.5. Site-specific entrainment studies have not been conducted at any of these projects; however, fish distribution surveys have been conducted in all three reservoirs and concluded that native salmonids are rare (R.L. & L. 1999; R.L. & L. and Taylor Associates 2001, Ashe and Scholz 1992). Neither the Waneta nor Seven Mile projects have facilities to connect fish populations or habitats around the dams. BC Hydro, which runs the Seven Mile Project, is planning to implement a biotelemetry study of bull trout from the Salmo River to evaluate whether bull trout are being entrained at Seven Mile Dam (BC Hydro Project Team 2003). The Pend Oreille County Public Utility District (POPUD), which operates the Box Canyon Project, is planning to conduct entrainment studies at Box Canyon Dam beginning in 2007 (EES Consulting 2006). The POPUD is also planning to install a temporary upstream fishway in the tailrace of Box Canyon Dam in 2007 (Pend Oreille Public Utility District 2006).

As described above, if fish pass downstream through Boundary Dam facilities, they are exposed to potential injury and mortality. However, entrainment does not necessarily lead to mortality of all fish. R.L.&L. and Taylor Associates (2001) suggested that the presence of exotic fish in Seven Mile Reservoir was due to entrainment from upstream projects, but no empirical evidence was provided to indicate the potential magnitude of entrainment. Although no site-specific field study of injury or mortality has been conducted at the Boundary Project, the mortality for different size classes of fish was estimated for each potential passage route. R2 Resource Consultants (2006b) used an equation developed by the U.S. Department of Energy's Advanced Hydro Turbine System to estimate fish passage mortality. The procedures used to estimate entrainment mortality and the results of the analysis were reviewed by relicensing participants, and agreement was reached in 2006 that the mortality estimates could be used in place of site-specific mortality studies (R2 Resource Consultants 2006b). If fish pass through the spillway, the majority will be killed, while a large percentage of fish are expected to survive passage through the turbines (Table 2.4-1). A detailed discussion of factors related to injury and mortality of fish during entrainment at the Boundary Project is presented in the summary report (R2 Resource Consultants 2006b).

Table 2.4-1. Estimated ranges of fish mortality for existing downstream passage routes (R2 Resource Consultants 2006b)

Passage Route	Range of Estimated Mortality by Fish Length			Comments
	100 mm	250 mm	600 mm	
Turbines 51–54	6% – 15%	13% – 33%	26% – 65%	Original Units
Turbines 55–56	5% – 12%	11% – 28%	23% – 59%	New Units (larger turbines with fewer buckets & higher flow)
Spillways	50% – 80%	35% – 65%	20% – 50%	Depends on spill flow rate Spillway 1 better for smaller fish Spillway 2 better for larger fish
Sluiceways	40% – 70%	25% – 55%	10% – 40%	Speculative based on assumed reduction from spill estimates Assumes adjacent sluiceways are not operated simultaneously Does not consider influence of TDG impacts
Skimmer Gate	0% – 20%	10% – 30%	50% – 80%	Assumes fully aerated spray with freefalling fish upon tailrace entry

Need for Additional Information

The Fish Entrainment and Habitat Connectivity Study is designed to estimate the number and species of fish that could potentially be entrained through the Project turbines and spillways. The results of the study will be combined with the estimates of fish entrainment mortality to evaluate the potential risk of Project operation on the fish populations in the Pend Oreille River.

2.5. Detailed Description of Study

Study Area

The study area encompasses the Forebay Reach, Boundary Dam and associated structures, and the Pend Oreille River in the immediate vicinity of the Boundary Dam tailrace (Figure 1.0-1).

Description of Study Components

The proposed effort consists of Turbine Entrainment and Spillway Entrainment study components. Sluiceway and skimmer gate entrainment components are not proposed for this study because the skimmer gates have not been used since 1986 and the sluiceways are only used infrequently during major spill events.

Turbine Entrainment

Hydroacoustic monitoring is the proposed method to estimate the number, size, and timing of fish entrained within the Boundary Project turbine intakes. Fyke net sampling within the draft tube gate well slot or at the intake tunnel entrance will be used to verify hydroacoustic targets and identify the species composition of entrained fish. Other methods of estimating entrainment were considered, but the proposed methods were considered preferable given the site characteristics and desire for robust study results. Gill nets will be deployed in the Forebay Reach as part of the Fish Distribution, Timing and Abundance Study (Study No. 9), and while the results will indicate the number, size and species of fish in the general vicinity of the spillway and trashrack structures, they will not identify whether those fish passed downstream through the dam. Fyke nets, scoop or screw traps could be placed immediately downstream of the trashracks, but the water velocity in that area is low enough that fish might escape capture. Scoop or screw-traps could be placed downstream of the turbine outfalls, but fish that were injured or killed during turbine passage might pass under these surface-oriented traps and avoid detection. Fyke net arrays are expected to be the most accurate method of intercepting fish that are unquestionably entrained into turbine flow.

Three potential fyke net locations were described in the PSP: 1) within the intake gatewell slot, 2) within the draft tube gatewell slot and 3) at the turbine outfall.[1] At each location, the objective was to design the fyke net array to subsample all portions of the water column. Engineering, operational, safety and sample design assessments of each location eliminated two of the three alternatives identified in the PSP, and identified a new possible location. It remains unclear which of the two remaining locations will prove suitable, and a feasibility study is underway by the Technical Consultant. The following discussion identifies the advantages and disadvantage of each location identified by SCL.

[1] Following submittal of the PSP, SCL continued to evaluate potential locations to deploy fyke net arrays designed to sample fish entrained through the turbines. In January 2007, SCL retained a Technical Consultant to continue the evaluation of alternate locations and sampling procedures. Study plan information presented in this RSP reflects information developed since the PSP. Additional information regarding the sample design will be developed in early 2007 when the Technical Consultant finalizes study implementation details in coordination with SCL and relicensing participants (Attachment 1, section 2.2 of this RSP).

1) Fyke Net Array within the Intake Gatewell Slot

Fyke net arrays are a common method for sampling entrainment at hydroelectric projects. The general method employed is to lower a fyke net frame into a stop log slot upstream of the turbine. This stop log slot is typically adjacent to the slot used to store or drop the intake gate. Intake gates are used for dewatering turbines for maintenance or emergency shutdowns. At the Boundary Project, there is only one gatewell slot in the vicinity of the intake area and this is where the intake gate is stored. This slot could be used to lower a fyke net frame into the flowline, but it would eliminate the ability the drop the intake gate in the event of an emergency. The intake gate is the only backup means available to stop a turbine if the turbine governor fails. If the gate was not available and the turbine governor failed, there would be a threat to human safety and significant powerhouse damage could occur. For this reason, the intake gatewell slot has been eliminated as a feasible location for sampling turbine entrainment.

2) Fyke Net Array within the Draft Tube Gatewell Slot

Fyke Nets are generally not installed within draft tube gatewell slots because stop log slots upstream of intake gatewell slots are generally available and flow conditions are more uniform. It is also preferable to sample fish before they enter the turbine to assure collection of whole fish. The hydraulic conditions downstream of draft tubes can be highly turbulent and circular after leaving the turbine runner. Fyke netting in this area may be less effective due to currents that can twist the net(s). It is also possible that turbulent and circular flow patterns immediately downstream of the turbine will grind fish into small pieces and hinder fish species identification and enumeration. There is also concern that fish in the tailrace area could swim upstream of the net when the turbine is shut down for net deployment. This could result in the capture of fish within the fyke nets during turbine start-up that were not entrained through the turbine.

SCL envisions that it will be challenging to modify the draft tube gatewell slot to support a fyke net array. A new guide-rail support would need to be constructed by divers at depths up to 90 feet deep. It also may be necessary to remove and dismantle the draft tube gate to install the fyke net frame. If this were required, maintenance or repair of the turbine would require removal of the fyke net frame and reinstallation of the gate. Although there are clear disadvantages of this alternative, SCL still considers this alternative feasible from an engineering standpoint and is continuing to investigate this location for fyke net deployment.

3) Fyke Net Array at the Turbine Outfall

Several concepts for the installation of various types of nets in the turbine outfall area were discussed at Fish & Aquatic workgroup meetings. The alternative that was viewed as the most promising was a fyke net array that would be lowered into a fishing position on tracks that would be installed on the outside face of the turbine outfall tunnel. Two serious difficulties were identified as this alternative was investigated further. Rock fall occurs on the cliff above the turbine outfall area. In 2005, rock fall damaged a transmission tower exiting the powerhouse at the base of the cliff. Although a steel roof could be constructed for worker safety directly above where the nets would be located, rocks could fall outside this immediate area as they tumble off the cliff. Workers could be seriously injured or killed by rock fall. Another problem with this alternative is the ability to guarantee the net frame can be lowered to the bottom of the turbine outfall in order to sample the entire opening. Since construction of the Project, large rocks and boulders have sloughed off the old cofferdam that was used during original construction of the

Project. The old cofferdam is just downstream of the turbine outfall area and strong currents during high flow spill events continue to recruit rocks from the cofferdam into the turbine outfall area. Diving inspections in 1999 and 2000 identified very large boulders and very uneven conditions at the floor of the turbine outfall. It is unknown if boulders could be effectively removed and continually cleared from the turbine outfall opening that is being sampled. The proximity of the old cofferdam to the turbine outfall may also compromise the full deployment of large nets extending downstream from the outfall opening. The uncertainty of being able to repeatedly lower the frame to the floor of the turbine outfall and concerns for worker safety eliminated this alternative from further consideration.

4) Fyke Net Array at the Intake Tunnel Entrance

During the post-PSP evaluation of alternate fyke net locations, additional investigations identified that the intake tunnel entrance might be a suitable location to deploy and effectively fish a fyke net array. An earlier alternative of fyke net deployment in this location had been rejected prior to the PSP due to design complications and potential interference with the hydroacoustic equipment. A conceptual solution has since been developed that would enable this system to be deployed and retrieved without conflicting with the hydroacoustic equipment. SCL now believes this site may be the most suitable location and is actively investigating engineering and study design details.

A number of assumptions, listed below, are associated with the use of the proposed methods. If the following assumptions are false, the study may fail to meet one or more of its objectives or may require substantial changes to the methodology:

- Fixed-location hydroacoustic transducers can be installed at the entrance to the Boundary Project intake tunnels and used to quantify the timing, number and size of hydroacoustic targets passing into the intakes.
- Fyke net sampling within the Boundary draft tube gatewell slot or at the intake tunnel entrance can be used to validate and translate hydroacoustic targets into the number, size, and species of fish.
- Trapping efficiency of entrained fish does not differ among species, and is not affected by whether a fish is dead or alive.
- Both hydroacoustic and fyke net sampling provide imperfect estimates of fish entrainment. Comparison of sampling methods provides the opportunity to identify potential biases and highlight strengths and weaknesses, and the use of two methods will improve overall sampling effectiveness.
- If discrepancies are identified between hydroacoustic and fyke net sampling, fyke net sampling is expected to provide a better estimate of fish entrainment (species, size, and number) than hydroacoustic sampling.
- All fish captured within the fyke nets will suffer injury or mortality. Federal and state collecting permits will be obtained that allow sampling to continue up to a defined level of take.

Proposed Methodology

The work effort for this study has been divided into six tasks, as described below.

Task 1) Deploy Intake Hydroacoustic System

Design, install, and test a hydroacoustic system to enumerate targets within or passing into Boundary Project intake tunnels. A stratified sampling program will be developed to extrapolate the results obtained for the hydroacoustic measurement fields to the total intake area for all six intakes and correlated to the duration, timing and magnitude of generation. Testing will be conducted to identify effective transducer aiming angle, ping rate, and mounting depth. The hydroacoustic sampling approach, including number and type of transducers, transducer locations, and data analysis procedures will be identified by the Technical Consultant in coordination with SCL and relicensing participants.

Task 2) Intake Hydroacoustic Monitoring

Continuously monitor a hydroacoustic array 24 hours per day and 7 days per week throughout the year, with weekly data downloads. Sampling will continue for two years; however, when 12 months of sampling have been completed and analyzed, sampling during some periods may be curtailed based on site conditions (for example, during December and January if ice conditions interfere with readings). Any change in sampling procedures will be coordinated with relicensing participants.

Task 3) Fyke Net Array Installation

Use a stacked fyke net assembly, consisting of an array of multiple fyke nets, to sample one turbine intake that is being monitored using hydroacoustics. Access to the Boundary Project intakes will be gained through the draft tube gatewell slot or at the intake tunnel entrance. The final selection of one of these locations will be based on a feasibility analysis to be done in the first quarter of 2007. This feasibility analysis will be developed in coordination with relicensing participants. When a feasible location is selected, a turbine will be selected to install the fyke net system. This selection will be based on physical site constraints, turbine frequency of use, and distribution of fish between turbine intakes based on early hydroacoustic sampling results. Turbines that are in frequent use, provide physical access for net deployment, and appear to pass a greater proportion of fish relative to the other intakes will be given highest consideration for sampling. The selection of an intake to sample in 2007 will be identified by the Technical Consultant in coordination with SCL and relicensing participants. Based on the success of this installation and the need for additional information from a longer period of hydroacoustic sampling, a second fyke net array may be installed in 2008. This decision will be made in coordination with relicensing participants. Accuracy of entrainment estimates will depend on robust estimates of trapping efficiency. Methods will be developed by the Technical Consultant in coordination with SCL and relicensing participants.

Task 4) Fyke Net Sampling

Develop a stratified, subsampling approach to guide fyke net sampling. For planning purposes, sampling is expected to occur for at least four 24-hour periods per month. Depending on the rate

of fish and debris build-up in the cod end of the fyke nets, nets may be fished continuously for 24-hour periods, or split into shorter time intervals. Install the fyke net assembly prior to project start-up during each sampling period. If high flows result in extended periods of continuous operation, short-term shut-down of sampled intakes may be needed to install and retrieve the fyke net frame. Planned nighttime generation and planned spill events may be required during some months to provide adequate day versus night comparisons and evaluation of spillway hydroacoustic signatures. Sampling may not be available during periods of maintenance or repair of the turbine(s) selected for fyke net sampling.

Task 5) Fish Handling

Identify and quantify all fish collected during fyke net sampling; fish will be identified to species and measured to the nearest millimeter (mm) total length. All captured salmonids will be scanned for tags, including scanning for passive integrated transponder (PIT) tags using a portable tag reader.

Task 6) Data Analysis

Quantify the size, number and species of fish entrained within the Project intakes correlated to the duration, timing and magnitude of generation. Hydroacoustic target counts and signal strengths will be translated into the number and size of entrained fish using the results of the fyke net sampling. The results of fyke net sampling will also be used to identify the relative proportion of species entrained into the intakes. Data analysis procedures will be developed by the Technical Consultant in coordination with SCL and relicensing participants.

Work Products

The work products for the Turbine Entrainment study component will include tabular summaries of the relative proportion, size, number, and species of fish entrained within the Project intakes, and interim and final study reports. Statistical analyses that correlate the magnitude of entrainment to the duration, timing and magnitude of generation will also be summarized and described in text. Electronic copies of datasheets, including at a minimum species, size, timing, total dissolved gas level, and flow, will be available upon request.

Schedule

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

Table 2.5-1. Schedule for conducting the Turbine Entrainment 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	--------										
Hydroacoustic sampling		--------	--------	--------	--------	--------	--------	--------	--------		
Fyke net fabrication		--------	------								
Fyke net sampling				--------	--------	--------	--------	--------	--------		
Data analysis				------				--------	--------		
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					●						
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									●		

Spillway Entrainment

Hydroacoustic monitoring is the proposed method to estimate the number, size, species and timing of fish entrained within Boundary Dam Spillways 1 and 2. Fyke net sampling within the Project draft tube gatewell or at the intake tunnel entrance will be used to verify hydroacoustic targets and identify species composition of entrained fish.

A number of assumptions, listed below, are associated with the use of the proposed methodology. If the following assumptions are false, the study may fail to meet one or more of its objectives or may require substantial changes to the methodology:

- The species composition of fish captured in the turbine fyke nets is similar to the composition of fish entrained in the spillways.

- Fixed-location hydroacoustic transducers can be installed at the entrance to the Boundary Project spillway gates and used to quantify hydroacoustic targets passing through a defined field of view when spill gates are in use.
- Hydroacoustic target signatures can be adequately translated to size and numbers of fish.
- Hydroacoustic sampling provides an imperfect estimate of fish entrainment. If needed, other potential sampling methods will be considered to identify potential bias, highlight strength and weaknesses and used to improve overall sampling effectiveness.
- Spillway discharge, and associated potential spillway fish entrainment, primarily occurs from early April through mid-July. If no spill events occur during the initial period of hydroacoustic monitoring, planned spill events will be scheduled to evaluate potential spillway entrainment.

Proposed Methodology

The work effort for this study has been divided into five tasks, as described below.

Task 1) Deploy Spillway Hydroacoustic System

Design, install, and test hydroacoustic systems within Spillways 1 and 2. A level of effort is described for planning purposes, but the selection of hydroacoustic equipment, number and type of transducer, transducer location, aiming angle, depth of attachment and transducer ping rate will be identified by the Technical Consultant in coordination with SCL and relicensing participants.

Task 2) Spillway Hydroacoustic Monitoring

Continuously monitor Spillway gates 1 and 2 using hydroacoustics for the period April through July during 2007 and 2008. Monitoring will occur 24 hours per day and 7 days per week throughout the sampling season with weekly data downloads. Hydroacoustic sampling will be extended if a high likelihood of spill events can be forecast outside of the April through July period.

Task 3) Hydroacoustic Data Analysis

Quantify the number and signal strength of hydroacoustic targets entrained within the Project spillways. The hydroacoustic array will provide estimates of the number and strength of targets passing through a defined field of view which will be extrapolated to the entire spillways and correlated to spill timing, duration and magnitude. A stratified sampling approach and data analysis procedure will be developed by the Technical Consultant in coordination with SCL and relicensing participants.

Task 4) Translate Hydroacoustic Data to Fish Data

Translate spillway hydroacoustic target signatures to numbers, size and species of fish using:

- the relationship between spillway hydroacoustic target signatures and the results of simultaneous fyke net sampling of the turbine intakes;
- the results of biological sampling in the forebay and immediately in front of the spillway gates during days/nights when spillways are not in use (see Study No. 9, Fish Distribution, Timing and Abundance Study);
- the relationship between turbine intake hydroacoustic target signatures and fish size and species; or
- if spillway hydroacoustic target signatures cannot be translated to fish size and numbers using these available data, other opportunities to translate hydroacoustic targets to numbers and size of fish will be considered including, but not limited to, an underwater video system installed to record the passage of fish during periods of spillway use, or a screw trap or scoop trap installed in the tailrace during spill conditions.

Task 5) Fish Data Analysis

Estimate the number, size and species of fish passing through the spillways for a range of spill conditions. Data analysis procedures will be developed by the Technical Consultant in coordination with SCL and relicensing participants.

Work Products

The work products for the Spillway Entrainment study component will include tabular summaries of the relative proportion, size, number and species of fish entrained within the Project spillways, and interim and final study reports. Statistical analyses that correlate the magnitude of entrainment to the duration, timing and magnitude of spill will also be summarized and described in text. Electronic copies of datasheets, including at a minimum species, size, timing, total dissolved gas level, and flow, will be available upon request.

Schedule

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

Table 2.5-2. Schedule for conducting the Spillway Entrainment 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	--------										
Hydroacoustic sampling		--------	--------	--------	--------	--------	--------	--------	--------		
Data analysis				------				--------	--------		
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					●						
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

The study methods have been developed in consultation with relicensing participants. The study approach and methods are consistent with those used as part of licensing studies on large rivers throughout the northwestern United States (e.g., Columbia River, Snake River, Lewis River, and Cowlitz River) to evaluate the impact of turbine entrainment on fish species.

2.7. Consultation with Agencies, Tribes, and Other Stakeholders

Input regarding the Fish Entrainment and Habitat Connectivity Study was provided by relicensing participants during workgroup meetings. Workgroup meetings were held in Spokane, Washington, on April 20, 2006, and May 23, 2006. During the April workgroup meeting, outlines for turbine and spillway entrainment sampling at the Boundary Dam were presented and discussed with relicensing participants. Following the April workgroup meeting, the USFWS provided written comments on the study outlines (see PSP Attachment 4-1, SCL

2006b). During the May workgroup meeting, SCL responses to the USFWS comment letter were discussed and relicensing participants provided additional feedback and continued discussions of entrainment sampling at the Boundary turbine intake tubes. The study plan for the Fish Entrainment and Habitat Connectivity study was developed from these outlines and relicensing participant comments. Comments provided by relicensing participants on the review outlines are summarized in the PSP Attachment 4-1 (SCL 2006b) and can be found in meeting summaries available on SCL's relicensing website (www.seattle.gov/light/news/issues/bndryRelic/).

As part of an early information development effort, SCL contracted with R2 Resource Consultants to compile existing information regarding Project facilities and evaluate the risk of injury and mortality if native salmonids passed downstream through various routes. The objective of this effort was to support future relicensing participant discussions of potential fish connectivity and entrainment protection measures. No site-specific field studies of entrainment or upstream and downstream fish connectivity were conducted in 2006. As part of the early information development effort, descriptions of existing Boundary Project facilities and operations and background information relevant to upstream and downstream fish connectivity and entrainment were compiled for the Boundary Project. Because the movement and potential connectivity of fish throughout the Pend Oreille River system is pertinent to the issue of fish passage at the Boundary Project, a brief summary of existing and planned fish connectivity programs was also compiled for other hydropower projects on the Pend Oreille River.

Fish that might be migrating downstream and pass through Project facilities may be directly injured or killed or indirectly impacted if they are made temporarily more vulnerable to predation due to disorientation and stress. The summary report of the early information development effort presented estimated ranges of fish mortality for existing downstream passage routes based on a review of available information in the literature (see Table 2.4-1). SCL proposed to adopt these mortality estimates in lieu of conducting site-specific studies of entrainment mortality. The USFS, in an e-mail dated May 8, 2006, and the USFWS in an e-mail dated July 21, 2006 (see PSP Attachment 4-1; SCL 2006b), agreed to the use of the mortality estimates in lieu of site-specific studies for purposes of Boundary Project relicensing. During the August 14, 2006, workgroup meeting, relicensing participants confirmed that the estimated turbine and spillway mortality rates described in Table 2.4-1 could be used during relicensing in place of empirically derived results.

In its PAD/Scoping comment letter (USFWS 2006), the USFWS endorsed the turbine and spillway study outlines presented at the workgroup meetings, noting that written comments had previously been provided and discussed (see May 23, 2006 meeting record). WDFW (in a letter to SCL dated August 28, 2006) and the USFS (in its PAD/Scoping comment letter [USFS 2006]) did not specifically reference the Fish Entrainment and Habitat Connectivity Study outlines in their letters, but in a follow-up conference call with USFS staff on September 8, 2006, USFS staff indicated that there was general agreement on the outlines.

The Fish Entrainment and Habitat Connectivity 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) and USFWS (2007) were supportive of the proposed study. (Comments are summarized in Attachment 3 and consultation documentation is included in Attachment 4 of this RSP). SCL has further modified the Fish Entrainment and Habitat Connectivity Study plan. Modifications include the possible installation of a second fyke net array in study year two based on the results of study year one. Additional implementation details of the study components will be developed in early 2007 when the Technical Consultant finalizes the study design in coordination with SCL and relicensing participants (Attachment 1, section 2.2 of this RSP).

2.8. Progress Reports, Information Sharing, and Technical Review

An interim study report describing the first year's monitoring results and analyses and recommendations, if any, for modifying 2008 survey procedures will be produced. Relicensing participants will be provided an opportunity to discuss the interim study report results at one (or more, if necessary) relicensing participant meetings. A final study report describing survey methods and results of 2007 and 2008 monitoring will also be produced. 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.

2.9. Anticipated Level of Effort and Cost

SCL envisions that the Turbine and Spillway Entrainment study components will be implemented as a combined effort to increase study efficiencies and ensure the use of complementary equipment where feasible. The total estimated cost of implementing both study components is expected to range from $1,800,000 to $2,500,000; estimated study costs are subject to review and revision as additional details are developed.

3.0 LITERATURE CITED

Ashe, B.L. and A.T. Scholz. 1992. Assessment of the Fishery Improvement Opportunities on the Pend Oreille River: Recommendations for Fisheries Enhancement - Final Report. U.S. Department of Energy, Bonneville Power Administration. Division of Fish and Wildlife. Project Number 88-66. Agreement DE-179-88BP39339. 295 p.

BC Hydro Project Team. 2003. Seven Mile River Consultative Report and Water Use Plan, Executive Summary. BC Hydro Website URL: http://www.bchydro.com/wup/completed/seven_mile/seven_mile_exec_sum_cc.pdf.

EES Consulting. 2006. Box Canyon Hydroelectric Project FERC No. 2042 Downstream Fishways Behavior, Survival and Design Investigation Plan. Prepared for Public Utility District No. 1 of Pend Oreille County, Newport, Washington. 38 pp.

McLellan, J.G. 2001. 2000 WDFW Annual Report for the Project, Resident Fish Stock Status Above Chief Joseph and Grand Coulee Dams. Part I. Baseline Assessment of Boundary Reservoir, Pend Oreille River, and its Tributaries. Report to Bonneville Power Administration, Contract No. 00004619, Project No. 199700400.

Pend Oreille Public Utility District. 2006. People & Power Summer 2006 Newsletter. Pend Oreille Public Utility District Website URL: http://www.popud.com/Summer2006.pdf

R.L. & L. Environmental Services Ltd. 1999. Review of Information on the Fish Resources of the Lower Pend Oreille River. Seattle City Light.

R.L. & L. Environmental Services Ltd. and Taylor Associates. 2001. Fish Population Assessment of the Lower Pend Oreille River, Draft Report. Seattle City Light.

R2 Resource Consultants. 2006a. Compilation of Project Hydrologic Data, Phase 2: Preparation of Hydrologic Database and Hydrologic Statistics for Preliminary Application Document (PAD), Boundary Hydroelectric Project (FERC No. 2144). Prepared for Seattle City Light. Draft dated January 3, 2006.

R2 Resource Consultants, Inc. 2006b. Early Information Development: Fish Connectivity at the Boundary Hydroelectric Project. Boundary Hydroelectric Project (FERC No. 2144). Prepared for Seattle City Light, Seattle, WA. November 2006. Available online at http://www.seattle.gov/light/news/issues/bndryRelic/br_document.asp

SCL (Seattle City Light). 2006a. Pre-Application Document for the Boundary Hydroelectric Project (FERC No. 2144). Seattle, Washington. May 2006. Available online at http://www.seattle.gov/light/news/issues/bndryRelic/br_document.asp

SCL. 2006b. Proposed Study Plan for the Boundary Hydroelectric Project (FERC No. 2144). Seattle, Washington. October 2006. Available online at http://www.seattle.gov/light/news/issues/bndryRelic/br_document.asp

USFS (USDA Forest Service). 2006. Boundary Hydroelectric Project, FERC No. 2144-035, Response to Scoping Document 1, Comments on Pre-Application Document, and Study Requests. Colville National Forest. August 31, 2006.

USFS. 2007. Boundary Hydroelectric Project, No. 2144-035, comments to Proposed Study Plan. Colville National Forest. January 9, 2007.

USFWS (U.S. Fish and Wildlife Service). 2002. Bull Trout (*Salvelinus confluentus*) Draft Recovery Plan. Region 1 U.S. Fish and Wildlife Service Portland, Oregon.

USFWS. 2006. Seattle City Light, Boundary Dam Relicensing (FERC No. 2144), Comments on Pre-Application Document, Study Proposals, and Scoping Document 1 (TAILS #14421-2006-FA-0012, File #503.0006). September 1, 2006.

UFSWS. 2007. Seattle City Light, Boundary Dam Relicensing (FERC No. 2144), Comments on Proposed Study Plan (TAILS #14421-2007-FA-0001, File #503.0006. Letter dated January 12, 2007.

WDFW (Washington Dept. of Fish and Wildlife). 1997. Policy of Washington Department of Fish and Wildlife and Western Washington Treaty Tribes Concerning Wild Salmonids. WDFW. Website URL: http://wdfw.wa.gov/fish/wsp/wsp.htm. 46 pp.