Revised Study Plan

Boundary Hydroelectric Project (FERC No. 2144)

Study No. 6
Evaluation of the Relationship of pH and DO to Macrophytes in Boundary Reservoir

Seattle City Light

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Study No. 6 – Evaluation of the Relationship of pH and DO to Macrophytes in Boundary Reservoir

1.0 INTRODUCTION

High daytime pH levels have been documented throughout the Pend Oreille River and in Boundary Reservoir (Ecology 2005, SCL 2006b). The cause of these high pH levels is unknown, but both background geologic conditions and the growth of macrophytes appear to be contributing factors. The geology of the Pend Oreille River basin includes limestone, which has the potential to influence the pH of nearby waters by contributing alkalinity (in the form of carbonate). Alkalinity absorbs the acid present in the water, thereby raising the pH. A total maximum daily load (TMDL) was established by the Washington Department of Ecology (Ecology) for pH in streams of the Colville National Forest. A study associated with the TMDL found that pH levels are uniformly elevated in surface waters across the forest as a result of the regional limestone geology.

Invasive macrophytes in Boundary Reservoir, such as Eurasian watermilfoil (*Myriophyllum spicatum*) and curly pondweed (*Potamogeton crispus*), also have the potential to affect water chemistry. Both pH and dissolved oxygen (DO) can be altered through the processes of photosynthesis, respiration, and senescence. Changes in pH and DO have been documented in and around macrophyte beds (Coots and Carey 1991; FERC 2002). Dense macrophyte growth can increase pH through the uptake of carbon dioxide during photosynthesis. Alternatively, with either nighttime respiration or senescence, macrophytes can reduce DO levels and produce carbon dioxide. Under these conditions macrophytes can reduce both DO and pH in surrounding waters.

The goal of this study is to explore the relationship of pH and DO to macrophytes in Boundary Reservoir to learn if macrophytes are contributing to high pH readings and, if so, to explore the indirect effect of the Boundary Project (Project) on pH and DO in the reservoir via its influence on macrophyte distribution and growth.

2.0 STUDY PLAN ELEMENTS

2.1. Nexus between Project Operations and Effects on Resources

Reservoirs provide shallow, low-velocity conditions that are conducive to macrophyte growth. Operation of Boundary Dam affects the reservoir's stage and velocity, which can influence macrophyte growth. In turn, the growth of macrophytes can affect water quality conditions, especially pH and DO. The direct effect of the Project on macrophyte distribution and abundance will be addressed under the Mainstem Aquatic Habitat Modeling Study (see Attachment 2, Study No. 7 of this RSP) being conducted under the Fish and Aquatics resource area. This study addresses the potential effect of existing macrophyte beds on DO and pH in Boundary Reservoir.

2.2. Agency Resource Management Goals

In addition to providing information needed to characterize Project effects, the proposed studies will provide information to help agencies with jurisdiction over water quality resources in the Project area identify appropriate conditions for the new Project license pursuant to their respective mandates. Boundary Project studies are specifically designed to meet FERC relicensing requirements, but may also provide information relevant to recent, or ongoing, management activities in the Pend Oreille River basin. Brief summaries of relevant water quality regulatory and planning documents follow.

Washington Department of Ecology (Ecology)

The relevant Ecology criteria for DO and pH are shown in Table 2.2-1. Water quality criteria for other parameters are provided in section 4.4.5.4 of the Boundary Project Pre-Application Document (PAD) (SCL 2006a).

Table 2.2-1. Applicable Washington State surface water quality standards for the Pend Oreille River between the Idaho border and the Canadian border (WAC 1997; WAC 2003).

Parameter	1997 Standard (Class A)[1]	2003 Standard (salmon and trout spawning, non-core rearing, and migration)[2]	Applicable Standard
Dissolved Oxygen	Levels shall exceed 8.0 mg/L	Levels shall exceed 8.0 mg/L	1997 Standard
pH	Within 6.5-8.5 with human caused variation within the above range of less than 0.5 units	Within 6.5-8.5 with human caused variation within the above range of less than 0.5 units	1997 Standards

Notes:

1 Chapter 173-201A WAC Water Quality Standards for Surface Waters of the State of Washington. November 1997.
2 Chapter 173-201A WAC Water Quality Standards for Surface Waters of the State of Washington. July 2003.

In addition to setting water quality standards, Ecology created the Aquatic Plant Technical Assistance Program to provide technical expertise within Ecology and other agencies and the general public regarding aquatic plant ecology, taxonomy, and management. This program has three main goals (Parsons 1995):

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

U.S. Environmental Protection Agency (EPA)

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

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

Water Resource Inventory Area (WRIA) 62

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

- WQUAL-1: WRIA-wide coordination of water quality monitoring.
- WQUAL-2: Watershed Planning Implementing Body support of actions that aim to reduce Eurasian watermilfoil and other aquatic nuisance weeds in WRIA 62.

  Objective: Reduce Eurasian watermilfoil and other aquatic nuisance weeds in WRIA 62.
- WQUAL-3a: Watershed Planning Implementing Body to participate in (interact and provide input to) the TMDL process for tributary streams that originate within WRIA 62.

  Objective: Remove tributary streams in WRIA 62 from the 303(d) list of impaired waters by meeting State and tribal (where appropriate) water quality standards in impaired tributary streams.
- WQUAL-3b: Watershed Planning Implementing Body to participate in (interact and provide input to) the TMDL process for the mainstem of the Pend Oreille River.

  Objective: Meet State and tribal (where appropriate) water quality standards in the mainstem Pend Oreille River.
- WQUAL-5: Protect water bodies of high water quality and improve water quality of impaired water bodies.

  Objective: Maintain compliance with state water quality standards and prevent degradation of waters that meet or exceed state water quality standards in WRIA 62.

Columbia River Subbasin Plans

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

- Subbasin Objective 1B2: Improve water quality to meet or exceed applicable water quality standards in the Subbasin.

  Strategy c: Identify pollution sources, causes, and constituents on tributaries and mainstem Pend Oreille River; determine and implement actions necessary to eliminate or mitigate effects.

  Proposed Strategy e: Continue monitoring the water quality of Lake Pend Oreille, Clark Fork River and Pend Oreille River to insure it meets State and Federal standards.

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

  Strategy a: Inventory and map locations of milfoil occurrence.

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

USDA Forest Service (USFS)

The Colville National Forest is located within the Pend Oreille River basin and as such, the USFS is a participating stakeholder in the relicensing of the Boundary Project. The Land and Resource Management Plan was developed by the USFS and completed in 1988 (USFS 1988). This plan identifies five management activities in the soil and water division including:

1. Coordinate with other resources to provide support and advice that helps protect the soil and water resource.
2. Monitor the effect of the Forest Plan activities on the soil and water resources.
3. Restore damaged soil and water resources.
4. Work with Washington State Department of Ecology or others as needed to secure water rights.
5. Coordinate with other agencies or interested parties.

Specific standards and guidelines related to aquatic macrophytes, pH, and DO include:

1. Maintain water quality parameters within the range of good fish habitat conditions, and within State water quality standards. Natural pH levels within the Colville National Forest are normally between 6.5 and 9.0. Any man-caused variation is not to exceed 0.2 units. Dissolved oxygen measurements should be more than 9.5 mg/L.

2. Complying with State requirements in accordance with the Clean Water Act for protection of waters of the State of Washington through planning, application, and monitoring of Best Management Practices in conformance with the Clean Water Act, regulations, and federal guidance issued thereto.
3. In watersheds where project scoping identifies an issue or concern regarding the cumulative effects of activities on water quality or stream channels, a cumulative effects assessment will be made. This will include land in all ownerships in the watershed. Activities on National Forest System lands in these watersheds should be dispersed in time and space to the extent practicable, and at least to the extent necessary to meet management requirements. On intermingled ownerships, coordinate scheduling efforts to the extent practicable.

US Fish and Wildlife Service (USFWS)

The US Fish and Wildlife Service is responsible for some federally listed species, including threatened bull trout (*Salvelinus confluentus*), migratory birds, and the habitats that support them. A short reach of Sullivan Creek, commencing at its confluence with the Pend Oreille River, has been designated as critical habitat for bull trout. The draft Bull Trout Recovery Plan identifies as a recovery objective, “restore and maintain suitable habitat conditions for all bull trout life history stages and strategies,” and identifies investigation and improvement of water quality as a specific action to address this objective.

2.3. Study Goals and Objectives

The goals of this study are 1) to assess whether macrophytes are contributing to high pH and low DO readings in Boundary Reservoir, and 2) to investigate potential indirect effects of Project operations on pH and DO via macrophytes. In order to achieve these goals, the following objectives have been defined:

- *Objective 1*: Document and determine the magnitude of the impact macrophyte respiration/photosynthesis and senescence have on pH and DO levels in Boundary Reservoir.
- *Objective 2*: Assess the effect of varying densities of macrophyte beds on changes in pH and DO in support of the fish habitat analysis.
- *Objective 3*: Assess the effect of Project operations, specifically inundation and frequency of dewatering, on changes in pH and DO in macrophyte beds. This objective is important because it addresses a potential Project nexus, whether reservoir operations influence the physiology of macrophytes and, hence, water chemistry.

2.4. Need for Study

Summary of Existing Information

Macrophyte growth has become an increasing problem in the Pend Oreille River. Eurasian watermilfoil, a non-native aquatic plant, has been proliferating in the shallow, low-velocity areas of the river (EPA 1993, Pelletier and Coots 1990). Recent observations indicate the presence of another exotic macrophyte, curly pondweed, in the Project vicinity as well (Colleen McShane, EDAW, personal communication, 2005).

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

Studies in the Pend Oreille River have found that aquatic macrophytes impact water quality. The Box Canyon Environmental Impact Statement (EIS) concluded that the highest pH levels observed were recorded in the summer as a result of considerable aquatic macrophyte growth (FERC 2004). The EIS also documents that pH measurements were found to be on average 0.4 units higher in macrophyte beds than in the main channel.

Spot measurement data collected in the lower Pend Oreille River during 1962 and 1963 (pre-Boundary Project) documented that pH measurements ranged from 7.6 to 8.2 (Pine et al. 1964). Ecology has collected pH measurements at Metaline since 1949 (Ecology 2005). Of the 149 readings taken at this site from 1949–1962 and 1994–2006, 9 (6 percent) exceeded the state water quality standard of 8.5 pH units. Seattle City Light (SCL) began collecting pH data in 2004 as part of its water quality monitoring program (Taylor Associates 2005). This program involved collection of pH profiles at six locations in Boundary Reservoir on five dates in 2004. The data show that pH exceeds water quality standards at many of the sites. In general, the exceedances are within one tenth of a pH unit of the standard. However, on some occasions pH was measured as high as 9.6 (for more detail on existing pH data, refer to section 4.4.5.3.9 of the PAD).

As part of the Colville National Forest TMDL, which was completed in April 2005, pH data were reviewed for streams in the Colville National Forest with at least 10 pH measurements collected since 1990 (Whiley et al. 2005). The majority of these streams are within the Pend Oreille watershed. In all, data were collected for 84 sites, including tributaries to Boundary Reservoir. Maximum pH levels observed at the monitoring locations varied between 8.0 and 9.0 with an overall median of 8.5. Of the 84 monitoring locations considered, 32 (38 percent) had maximum pH levels above 8.5, the Ecology pH standard. Forty-three (51 percent) of the measurements fell within a range of less than 1 pH unit. In general, data from these sites showed that pH levels across the forest are uniformly elevated, with relatively low variation in median values. In addition, the pH variation seen was evident among groupings of stations, indicating spatial influences (Whiley et al. 2005). Geologic features were compared with stream pH measurements, and streams with higher median pH values were usually found in areas with carbonate-based geology. As a result of these findings, the TMDL concluded that elevated pH levels and minor variation in pH within the forest were primarily a result of the regional geology and represent a natural condition. For this reason, the expected upper range in pH for forest streams was extended from 8.5 to 8.8 (Whiley et al. 2005).

DO measurements taken in Boundary Reservoir in 1998 (Herrera 1999) and 2004 (Taylor Associates 2005) show that DO concentrations ranged from 8.5 mg/L to 9.5 mg/L and that there was little vertical or longitudinal variation in DO concentrations (for more detail on existing DO data, refer to section 4.4.5.3.10 of the PAD). Historical DO data were collected by Ecology at Metaline Falls between 1959–1962 and 1993–2002 (Ecology 2005). Pre-Project data (1959–1962) ranged from 7.5 mg/L to 13.7 mg/L with an average concentration of 10.9 mg/L. Post-Project data (1993–2002) ranged from 7.8 mg/L to 14.8 mg/L with an average concentration of 10.8 mg/L.

Need for Additional Information

As explained above, the respiration and senescence of invasive macrophytes, such as Eurasian watermilfoil and curly pondweed, in Boundary Reservoir have the potential to affect water chemistry, pH and DO in particular. Excessive macrophyte growth can increase pH through the uptake of carbon dioxide during photosynthesis. High pH levels in Boundary Reservoir have been documented by Ecology and SCL. The cause of these high pH levels is not known. Studies in Box Canyon Reservoir showed elevated pH levels in macrophyte beds (FERC 2004). There are also data from the Project area that suggest background geologic conditions may be the cause of high pH. To understand the potential for Boundary Reservoir to affect pH/DO, additional data collection is needed.

The goal of this study is to collect water quality information that will be used to assess pH in Boundary Reservoir and the potential effect of macrophytes on pH in the reservoir. Although SCL has been collecting water quality data since 2004, no continuous monitoring of pH has been conducted, and only limited water quality data have been collected for comparing water quality in and around macrophyte beds. A pilot study was conducted in 2006 to preliminarily assess the relationship between macrophytes and pH; however, a more robust study as described below is needed for the purposes of the application for certification under Section 401 of the Federal Clean Water Act. The study outlined herein includes collection of pH data in and adjacent to macrophyte beds in Boundary Reservoir to assess the possible relationship between photosynthesis in macrophyte beds and pH in the reservoir, and to assess any potential impacts of the Project on this relationship.

2.5. Detailed Description of Study

Study Area

The study area encompasses Boundary Reservoir, including side channels off the main channel (Figure 2.5-1). (Refer to section 1.3 of the Proposed Study Plan [PSP; SCL 2006c] for a description of the Boundary Project location, facilities, and reservoir.) Eurasian watermilfoil and curly pondweed are found in shallow coves and bays of Boundary Reservoir, and dense mats of macrophytes have been found in side channels upstream of Peewee Creek near RM 19.5, upstream of Metaline Falls between RM 27 and RM 29, and between the gaging station and Metaline Falls at RM 31–33. A description of the distribution of macrophytes in Boundary Reservoir can be found in section 4.6 of the PAD (Botanical Resources) and corresponds to the area mapped as Lacustrine Aquatic Bed in the vegetation cover type map presented in Figure 4.6-1 of the PAD (SCL 2006a). This cover type includes shallow water areas, typically below elevation 1,980 feet NGVD 29 (1,984 feet NAVD 88), which are characterized by the presence of aquatic vegetation, primarily milfoil, coonwort (*Ceratophyllum demersum*), and elodea (*Elodea canadensis*) (SCL 2006a).

Proposed Methodology

Data collection to address the three objectives identified above will be based on a similar overall design, but data for each objective will be collected and analyzed separately. To address differences in reservoir morphology and habitat types, data will be collected within two reaches, upstream and downstream of Metaline Falls. Ideally, different macrophyte beds upstream and downstream of Metaline Falls will be used to meet each of the objectives; however, if appropriate based on site conditions, data collection for one or more objectives may occur in the same macrophyte bed.

Prior to any data collection, the first step in this study will be to conduct a site investigation to identify locations for sampling stations. Potential locations of monitoring stations are shown in Figure 2.5-1. For this task and the field efforts described below, Boundary Reservoir has been divided into two distinct reaches, upstream and downstream of Metaline Falls. These two reaches are distinguished by differences in river gradient, depth, habitat types, and geologic features. Multiple sampling stations will be located within each reach and multiple sampling sites will be located within each station to collect data necessary to address study objectives. The site investigation task will locate macrophyte beds in the two reaches for each of the comparisons described in the field sampling efforts below and in Objectives 1 through 3. All sampling sites in and around macrophyte beds will be established far enough from tributary inflows that pH and DO measurements reflect ambient reservoir conditions and not the water chemistry of a nearby tributary.

Additional study design details are described below, by objective, and are summarized in Table 2.5-1.

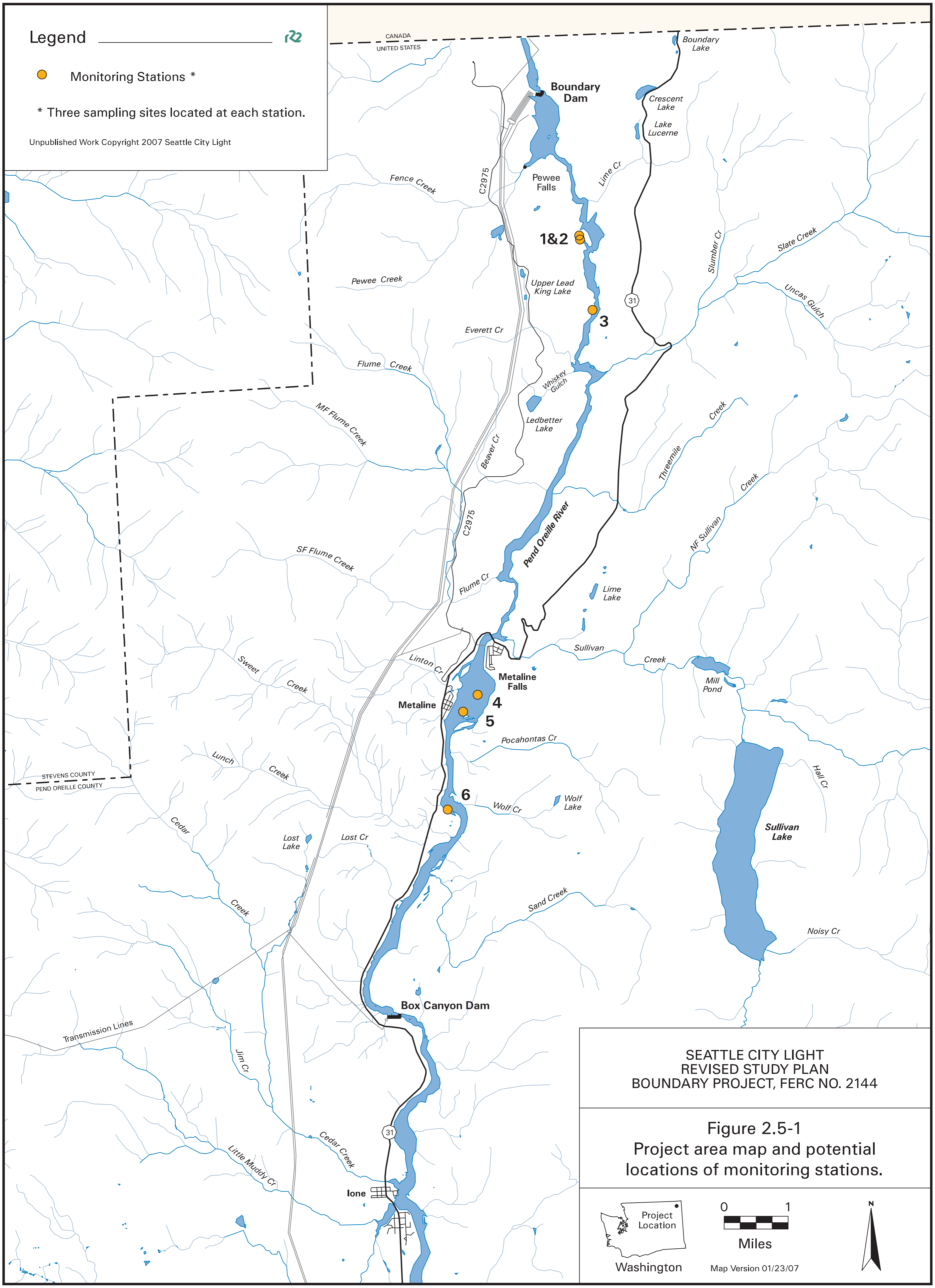

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Figure 2.5-1
Project area map and potential locations of monitoring stations.

Table 2.5-1. pH/DO and macrophyte sampling design.

Objective, Description	**Sampling Method**	**Number, location sampling stations**	**Number of sampling sites per station**	**Sampling Schedule**	**Sampling Duration, Interval**	**Figure/ Schematic**
1, Assess pH/DO within and apart from macrophyte beds.	Remote	1, upstream of Metaline Falls	9 (3 upstream, 3 within, and 3 downstream of the macrophyte bed)	May–November	Every 0.5 hr	NA
	Profile	6, 3 above Metaline Falls and 3 below Metaline Falls	9 (3 upstream, 3 within, and 3 downstream of the macrophyte bed)	Late spring, July, August, November	24 h, 4–6 h 72 h, 4–6 h 72 h, 4–6 h 24 h, 4–6 h	Figure 2.5-2
2, Assess pH/Do at different densities of macrophytes	Profile	6, 3 above Metaline Falls and 3 below Metaline Falls	9 (3 high, 3 medium, and 3 low density sites)	Late spring, July, August, November	24 h, 4–6 h 72 h, 4–6 h 72 h, 4–6 h 24 h, 4–6 h	Figure 2.5-3
3, Assess pH/DO at sites with variable lengths of exposure	Profile	6, 3 above Metaline Falls and 3 below Metaline Falls	6 (3 continuously inundated,4–6 hours exposure, and 3 8–12 hours exposure)	Late spring, July, August, November	24 h, 4–6 h 72 h, 4–6 h 72 h, 4–6 h 24 h, 4–6 h	Figure 2.5-4

Objective 1

Description of Objective: Document and determine the magnitude of the impact macrophyte respiration/photosynthesis and senescence have on pH and DO levels in Boundary Reservoir.

Approach: Collect and analyze pH, DO, conductivity, cloud cover, and temperature data within and apart from macrophyte beds. Two different methods will be used to collect and analyze water chemistry data within and apart from macrophyte beds. The first method employs the use of remote monitors. To obtain detailed long-term hourly information, remote water quality monitors will be deployed in the reach upstream of Metaline Falls as follows: one monitor will be located within a dense macrophyte bed, one monitor will be located in the open channel of the reservoir, slightly upstream and out of the localized effect of the macrophyte bed, and one unit will be located in the open channel of the reservoir, slightly downstream and out of the localized effect of the macrophyte bed. The monitors will be installed prior to significant macrophyte growth and will not be removed until after substantial senescence of the macrophyte bed has occurred.

The second method requires the collection of multiple sets of water chemistry profile data. Multiple vertical profile measurements will be taken within and outside macrophyte beds in both reservoir reaches. Each reach will contain nine sites; three within the macrophyte bed, three upstream of the macrophyte bed, and three downstream of the macrophyte bed. The upstream, downstream, and within-bed sites will be located in areas of similar characteristics except for the growth of macrophytes. In order to achieve this similarity, an attempt will be made to locate the upstream and downstream sites on bedrock or gravel surfaces. Sites within macrophyte beds will be located in areas of high density macrophyte growth. All sampling sites for remote water quality monitors and vertical profiles will be established far enough from tributary inflows that pH and DO measurements made in and around the macrophyte beds reflect ambient reservoir conditions and not the water chemistry of a nearby tributary.

Vertical profile measurements will be taken during four periods: one in late spring, two during peak macrophyte growth, and one in the fall. The first field sampling event will be conducted in May or early June, depending on flow conditions, before substantial macrophyte growth. During this period, vertical profile information will be collected over a 24-hour period. More intensive field sampling efforts will be conducted in July and August, when vertical profile data will be collected over a 72-hour period. During November, vertical profile data collection will again occur over a 24-hour period. For each sampling event, vertical profiles will be collected approximately every four to six hours, or with sufficient frequency to capture diurnal fluctuations in pH and DO. A schematic outlining sampling for the region upstream of Metaline Falls (Station #6) is shown in Figure 2.5-2. This figure illustrates example vertical profile sites for within, upstream, and downstream of the macrophyte beds (actual sampling in this reach will occur at nine sites, as specified above). Note that specific locations of sites are dependent on actual macrophyte bed locations and other environmental considerations. If possible, triplicates will be located in different macrophyte beds, with measures taken to ensure that the upstream and downstream sites are not influenced by other nearby macrophyte beds. However, given the limited knowledge of the specific locations and suitability of macrophyte beds, using separate beds for triplicates may not be feasible. Thus, sites can be located within the same bed; however, measures should be taken to place the sites sufficiently far apart to avoid pseudo-replication.

Figure 2.5-2. Schematic Plan view of Station #6 (presence comparison station upstream of Metaline Falls) and example location of profile sites used to address Objective 1.

The pH and DO data will be compared to determine whether pH and DO are similar among sites located inside and outside of macrophyte beds. The analysis will also attempt to quantify the magnitude of this effect. The hypotheses to be evaluated and the corresponding statistical tests that will be conducted include the following:

a. To identify whether or not the presence of macrophytes influences pH or DO, both the remote and vertical profile data will need to be reviewed and compared. The hypotheses that macrophyte growth has no impact on pH and DO and that measured maximum or minimum values are the same between the locations will be tested. To test these hypotheses, a time series model will be developed to compare the within-bed, upstream, and downstream remote data. From this test, an estimate of the magnitude of the effect of macrophytes on pH can be quantified by comparing peak and average difference between the sites. For the profile spot measurement data, a multifactor Analysis of Variance (ANOVA) will be used to compare peak, minimum, and average values by time of day, site, and depth.

b. To investigate how the presence of macrophytes influences pH and DO over the sampling season and when the largest impact occurs, the remote data will be compared on a weekly basis. The hypothesis for this test is that measured pH and DO values are the same between locations regardless of the week. Analysis will include a nested ANOVA with time (or week) and location as the factors.

Tasks:

1. Conduct a site investigation survey to locate monitoring stations.
2. Install three remote water quality monitors at one station upstream of Metaline Falls as described above to measure pH, DO and temperature in half-hour increments.
3. Collect vertical profile measurements of pH, DO, conductivity, and temperature, within and apart from macrophyte beds in the two reaches of Boundary Reservoir (upstream and downstream of Metaline Falls).
4. Analyze and compare data collected within and outside the immediate influence of macrophyte beds to assess if they exhibit an influence on water chemistry in Boundary Reservoir.

Objective 2

Description of Objective: Assess the effect of varying densities of macrophyte beds on changes in pH and DO.

Approach: Collect and analyze water quality data (pH, DO, conductivity, and temperature) at sites with predetermined various degrees of macrophyte density. Multiple vertical profile measurements and macrophyte abundance information in areas of different densities will be collected within two reaches of Boundary Reservoir (above and below Metaline Falls). Nine sites will be located within each reservoir reach, with three each in areas of low, medium, and high macrophyte abundance. The field sampling effort will be identical to that described for Objective 1, with samples collected in May/June, July, August, and November. A schematic cross section showing vertical profile sampling sites at low, medium, and high macrophyte densities at the station upstream of Metaline Falls (Station #4) is shown in Figure 2.5-3 (This figure only shows three sites, not the total of nine specified for this reach.). Specific locations of sites will be dependent on actual macrophyte bed locations and other environmental considerations. If possible, density triplicates will be located in different macrophyte beds. However, given the limited knowledge of the specific locations and suitability of macrophyte beds, this placement may not be feasible. Thus, triplicates may have to be located within the same bed. If they are located within the same macrophyte bed, measures should be taken to place the sites sufficiently far apart to avoid pseudo-replication. All sampling sites will be established far enough from tributary inflows that pH and DO measurements made in and around the macrophyte beds reflect ambient reservoir conditions and not the water chemistry of a nearby tributary.

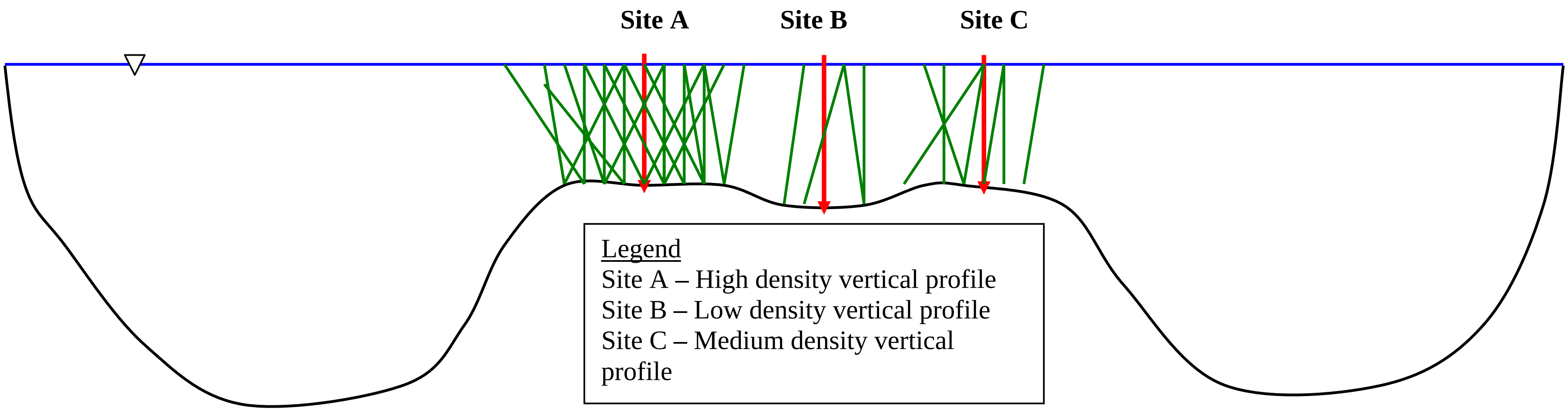

Figure 2.5-3. Schematic cross section of Station #4 density comparison station upstream of Metaline Falls.

Data from low, medium, and high macrophyte density sites will be compared to evaluate how macrophyte abundance influences the changes in pH or DO. Data analysis will specifically identify whether macrophyte density influences either the range or extreme pH or DO measurements. Hypotheses include a) extreme pH or DO values are the same between areas of differing macrophyte density, and b) the daily range in pH and DO is the same between areas of differing macrophyte density. To test these hypotheses, a nested ANOVA will be used to evaluate differences by depth, density, and season.

Tasks:

1. Conduct a site investigation survey to locate monitoring stations.
2. Collect vertical profile measurements of pH, DO, conductivity, and temperature in areas of low, medium, and high macrophyte density within the two reservoir reaches, upstream and downstream of Metaline Falls.
3. Estimate macrophyte abundance at all sites. Macrophyte density will be quantified using an aquatic rake or similar sampling technique. In addition, water depth, macrophyte depth, water velocity, and substrate information will be recorded.
4. Analyze and compare data collected at low, medium, and high macrophyte density to assess the impact of macrophyte density on water quality.

Objective 3

Description of Objective: Assess the effect of Project operations, specifically inundation and frequency of dewatering, on changes in pH and DO in macrophyte beds.

Approach: Collect and analyze water quality data (pH, DO, conductivity, and temperature) at different sites with various levels of inundation or dewatering. Multiple vertical profile measurements in areas with varying degrees of dewatering will be collected within the two reservoir reaches, i.e., above and below Metaline Falls. Each reach will contain nine sites, three in macrophyte beds in continuously inundated areas, three in macrophyte beds that are exposed to air for moderate periods (approximately 4–6 hr per day), and three in macrophyte beds that are exposed to air for long periods (approximately 8–12 hours per day). The exact length of exposure will be determined using bathymetric information, typical hourly fluctuations in water surface elevations, and information gathered during the site investigation step.

Field sampling will be identical to that described for Objectives 1 and 2, with samples collected in May/June, July, August, and November. Similar to Objective 2, macrophyte abundance data will be collected at the sampling sites for Objective 3 as a gross indicator of macrophyte growth. A schematic illustrating the sampling strategy for the inundation comparison for the reach upstream of Metaline Falls (Station #5) is shown in Figure 2.5-4. This figure shows an example of vertical profile sites in an area continuously inundated, exposed 4–6 hours per day, and exposed 8–12 hours per day. (This figure only shows three sites, not the total nine specified for this reach.) Note that specific locations of sites are dependent on actual macrophyte bed locations and other environmental considerations. Once again, if feasible, triplicates will be located in different macrophyte beds. However if this is not feasible, sites can be located within the same bed if measures are taken to avoid pseudo-replication. All sampling sites will be established far enough from tributary inflows that pH and DO measurements made in and around the macrophyte beds reflect ambient reservoir conditions and not the water chemistry of a nearby tributary.

The pH/DO data will be compared among macrophyte beds with different lengths of exposure to assess whether the length of inundation influences macrophyte growth and the potential corresponding impact on pH or DO. Hypotheses to answer this question include a) extreme (maximum pH, minimum DO) values are the same in areas with varying levels of dewatering, and b) the daily range in pH and DO is the same in areas with varying levels of dewatering. To test these hypotheses, a nested ANOVA will be used, which includes depth, relative time of exposure, and day as separate factors.

Tasks:

1. Conduct a site investigation survey to locate monitoring stations.
2. Collect vertical profile measurements of pH, DO, conductivity, and temperature in areas that are continuously inundated, exposed 4–6 hours per day, and exposed 8–12 hours per day within the two reaches of Boundary Reservoir, upstream and downstream of Metaline Falls.
3. Estimate macrophyte abundance at all sites. Macrophyte density will be quantified using an aquatic rake or similar sampling technique. In addition, water depth, macrophyte depth, water velocity, and substrate information will be recorded.
4. Analyze and compare data collected from continuously inundated and variable lengths of exposure to assess the effects of daily reservoir fluctuations on macrophyte respiration and senescence and corresponding water chemistry.

For the field efforts described above, macrophyte growth is assumed to be seasonal between May through November, with peak growth occurring in July and August and senescence occurring in October and November. For planning purposes, data collection will occur between May through November. Data collection methods will follow established Ecology and EPA guidelines. Prior to the data analyses required to meet each of the three objectives, review, verification, and validation of the data collected is required. Specific procedures for data verification and validation will be outlined in the QAPP. Data analysis will also be used to help determine whether additional field efforts will be needed in 2008.

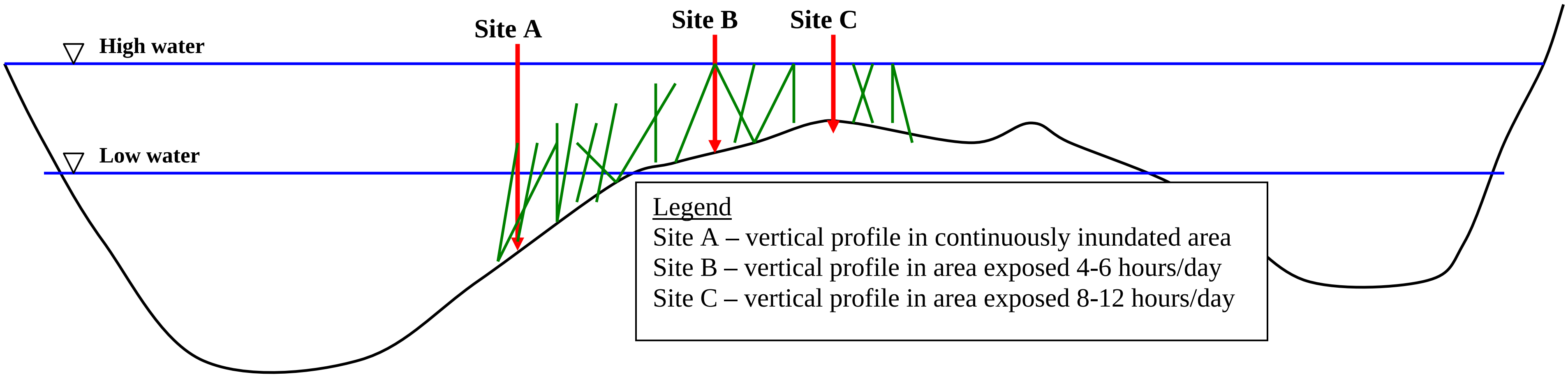

Figure 2.5-4. Schematic cross section of Station #5 inundation comparison station upstream of Metaline Falls.

2.6. Work Products

Four official work products are required for completion of the study of relationship of pH and DO to macrophytes in Boundary Reservoir:

- *Quality Assurance Project Plan* — The first work product is a Quality Assurance Project Plan (QAPP). The QAPP must address elements specified by Ecology guidelines including the following items:
    1. Title Page with Approvals
    2. Table of Contents with Distribution List
    3. Background
    4. Project Description
    5. Organization and schedule
    6. Quality Objectives
    7. Sampling Process Design
    8. Sampling Procedures
    9. Measurement Procedures
    10. Quality Control
    11. Data Management Procedures
    12. Audits and Reports
    13. Data Verification and Validation
    14. Data Quality Assessment
- *Draft study report* — A draft study report will contain monitoring methods, any deviations from the QAPP, a brief summary of the 2007 data collected, and a discussion of recommendations for additional monitoring, if needed.
- *Final study report* — A final study report will describe the monitoring methods, results of the 2007 monitoring and analysis, and conclusions of the study.
- *Summary* — In addition to the final report, the data collected and a short summary will be compiled for the Aquatic Macrophytes Study being conducted under the Fish and Aquatic resources study program. The summary will include macrophyte abundance, substrate, depth, velocity and corresponding water chemistry collected at different macrophyte densities and varying degrees of inundation. Data will be submitted in an electronic format so the information can be easily incorporated into the macrophyte assessment.

2.7. Consistency with Generally Accepted Scientific Practice

The methods described herein have been developed in consultation with relicensing participants. The study approach and methods are consistent with Ecology's Water Quality Certification for Existing Hydropower Dams: Preliminary Guidance Manual (September 2004). The QAPP will be consistent with State and federal guidelines including EPA's Quality System for Environmental Data and Technology and Ecology's Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies.

2.8. Consultation with Agencies, Tribes, and Other Stakeholders

As indicated above, SCL met with Ecology in 2005 to identify issues to be addressed as part of the 401 certification process. Input regarding water quality sampling was also provided by relicensing participants during workshops and workgroup meetings. Workshops were held in Spokane, Washington, on November 30, 2005, and February 16, 2006. Workgroup meetings were held in Spokane on May 22, 2006, and in Metaline Falls on June 29, 2006. During the May 22 workgroup meeting, an outline for this study plan was presented and relicensing participants provided comments. The proposed study plan was revised from the study outline based on comments received from relicensing participants at the May 22 workgroup meeting. During the June workgroup meeting, the draft study plan was presented and comments from relicensing participants were provided. Relicensing participants attending these meetings included Ecology, the U.S. Geological Survey (USGS), Confederated Tribes of the Colville Reservation, Kalispel Tribe of Indians, Canadian Columbia River Intertribal Fisheries Commission, BC Hydro, Pend Oreille County Public Utility District, Columbia Power Corporation, Environment Canada, Ponderay Newsprint, and Teck Cominco. Comments provided by relicensing participants on the draft study plan are summarized in the PSP Attachment 3-5 (SCL 2006c) and can also be found in workgroup meeting summaries, available on SCL's relicensing website at (http://www.seattle.gov/light/news/issues/bndryRelic/). The proposed study plan was included in the PSP that was filed with FERC on October 16, 2006.

Since filing the PSP, SCL has continued to work with relicensing participants on its proposed study plans. Relicensing participants provided no comments on the Relationship of pH and DO to Macrophytes in Boundary Reservoir study plan at the November 15 study plan meeting, and PSP comments filed with FERC by the USFS (2007) stated that "The Forest Service agrees with SCL's proposed study of the relationship between pH and DO and macrophytes. The agency [USFS] appreciates SCL's collaborative effort to provide a consensus based study proposal." No other PSP comments were filed with FERC regarding this study. (Comments are summarized in Attachment 3 and consultation documentation included in Attachment 4 of this RSP.) As a result, SCL has not revised this study plan from what was contained in the PSP, except for a statement of USFWS resource management goals added to Section 2.2.

2.9. Schedule

The schedule for this study is provided in Table 2.9-1.

Table 2.9-1. Proposed study schedule, Evaluation of the Relationship of pH and DO to Macrophytes in Boundary Reservoir.

Phase	Target Date
QAPP	March 31, 2007
Field Collection	May–November 2007
Prepare draft study report with recommendations for any additional 2008 sampling	November–December 2007
Distribute draft study report for relicensing participant review	January 2008
Meet with relicensing participants to review efforts and results	February 2008
Include final study report in Initial Study Report (ISR) filed with FERC	March 2008
Hold ISR meeting and file meeting summary with FERC	March 2008

2.10. Progress Reports, Information Sharing, and Technical Review

Both the draft and final study reports will be available to relicensing participants. Prior to release of the Initial Study Report (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. The final report will contain an appendix of the raw water quality data, which will also be available in digital format.

2.11. Anticipated Level of Effort and Cost

Based on a review of the study needs, the anticipated cost for this study totals $200,000. Approximately $160,000 will be required in 2007 for monitoring, the status report, and analysis, and an additional $40,000 will be required in 2008 for additional analyses and report preparation. This estimated cost assumes three remote monitoring units will be purchased for use during the project and that field costs can be minimized by conducting data collection in conjunction with the Water Quality Constituent and Productivity Monitoring Study (Study No. 5).

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