Boundary Hydroelectric Project (FERC No. 2144)

Study No. 5
Water Quality Constituent and Productivity Monitoring
Interim Report

Prepared for
Seattle City Light

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1 INTRODUCTION

Study No. 5, Water Quality Constituent and Productivity Monitoring, is being conducted in support of the relicensing of the Boundary Hydroelectric Project (Project), Federal Energy Regulatory Commission (FERC) No. 2144, as identified in the Revised Study Plan (RSP; SCL 2007) submitted by Seattle City Light (SCL) on February 14, 2007, and approved by the FERC in its Study Plan Determination letter dated March 15, 2007. This is the interim report for the 2007 study efforts of the Water Quality Constituent and Productivity Monitoring.

1.1. Study Background

As part of the FERC relicensing requirements, SCL must apply for certification under Section 401 of the Clean Water Act. The application for Section 401 certification requires characterization of existing water quality conditions in the Boundary Reservoir and an assessment of whether water quality meets Washington Department of Ecology (Ecology) regulatory standards. Potential water quality concerns in Boundary Reservoir and immediately downstream of the Project dam appear to be limited to pH, total dissolved gas (TDG), water temperature, and toxics.

Project operations have the potential to impact water quality in the Pend Oreille River within the Boundary Reservoir area. In support of Section 401 certification and FERC relicensing, potential impacts must be evaluated. Although some historical information exists, additional and ongoing data collection and analysis on specific water quality constituents is needed to evaluate potential Project operational effects. In addition, data on the productivity of the reservoir are needed to support evaluations of potential Project operational effects on aquatic habitat and fauna. Project studies are specifically designed to meet FERC relicensing and Ecology certification requirements.

Although SCL has been collecting water quality data since 2004, nutrient (nitrogen and phosphorus) data have been collected only in 2006 and only limited chlorophyll *a* (measure of phytoplankton) and zooplankton data have been collected; these parameters will be addressed as part of this study. Water quality parameters, including pH, dissolved oxygen (DO), nutrients, and phytoplankton/zooplankton abundance, are important factors determining the quality of fish habitat and food supply. In addition, water quality data are needed to assess Project effects on primary and secondary production in the reservoir.

Separate studies are being conducted to address concerns on the potential impact of Project operations on toxics in the reservoir (Study 4, Toxic Assessment: Evaluation of Contaminant

Pathways) and TDG levels immediately downstream of the Project dam (Study 3, Evaluation of Total Dissolved Gas and Potential Abatement Measures).

1.2. Study Description

Water quality monitoring for this study consists of two components: water quality and productivity data collection, and seasonal zooplankton drift data collection. Water quality constituent monitoring consists of data collection at eight sampling sites during 8 months of a 1-year period. Monthly samples (grab and in situ samples) were collected from May through September 2007, in November 2007, and in January and March 2008. Results contained in this report are preliminary and include data collected through August 2007. Water quality monitoring included the following variables: temperature, pH, DO, conductivity, Secchi depth, chlorophyll *a*, nutrients, zooplankton, hardness, and turbidity.

The second component of the study includes collection of seasonal zooplankton drift data below Box Canyon and Boundary dams within their respective tailraces to quantify the movement of zooplankton into and out of Boundary Reservoir. Downstream of Boundary Dam, samples were collected before, during, and after Project startup to quantify the impact of Project operations on zooplankton movement. Zooplankton samples were collected at similar times downstream of Box Canyon Dam. Spring zooplankton drift sampling was conducted in June 2007, summer sampling in August 2007, and winter sampling in January 2008.

2 STUDY OBJECTIVES

The goal of this water quality study is to evaluate existing water quality conditions in and immediately downstream of Boundary Reservoir in support of the application for Section 401 certification and Fish and Aquatics Resource studies. This goal will be accomplished by addressing two objectives. The first is to characterize water quality conditions in and immediately downstream of Boundary Reservoir to determine whether the Project meets Ecology’s water quality standards in support of the Section 401 application. The second is to collect water quality, nutrient, primary production, and zooplankton data in support of the assessment of reservoir productivity being conducted as part of the Fish and Aquatic Resources studies. To meet this second objective, samples were collected in both the pelagic (mid-river channel) and littoral zones of the reservoir.

3 STUDY AREA

Water quality monitoring was conducted at eight sampling locations in Boundary Reservoir and in Boundary Dam tailrace (Table 3.0-1). A site map with sampling locations is provided in Figure 3.0-1. The sampling sites for this study were chosen to be consistent with those used in the 2004, 2005, and 2006 SCL water quality monitoring studies. During those studies, water quality was monitored at six sites (V1-V6) within the reservoir that characterized the longitudinal profile of water quality constituents in Boundary Reservoir and represented important sites for assessing water temperatures in the reservoir. Two additional sites (V7, V8) were added to represent water quality just downstream of Box Canyon Dam and just downstream of Boundary Dam for this water quality study. At these two additional sites, a 24-hour zooplankton drift study was conducted seasonally in summer, winter, and spring.

Table 3.0-1. Water quality monitoring sampling locations.

Sample Site	Project River Mile	Location Description
Box Canyon Tailrace (V7)	34.3	In Boundary Reservoir just downstream of Box Canyon Dam
Wolf Creek (V1)	30.4	Adjacent to Wolf Creek inlet (upstream of Metaline Falls)
Metaline Old (V2)	28.1	Old channel of the Pend Oreille River across from the city of Metaline (upstream of Metaline Falls)
Pend Oreille Mine (V3)	25.4	Downstream of Pend Oreille Mine (downstream of Metaline Falls)
Slate Creek (V4)	22.2	Downstream of Slate Creek across from campsite on left bank (downstream of Metaline Falls)
Everett Creek Island (V5)	20.4	Upstream of Everett Creek Island (downstream of Metaline Falls)
Boundary Reservoir Forebay (V6)	17.6	Boundary Forebay
Boundary Tailrace (V8)	16.7	Downstream of Boundary Dam

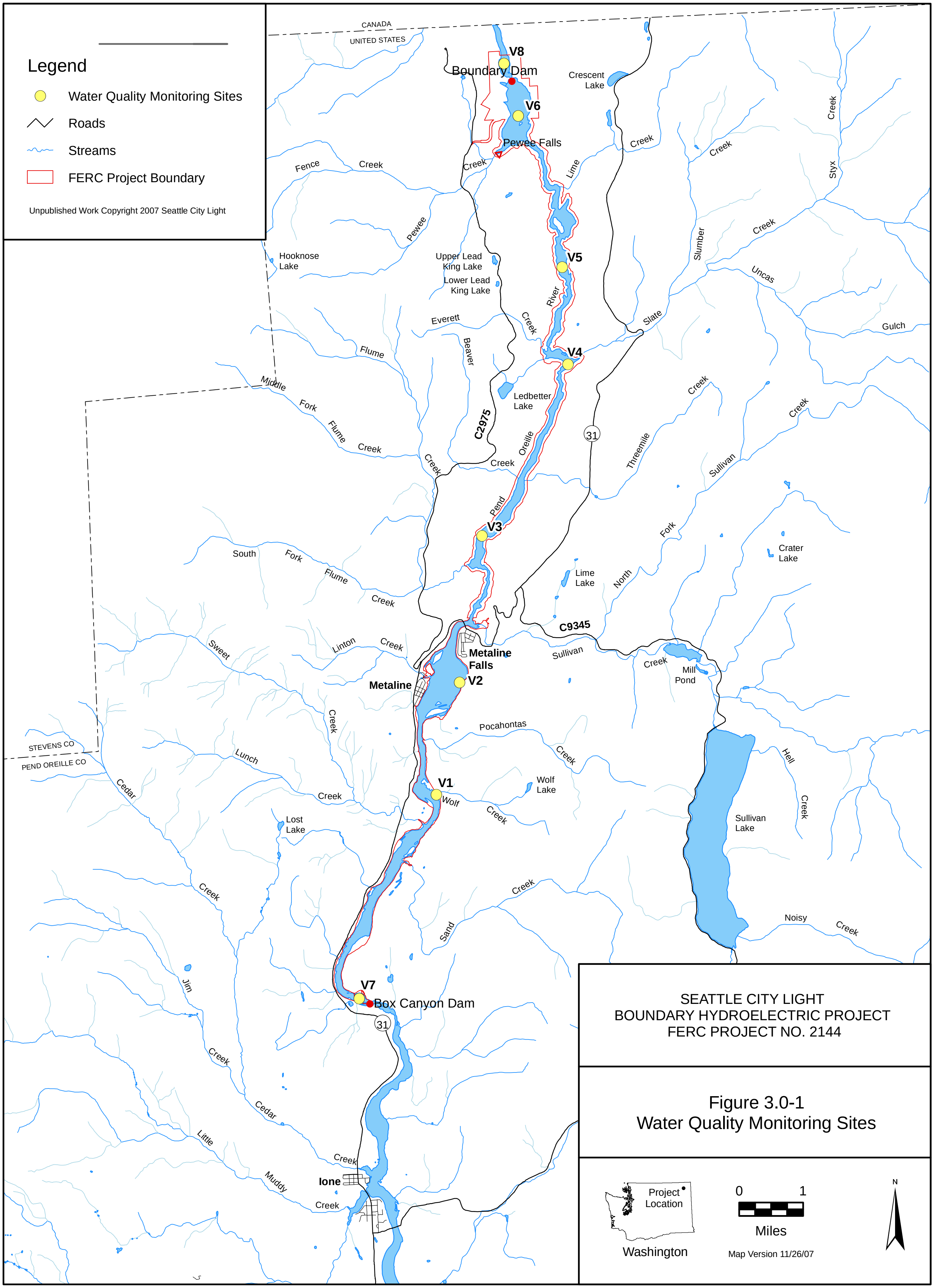

Figure 3.0-1
Water Quality Monitoring Sites

4 METHODS

As noted earlier, water quality monitoring for this study consists of two components: 1 year of water quality and productivity data collection, and seasonal zooplankton drift data collection. Water quality monitoring consists of data collection at eight sampling sites during eight months of a 1-year period. Monthly samples (grab samples and in situ data collection) were collected from May through September 2007, in November 2007, and in January and March 2008. Water quality monitoring included field measurement of temperature, pH, DO, conductivity, turbidity, and Secchi disk transparency; in addition, grab samples for chlorophyll *a*, nitrogen and phosphorus, zooplankton, and hardness were taken for laboratory analysis.

Water quality monitoring included three primary sampling strategies: 1) in situ water quality data collection, 2) point- or interval-specific grab samples requiring lab analysis, and 3) vertical tow integrated samples requiring lab analysis. (The term "tow" refers to a process of raising a zooplankton collection net vertically through the water column and at a given rate of ascent [feet/time]). Table 4.0-1 is a summary of the water quality monitoring parameters of interest, sampling methods, depth position, equipment, sensor or measurement range, and measurement and reporting accuracy. Table 4.0-2 is a summary of sampling locations and identification of parameters sampled. The samples were collected during the schedule period identified in Table 4.0-3. The sampling locations are a series of six maps shown in Figure 4.0-1.

Field sampling and measurement protocols follow established Ecology and U.S. Environmental Protection Agency (EPA) guidelines. All laboratory analyses were conducted by an Ecology- and EPA-accredited laboratory. Zooplankton and turbidity measurements were collected at a subset of the proposed sampling sites (zooplankton at sites V1, V4, V5, V6, V7, and V8; turbidity at sites V1, V3, V6, and V8).

Zooplankton data were collected in both the pelagic and littoral regions of the reservoir for use in the productivity analysis being conducted as part of Fish and Aquatic Resources studies. In the pelagic region, two water column vertical tows occurred from approximately 1 meter above the bottom to the reservoir's water surface using Wisconsin-style plankton net and bucket attached to a weighted cable. For the littoral region, the water column within the euphotic zone was sampled following standard methods for shallow areas, with and without vegetation. Zooplankton samples were collected within the water column and not on macrophytes themselves. Seasonal zooplankton drift samples were collected using a mechanical pump system and Tygon tubing to draw samples from a specific water column depth. Samples were collected for 20 minutes and filtered though an 80-micrometer (μm) mesh net.

Additional details regarding sampling design and methods can be found in the Study 5 Quality Assurance Project Plan (QAPP) included in Appendix 1.

Table 4.0-1. Water quality monitoring parameters.

Parameter	Units	Sampling Method	Sampling Depth Position	Measurement Equipment	Sensor or Measurement Range	Measurement and Reporting Accuracy
Temperature (Temp)	Degrees Celsius (°C)	Vertical profile of entire water column	10 measurements (minimum) at evenly spaced intervals	Hydrolab MS5	-5.0°C to 50.0°C	±0.1 °C
PH	Negative logarithm of the hydrogen ion concentration	Vertical profile of entire water column	10 measurements (minimum) at evenly spaced intervals	Hydrolab MS5	0.0 to 14.0 pH units	±0.2 units
Dissolved oxygen (DO)[1]	Milligrams per liter (mg/L)	Vertical profile of entire water column	10 measurements (minimum) at evenly spaced intervals (5-m intervals)	Hydrolab MS5	0.0 to 20.0 mg/l	±0.1 mg/L @ <8mg/L ±0.2 mg/L @ >8mg/L
Conductivity (Cond)	Micro Siemens per centimeter (mS/cm)	Vertical profile of entire water column	10 measurements (minimum) at evenly spaced intervals	Hydrolab MS5	0.0 to 100.0 mg/l	±0.001mS/cm
Secchi disk transparency (Secchi)	Meters (m)	Single measurement at maximum visual depth	Hand line w/ demarcation and Secchi disk	Hand line w/ demarcation and Secchi disk	n/a	±0.1m
Turbidity (Turb)	Nephelometric turbidity units (NTUs)	Grab sample	(1) surface pelagic (1) surface littoral	Field turbidimeter	0.0 to 1,000.0 NTU	± 1 NTU
Chlorophyll *a* (Chl *a*)	Micrograms per liter (µg/L)	Grab sample	(1) surface pelagic (Surf-Pel) (1) 15-ft pelagic (15-ft-Pel) (4.5 m) (1) surface littoral at zooplankton sites (Surf-Litt)	Pump system sampler	N/A	±0.0001 mg/L
Nutrients (TKN, TP, SRP)	Kjeldahl nitrogen (TKN-N in mg/l), Total Phosphorus (TP in µg/L), Orthophosphorus (SRP in µg/l)	Grab sample	(1) surface pelagic	Pump system sampler	N/A	± 0.010 mg/L
Hardness (Hard)	Parts per million (PPM)	Grab sample	(1) 1 meter above bottom pelagic (Bot-Pel)	Pump system sampler	N/A	± 3.0 as $CaCO_3$

Table 4.0-1 continued….

Parameter	Units	Sampling Method	Sampling Depth Position	Measurement Equipment	Sensor or Measurement Range	Measurement and Reporting Accuracy
Zooplankton (Zoo)	N/A	Vertical tows (Tow) of full profile starting 1 meter above bottom 80 micron net	4 tows total per section: (2) tows in littoral (Litt) region and (2) tows in pelagic (Pel) region, (2) mid-channel tows only at tailrace locations (Mid)	Pump system sampler	N/A	1 organism/L
Zooplankton (Zoo)	N/A	Drift (Drift) sample, (1) sample for 20-minute period, every 2 hours, over 24-hour period	Sample taken at 1 to 2 m depth	Pump system sampler	N/A	1 organism/L

Notes:
1 Sensor uses a trademark Hach LDO.
N/A – not applicable

Table 4.0-2. Water quality sampling locations.

		In Situ WQ Data Collection					WQ Grab Samples for Lab Analysis									Zooplankton Samples for Lab Analysis			
							Chl *a* (µg/L)			Nutrients			Hard (PPM)	Turbidity (NTUs)		Tows			Drift
Site ID	**Site Name**	**Temp (°C)**	**pH**	**D.O. (mg/L)**	**Cond (mS/cm)**	**Secchi (m)**	**Surf-Litt (Mid)**	**15ft-Pel (4.5m)**	**Surf-Pel**	**TKN (mg/L)**	**TP (µg/L)**	**SRP (µg/L)**	**Bot-Pel**	**Surf-Litt**	**Surf-Pel**	**Litt**	**Pel**	**Mid**	**Mid**
V7	Box Canyon Tailrace	•	•	•	•	•	■			•	•	•	•					•	▲
V1	Wolf Creek	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		
V2	Metaline Old	•	•	•	•	•	•	•	•	•	•	•	•						
V3	Pend Oreille Mine	•	•	•	•	•	•	•	•	•	•	•	•	•	•				
V4	Slate Creek	•	•	•	•	•	•	•	•	•	•	•	•			•	•		
V5	Everett Creek Island	•	•	•	•	•	•	•	•	•	•	•	•						
V6	Boundary Reservoir Forebay	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		
V8	Boundary Tailrace	•	•	•	•	•	■			•	•	•	•	•	•			•	▲

Notes:
■Tailraces Chl *a* data collected at surface, mid-channel location.
▲ Indicates sampling set for 20 minutes every 2 hrs for 24 hr period at mid-channel (pelagic) station.
°C – degrees Celsius
m – meter
mg/L – milligram per liter
mS/cm – microsiemen per centimeter
µg/L – microgram per liter
NTU – nephelometric turbidity unit
PPM – part per million

Table 4.0-3. Water quality monitoring schedule.

WQ Sampling and Zooplankton Tow Sites	2007								2008		
	May	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**
Box Canyon Tailrace (V7)	●	●	●	●	●		●		●		●
Wolf Creek (V1)	●	●	●	●	●		●		●		●
Slate Creek (V4)	●	●	●	●	●		●		●		●
Everett Creek Island (V5)	●	●	●	●	●		●		●		●
Boundary Forebay (V6)	●	●	●	●	●		●		●		●
Boundary Tailrace (V8)	●	●	●	●	●		●		●		●
Zooplankton Drift Sites (24-hr)											
Box Canyon Tailrace (V7)		▲		▲					▲		
Boundary Tailrace (V8)		▲		▲					▲		

Note:
▲ Indicates sampling set for 20 minutes every 2 hrs for 24-hr period at mid-channel (pelagic) site.

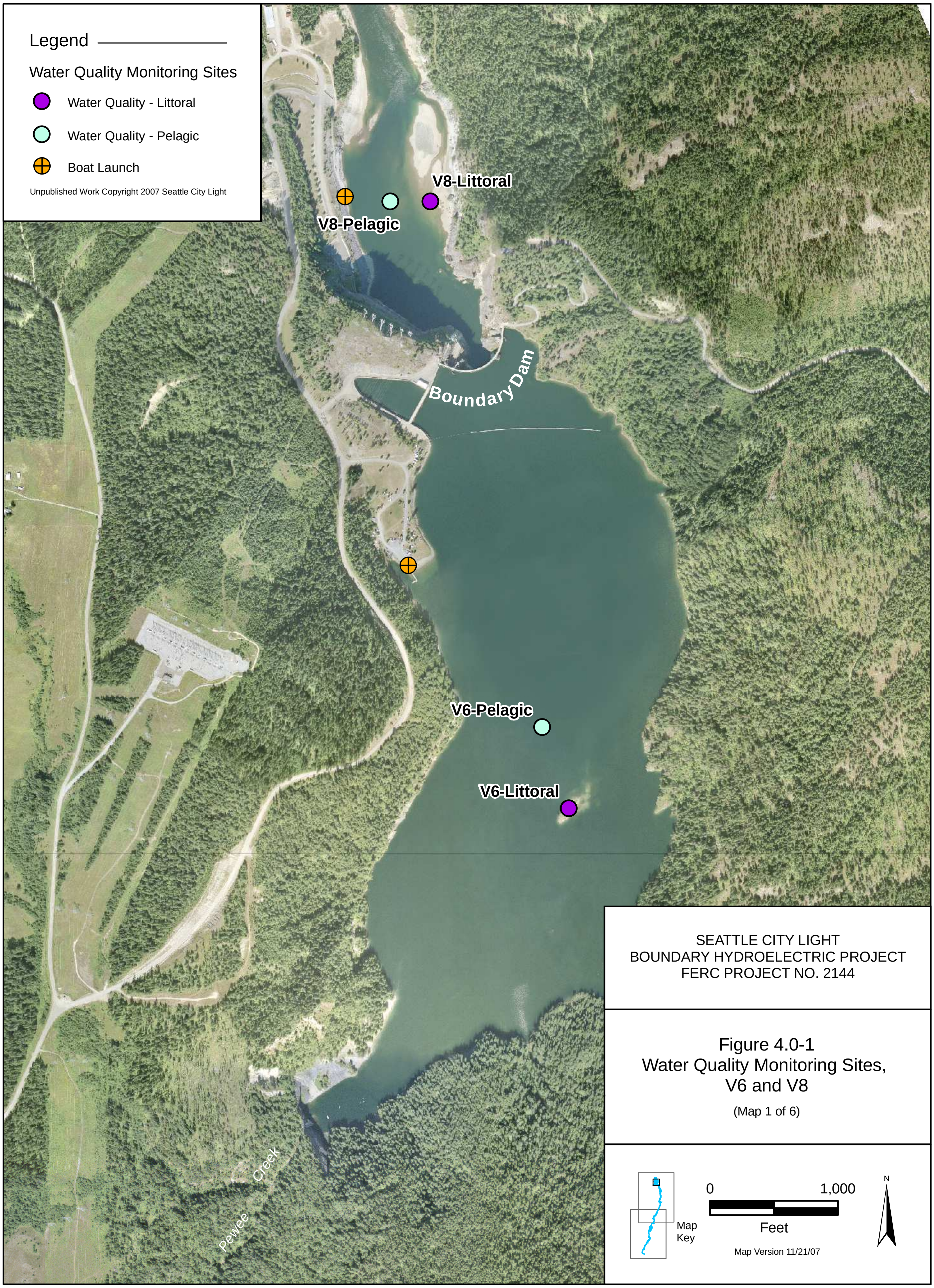

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Figure 4.0-1
Water Quality Monitoring Sites, V6 and V8
(Map 1 of 6)

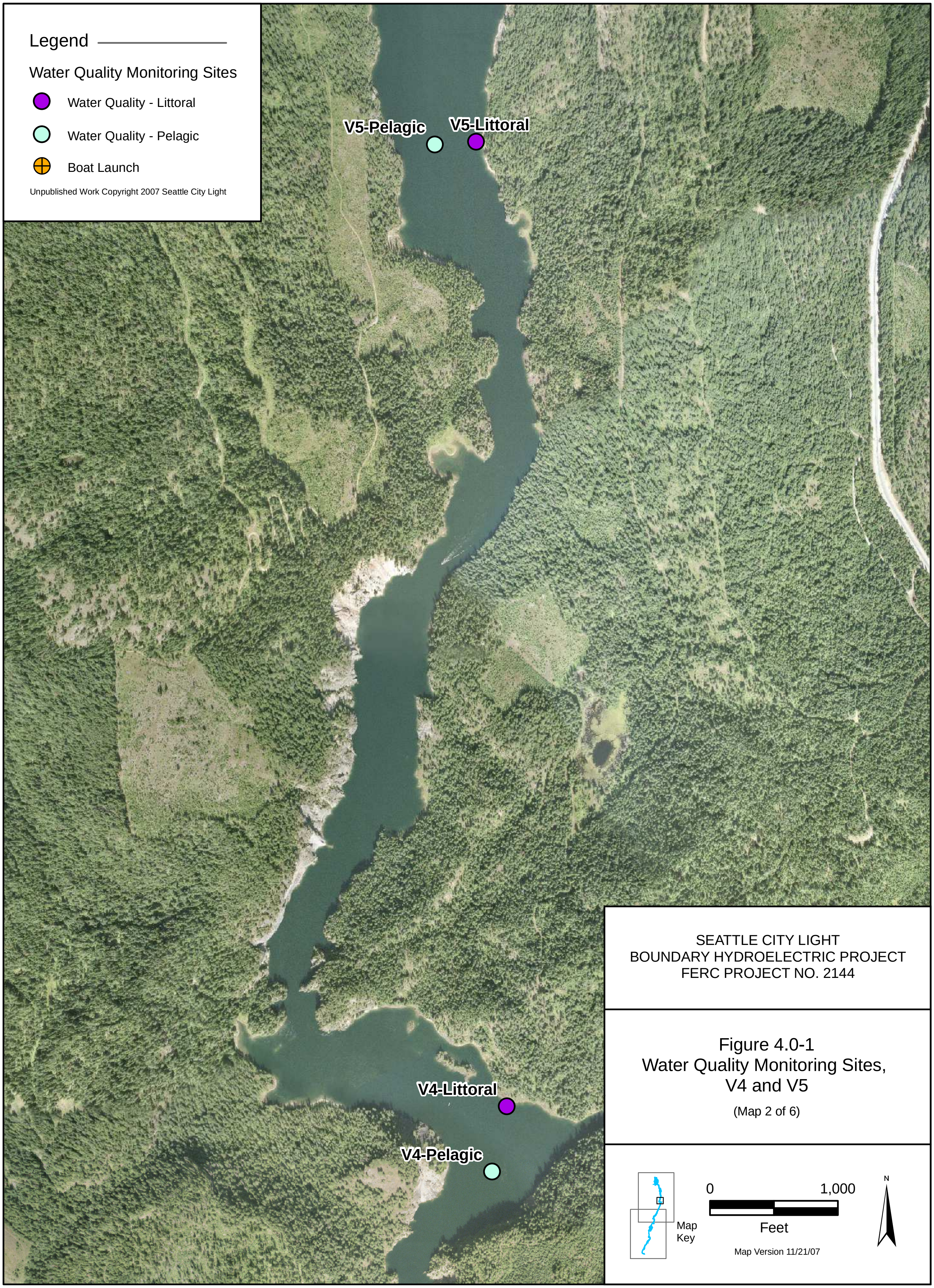

Figure 4.0-1
Water Quality Monitoring Sites, V4 and V5
(Map 2 of 6)

Figure 4.0-1
Water Quality Monitoring Sites, V3
(Map 3 of 6)

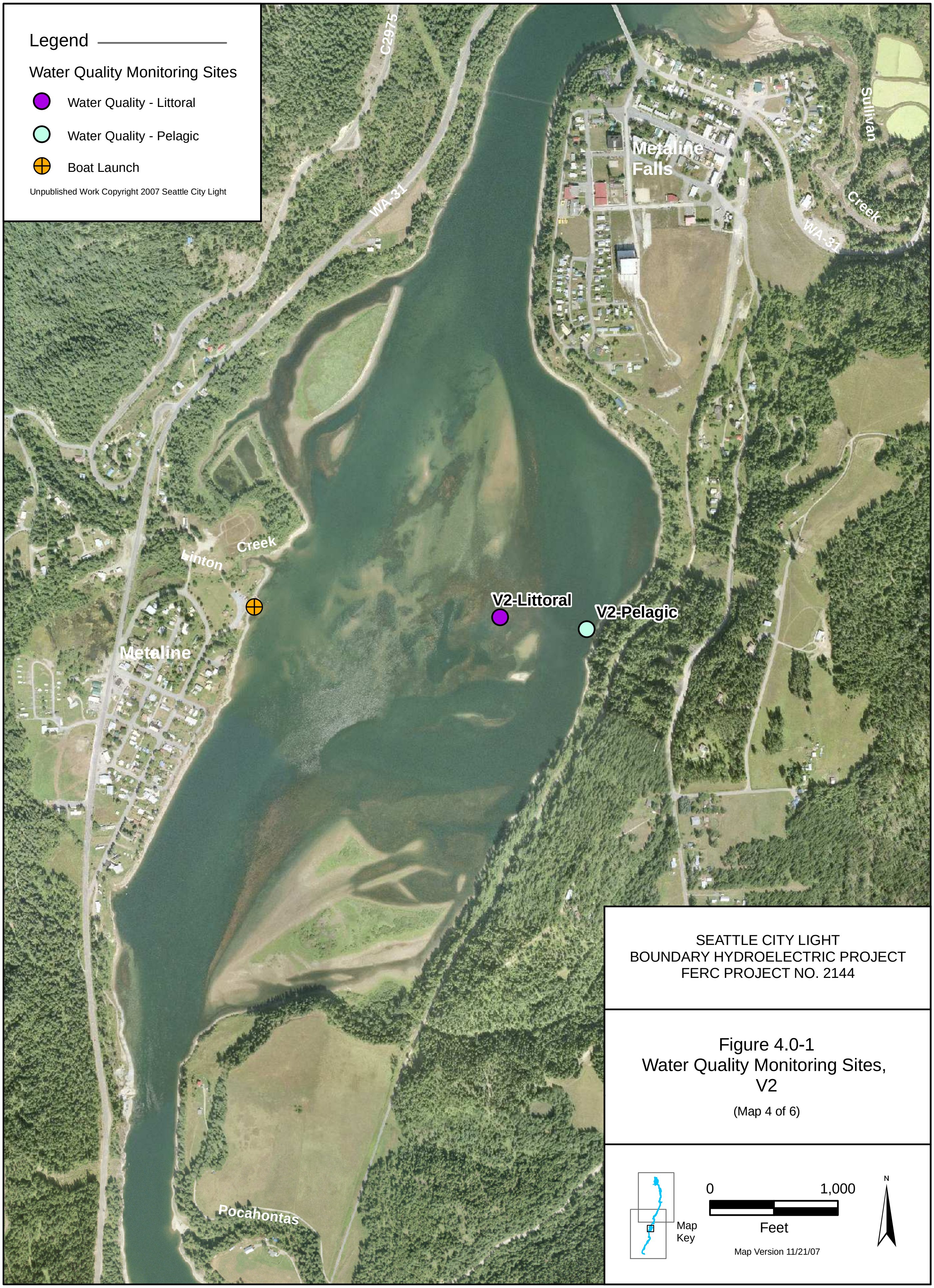

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Figure 4.0-1
Water Quality Monitoring Sites,
V2
(Map 4 of 6)

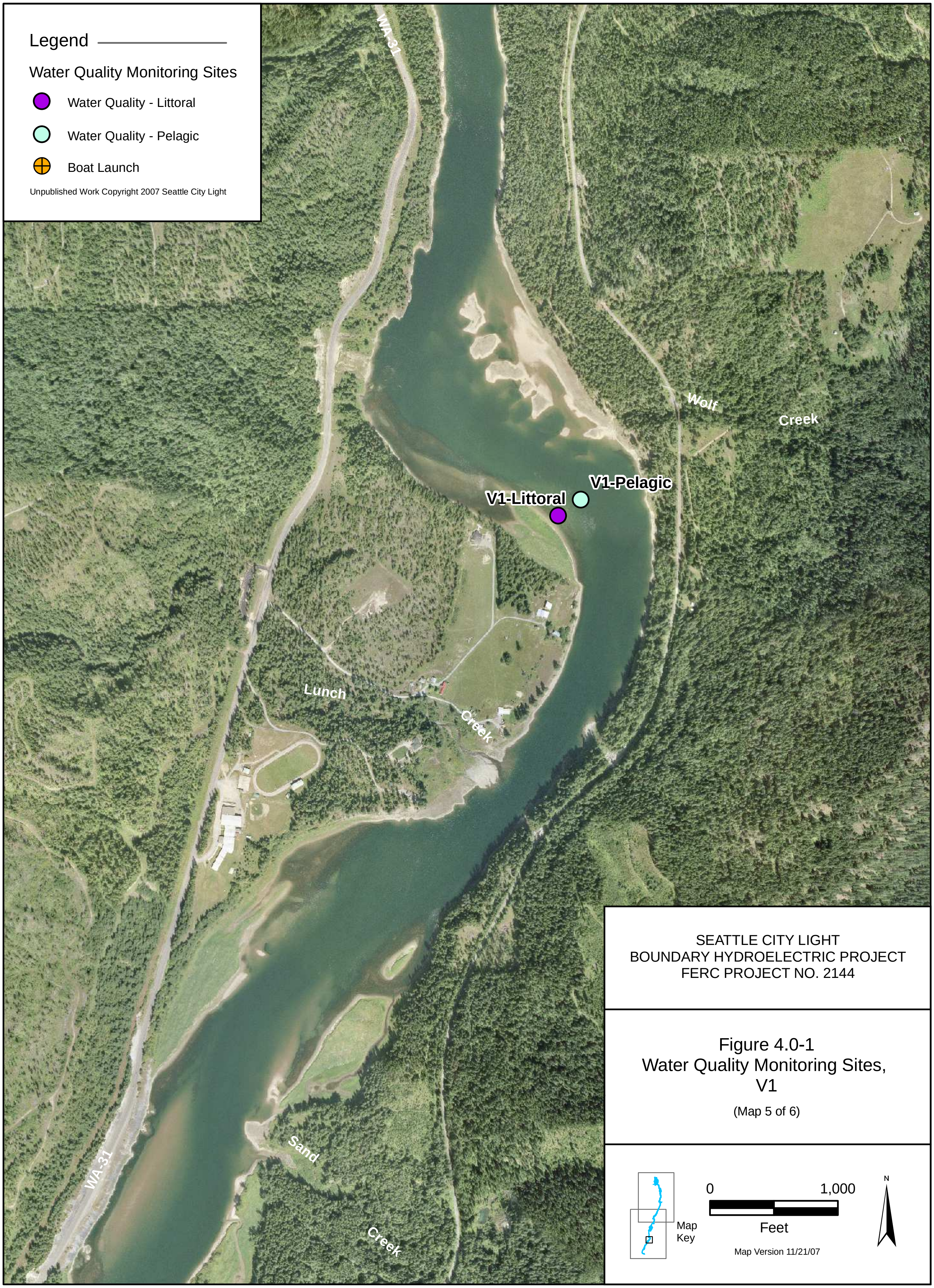

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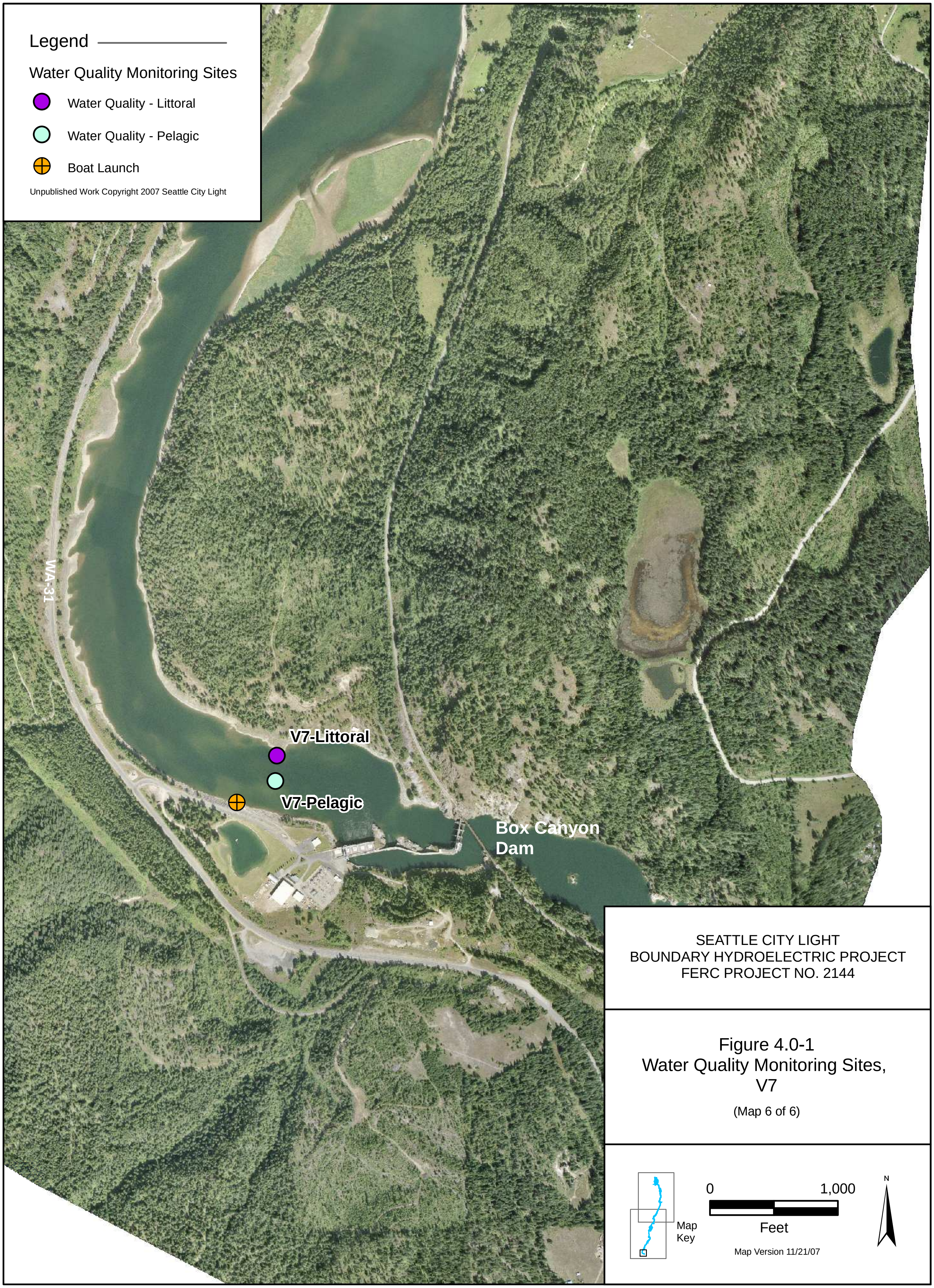
Figure 4.0-1
Water Quality Monitoring Sites, V1

(Map 5 of 6)


Legend
Water Quality Monitoring Sites
Water Quality - Littoral
Water Quality - Pelagic
Boat Launch
Unpublished Work Copyright 2007 Seattle City Light
WA-31
V7-Littoral
V7-Pelagic
Box Canyon Dam
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure 4.0-1
Water Quality Monitoring Sites, V7
(Map 6 of 6)
Map Key
0
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Feet
Map Version 11/21/07
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4.1. In Situ Water Quality Data Collection

In situ data on temperature, pH, DO, and conductivity were collected using a Hydrolab MS5 multiprobe water quality sampling instrument. Calibration and sampling were performed per the manufacturer's specifications. Field data technicians were trained for sampling and calibrating equipment, and a copy of the Hydrolab manual was kept with the field crew during sampling operations. The Hydrolab MS5 multiprobe was lowered through the water column using a cable winch and weight system. The Hydrolab data cable had demarcations of colored electrical tape and permanent markings for depth taken as the distance from the tip of the data sensors within the probe; in addition, a depth probe was included as part of the Hydrolab sensors bundle. Secchi disk transparency was measured following Ecology's *Citizen's Guide to Understanding and Monitoring Lakes and Streams* (Michaud 1994).

Continuous temperature data was collected and described from six locations over the length of Boundary Reservoir. These data represent continuous records for each site and logged at fifteen minute intervals using pressure transducers. The source for this data was from Seattle City Light and used as part of Study No. 7 to construct the hydraulic routing model.

4.2. Water Quality Grab Samples for Lab Analysis

Water quality grab samples for lab analysis used a mechanical pump system to draw samples from specific water column depth intervals. The automatic pump system included an anchor weight, 5/8-inch clear surgical Tygon tubing for the intake hose, a 5/8-inch water pump, electrical connections, and a cable winch. Samples were collected in polyethylene sample bottles at the pump outlet. For each sample the pump was run for a calculated period of time to flush the hose system with the ambient water from the sample collection depth. Surface grab samples were collected by hand at approximately 0.5 meter depth. Each sample bottle was rinsed three times with sample water before the sample was collected.

Turbidity was analyzed on site using a Hach 2100P portable turbidimeter. Sample analysis and calibration followed the manufacturer's specifications. A Hach turbidimeter laboratory manual was kept with the field data collection crew during field sampling.

4.3. Zooplankton Samples for Lab Analysis

Zooplankton samples characterizing the pelagic zone of the reservoir were collected via two water column vertical tows from approximately 1 meter above the bottom to the reservoir's surface using a Wisconsin-style 80-µm plankton net and bucket. Vertical tows were conducted using a cable winch and weight system. For the littoral region, two horizontal water column tows were conducted within the euphotic zone following standard methods for shallow areas, with and without vegetation. Seasonal zooplankton drift data were collected using a mechanical pump system to draw samples from 1 to 2 meters depth in the middle of the river channel. Samples were collected for 20 minutes and filtered through an 80-µm mesh net.

5 PRELIMINARY RESULTS

This section presents a preliminary analysis of the water quality data collected for Study 5 between May 2007 and August 2007. The data were evaluated to address the objectives of the study and are described on a reservoir-wide basis, as well as by depth and by site. Interpretation of the data is limited to significant observations that provide understanding of the water quality of Boundary Reservoir until all data have been analyzed. Field data collection for 2007 was completed in November 2007, and all data collected will be analyzed and presented in the final report that includes work through March 2008.

5.1. Existing Water Quality Conditions

Existing water quality conditions in and immediately downstream of Boundary Reservoir between May 2007 and August 2007 have been assessed. The following water quality parameters were addressed: temperature, pH, DO, conductivity, Secchi depth, chlorophyll *a*, nutrients, zooplankton, hardness, and turbidity. Results for the water quality evaluation are presented in Appendix 2.

The Project site is subject to water quality standards that have been designated by Ecology's Water Quality Standards for Surface Waters of the State of Washington (Chapter 173-201A Washington Administrative Code [WAC]) for the Pend Oreille River from the Canadian border (river mile [RM] 16) to the Idaho border (RM 87.7) (Ecology 2006). Use designations for fresh waters that apply include salmonid spawning, rearing, and migration aquatic life uses; primary contact recreation uses; water supply uses for domestic water, industrial water, agricultural water, and stock water; and miscellaneous uses for wildlife habitat, harvesting, boating and aesthetics.

The in situ data were collected along vertical profiles of the reservoir at each sampling location. The data were analyzed to identify whether stratification occurs along the vertical profile or whether the Boundary system is mixed vertically. Stratification in the water column refers to a distinct and identifiable temperature gradient and is usually characterized as a drop in temperature by 1 ^{o}C for each one-meter increase in depth (separation of cold water from overlying warm water can change more quickly than at one-meter depth intervals). The results of this analysis demonstrate that there is no thermal stratification at sites V1, V4, or V6 (Figures 5.1-1 through 5.1-3). Additional results from sites V2, V3, and V5 reporting on vertical profiles for temperature, pH, DO, and conductivity show similar patterns as those for temperature and are presented in Appendix 3. Isopleths in Figure 5.1-3 for 22.5°C through 24^{o}C are continuously joined and represent temperature ranges that are persistent through time. Horizontal continuity for temperature ranges indicate that water column depth was not identical between any two monitoring periods and that temperature was still uniform throughout the water column. Temperature measurements made in July were made at a depth 10 meters (33 feet) less and were warmer than those made in August 2007.

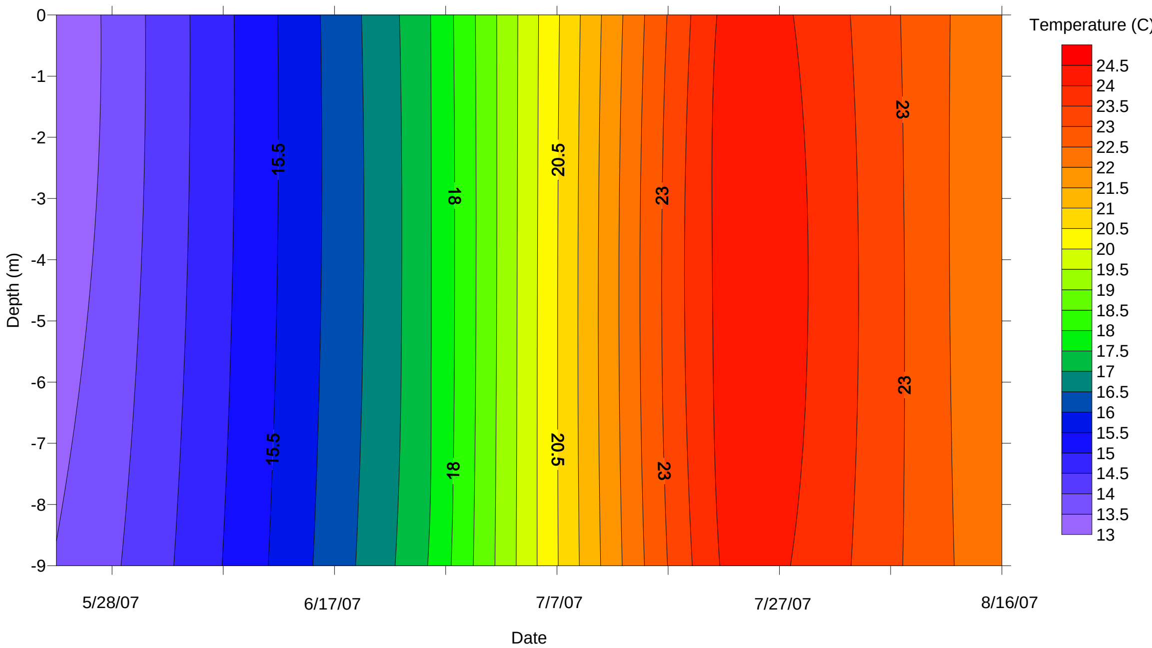

Figure 5.1-1. Site V1 temperature profile for May to August 2007.

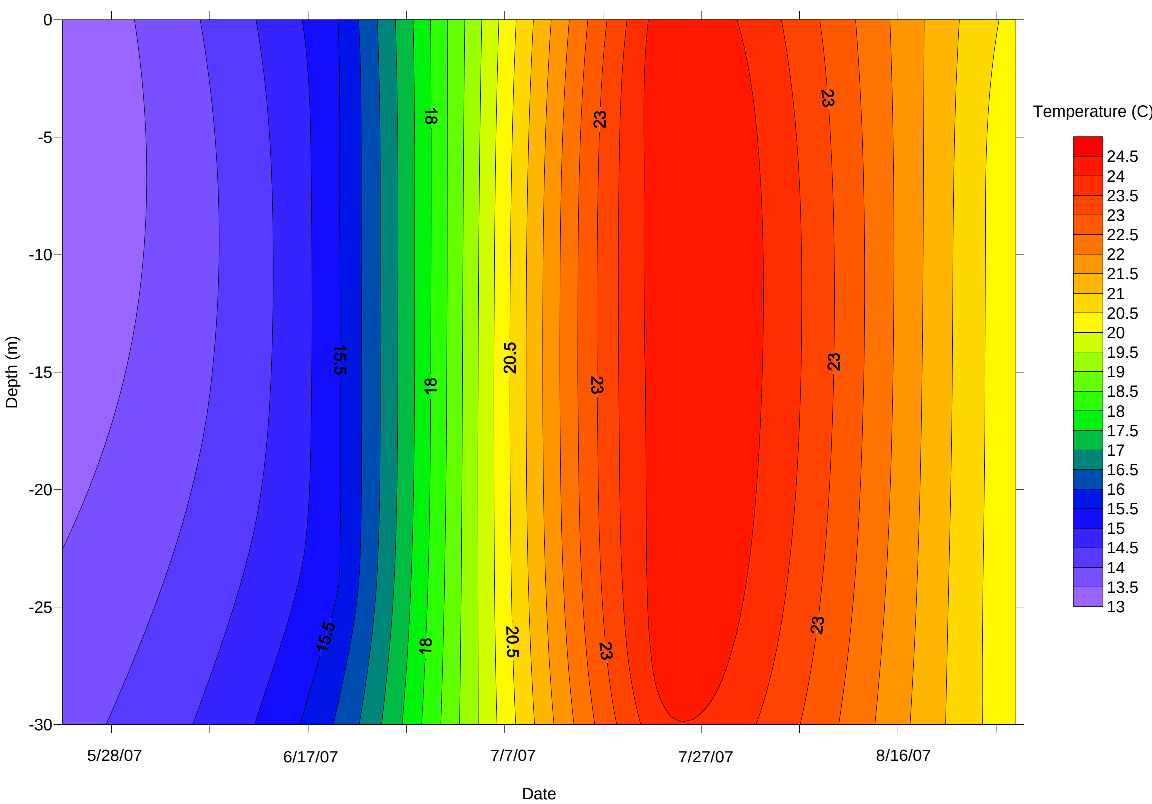

Figure 5.1-2. Site V4 temperature profile for May to August 2007.

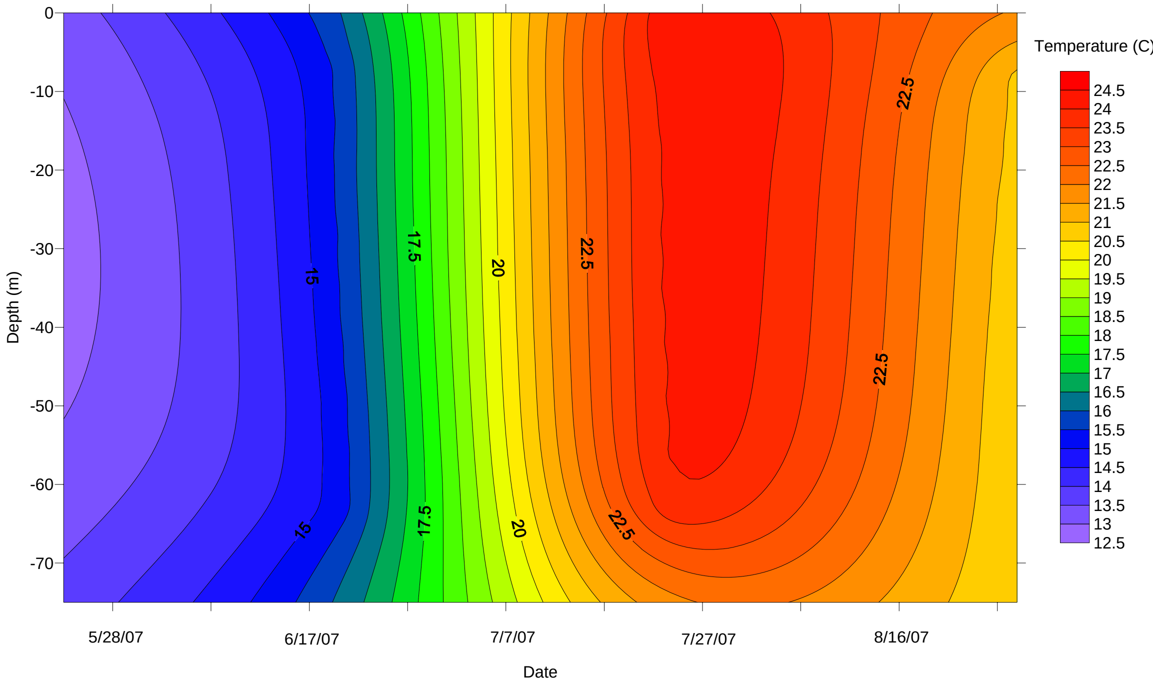

Figure 5.1-3. Site V6 temperature profile for May toAugust 2007.

5.1.1. Temperature

Average, maximum, and minimum values of the temperature profile data collected at every site for each month are presented in Table 5.1-1. The temperature values collected in situ were not collected simultaneously at each site and therefore do not allow comparisons among sites at this time. These temperature data will mainly be used in reference to other water quality parameters also collected in situ. However, the data do display interesting trends that support further investigation as described below.

Table 5.1-1. Temperature (°C) data summary for each site.

Site	May			June			July			August		
	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min
V7	12.86	12.86	12.86	17.25	17.25	17.24	24.03	24.30	23.98	22.02	22.03	22.02
V1	13.00	13.00	13.00	17.35	17.36	17.34	24.27	24.31	24.23	22.01	22.07	22.00
V2	12.86	12.99	12.79	17.41	17.61	17.31	24.54	25.19	24.32	21.96	22.17	21.91
V3	13.08	13.08	13.08	15.81	15.86	15.79	23.88	24.08	23.84	19.98	20.22	19.94
V4	13.01	13.01	13.01	15.45	15.47	15.44	24.37	24.51	24.33	20.13	20.33	20.09
V5	13.00	13.00	13.00	15.55	15.69	15.52	24.12	24.91	23.95	20.30	20.88	20.20
V6	13.22	13.22	13.22	15.49	15.95	15.24	24.15	24.50	21.74	20.79	21.95	20.55
V8	12.95	12.95	12.95	14.65	15.40	13.90	24.11	24.12	24.10	22.72	22.73	22.71

Temperatures entering the Project from Box Canyon were highest consistently in July and August at a number of sites. There is no observed pattern of thermal gain moving through the Project. A thorough analysis of the continuous temperature monitoring data (including from Study No. 6; influence of macrophytes on water quality) will be conducted and included in the final report.

No clear pattern of heat gain was observed along the longitudinal profile of the Project area based on the in situ data (Figure 5.1-4). Temperature profiles at the upper end of the Reservoir (Sites V1, V2, and V7) were higher than those at the lower end of the Reservoir during the June 2007 sampling date (Figure 5.1-4). Further evaluation of this temperature differential among sites during individual months will be addressed in the final report. Additional detail for continuous temperature monitoring data that was collected by Seattle City Light (Study No. 7) is provided in Appendix 4, Figure A.4-2. Continuous temperature measurements among these sources were made at the same time of day and at fifteen minute intervals. These data from each site will eventually be compared to identify longitudinal patterns when results from the routing model become available and can adjust for time of travel.

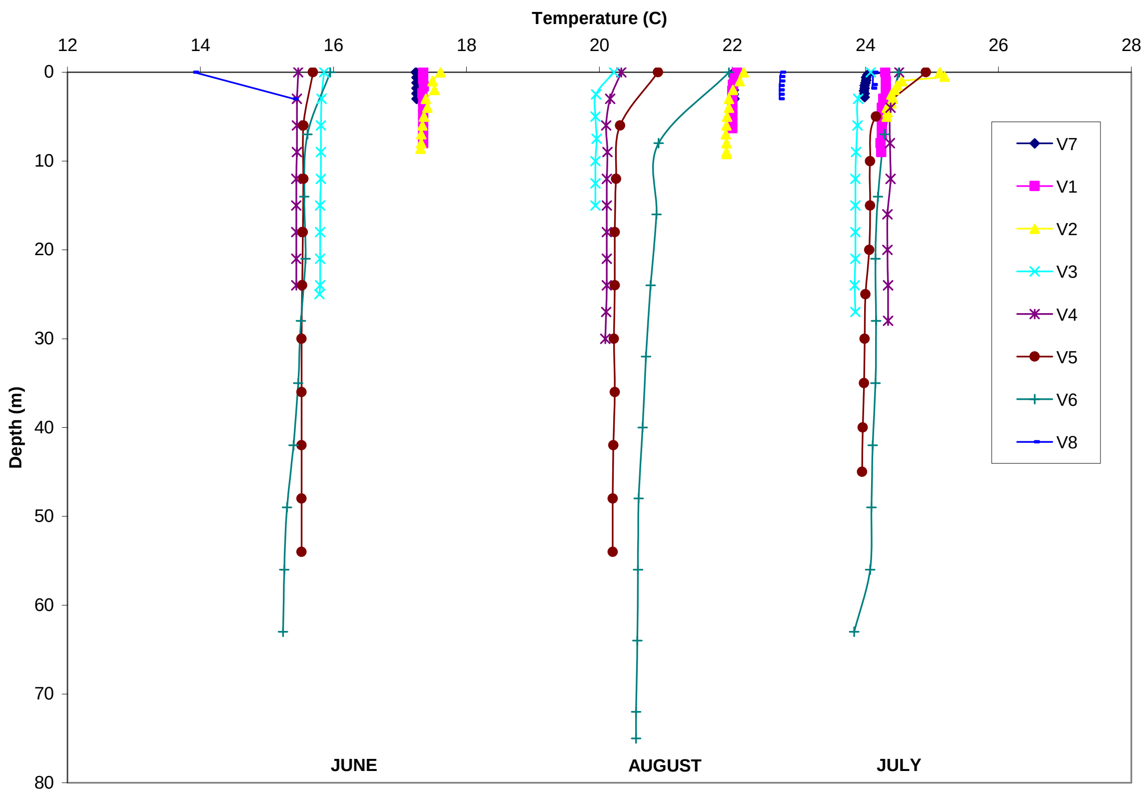

Figure 5.1-4. Boundary Reservoir temperature profiles for June to August 2007.

5.1.2. Dissolved Oxygen

Average, maximum, and minimum values of the DO profile data collected at every site for each month are presented in Table 5.1-2.

Table 5.1-2. Dissolved oxygen (mg/L) data summary for each site.

Site	May			June			July			August		
	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min
V7	10.98	10.98	10.98	10.01	10.03	9.99	8.60	8.62	8.45	8.38	8.40	8.36
V1	11.35	11.35	11.35	9.99	10.06	9.94	8.73	8.80	8.66	8.10	8.13	8.06
V2	11.25	11.32	11.17	10.00	10.10	9.90	9.23	9.74	8.94	7.94	7.99	7.88
V3	11.42	11.42	11.42	9.49	9.64	9.36	8.22	8.40	8.05	8.93	9.06	8.82
V4	11.30	11.30	11.30	9.21	9.33	9.12	8.52	8.70	8.36	8.76	8.99	8.58
V5	11.22	11.22	11.22	9.16	9.32	9.06	8.11	8.50	7.74	8.46	8.87	8.08
V6	11.23	11.23	11.23	9.00	9.27	8.78	7.81	8.43	7.03	8.00	8.44	7.62
V8	11.20	11.20	11.20	9.45	9.45	9.45	8.19	8.19	8.18	7.67	7.68	7.65

According to Ecology's aquatic life temperature criteria in fresh water, the lowest 1-day minimum DO criteria for salmonid spawning, rearing, and migration is 8.0 mg/L (Ecology 2006). DO concentrations in May and June were above the 8.0 mg/L Ecology standard (i.e., in compliance) at all sampling stations. In July, DO concentrations were above the Ecology standard at all sampling stations, except for V5 and V6, where minimum values fell below 8.0 mg/L. In August, DO concentrations were above the standard at most stations, except V2, V6, and V8. However, the DO measurements below 8.0 mg/L were still at or above saturation during July and August, indicating that the low DO values are in part due to the elevated temperature of water entering the Project from Box Canyon Reservoir (Figures 5.1-5 through 5.1-7).

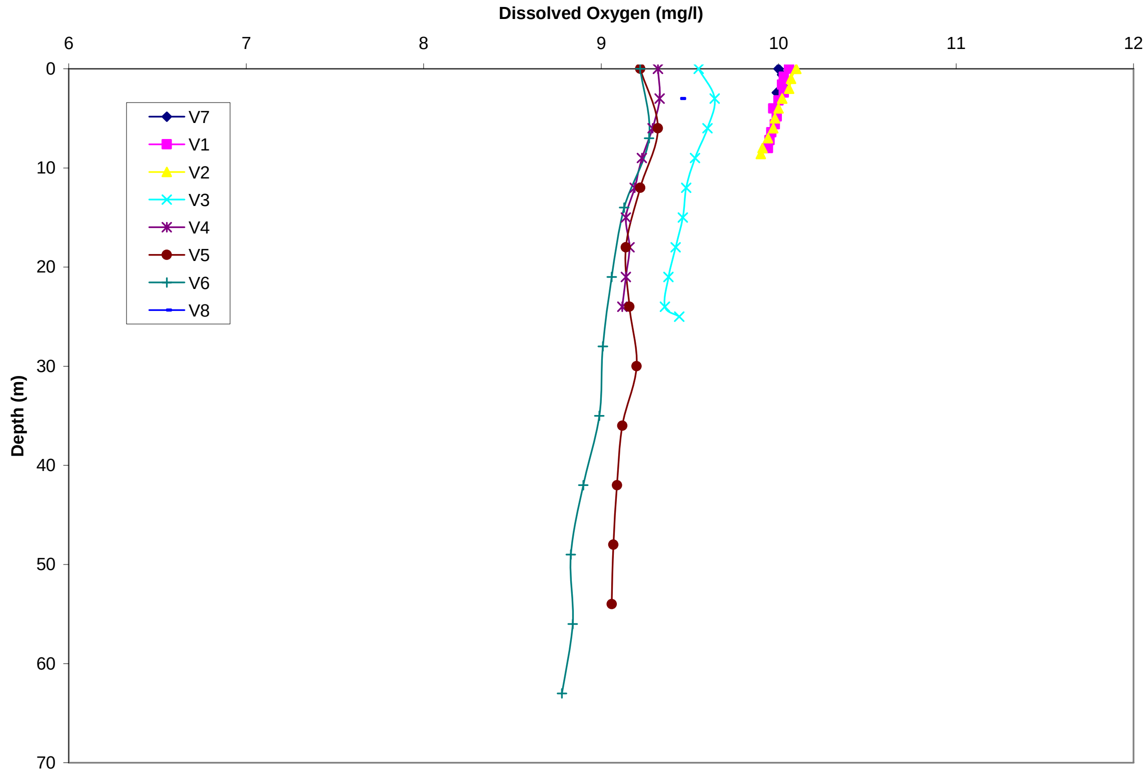

Figure 5.1-5. Boundary Reservoir dissolved oxygen profiles in June 2007.

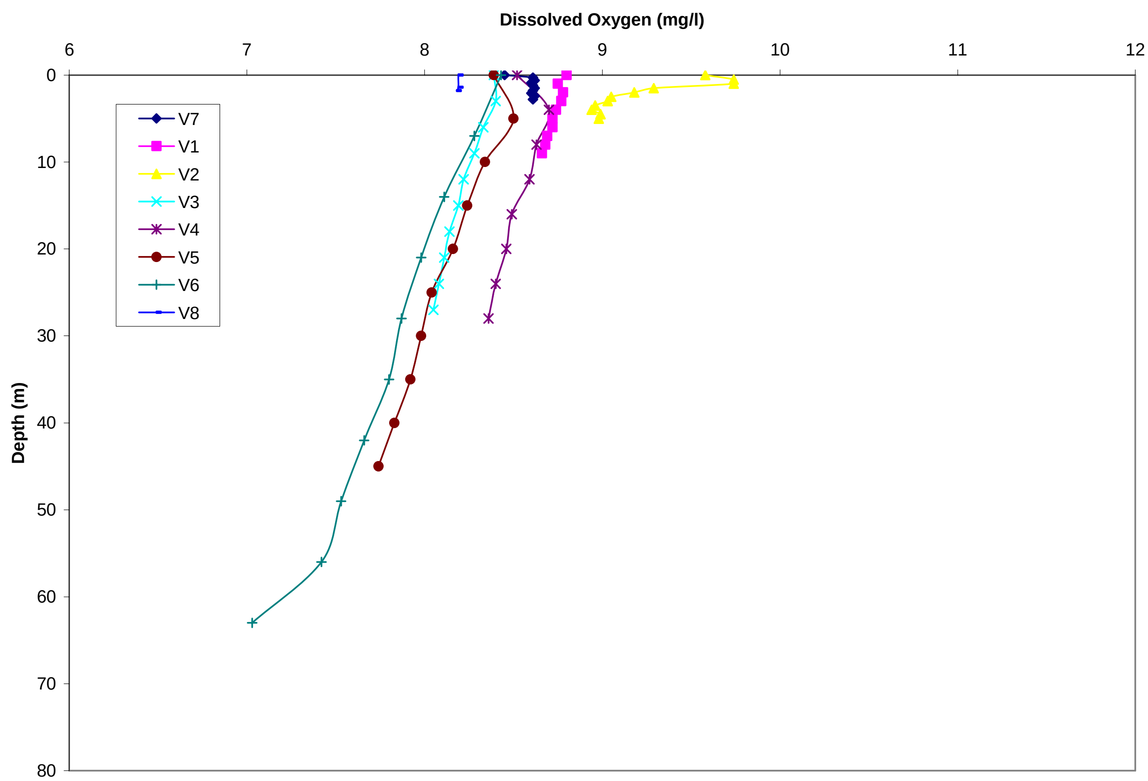

Figure 5.1-6. Boundary Reservoir dissolved oxygen profiles in July 2007.

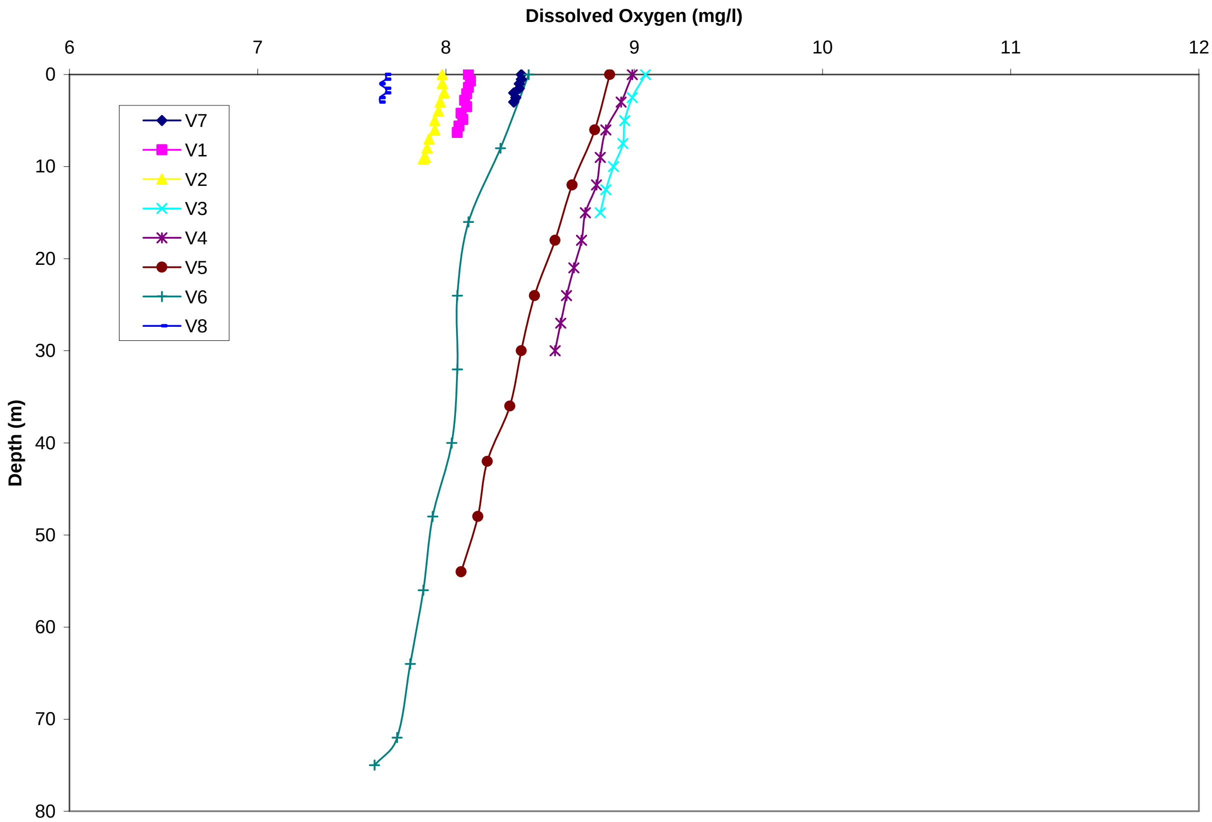

Figure 5.1-7. Boundary Reservoir dissolved oxygen profiles in August 2007

5.1.3. pH

Average, maximum, and minimum values of the pH profile data collected at every site for each month are presented in Table 5.1-3.

Table 5.1-3. pH (Standard Units) data summary for each site.

Site	May			June			July			August		
	Ave [1]	Max	Min	Ave [1]	Max	Min	Ave [1]	Max	Min	Ave [1]	Max	Min
V7	7.76	7.76	7.76	8.46	8.53	8.38	8.61	8.64	8.56	9.08	9.11	9.05
V1	7.98	7.98	7.98	8.34	8.35	8.30	8.46	8.56	8.23	8.53	8.60	8.45
V2	7.98	8.01	7.92	8.25	8.35	7.93	8.36	8.42	8.31	8.51	8.54	8.49
V3	7.88	7.88	7.88	8.65	8.77	8.57	8.98	9.10	8.70	8.45	8.46	8.45
V4	8.05	8.05	8.05	8.51	8.61	8.32	8.36	8.46	8.28	8.32	8.33	8.31
V5	7.93	7.93	7.93	8.51	8.62	8.06	8.58	8.64	8.43	8.27	8.31	8.25
V6	8.34	8.34	8.34	8.23	8.27	8.12	8.13	8.22	8.01	8.24	8.29	8.20
V8	8.40	8.40	8.40	8.21	8.24	8.18	8.33	8.41	8.18	8.57	8.59	8.55

Notes:
1 Logarithmic average

According to Ecology's aquatic life temperature criteria in fresh water, the pH criteria for salmonid spawning, rearing, and migration shall be within the range of 6.5 to 8.5, with a human-caused variation within this range of less than 0.5 unit (Ecology 2006). Based on the values observed from our in situ data collection, readings exceeded this criterion at a number of the sampling stations in June, July and August. The pH of water entering the Project area from Box Canyon Reservoir exceeds the 8.5 standard, and these high values reflect background geologic conditions of the limestone deposits within the river basin. Some fluctuations in the pH values are observed moving through the system as a result of localized geochemistry. There are limited differences observed between the pH values exiting and entering the Project (Figures 5.1-8 through 5.1-10).

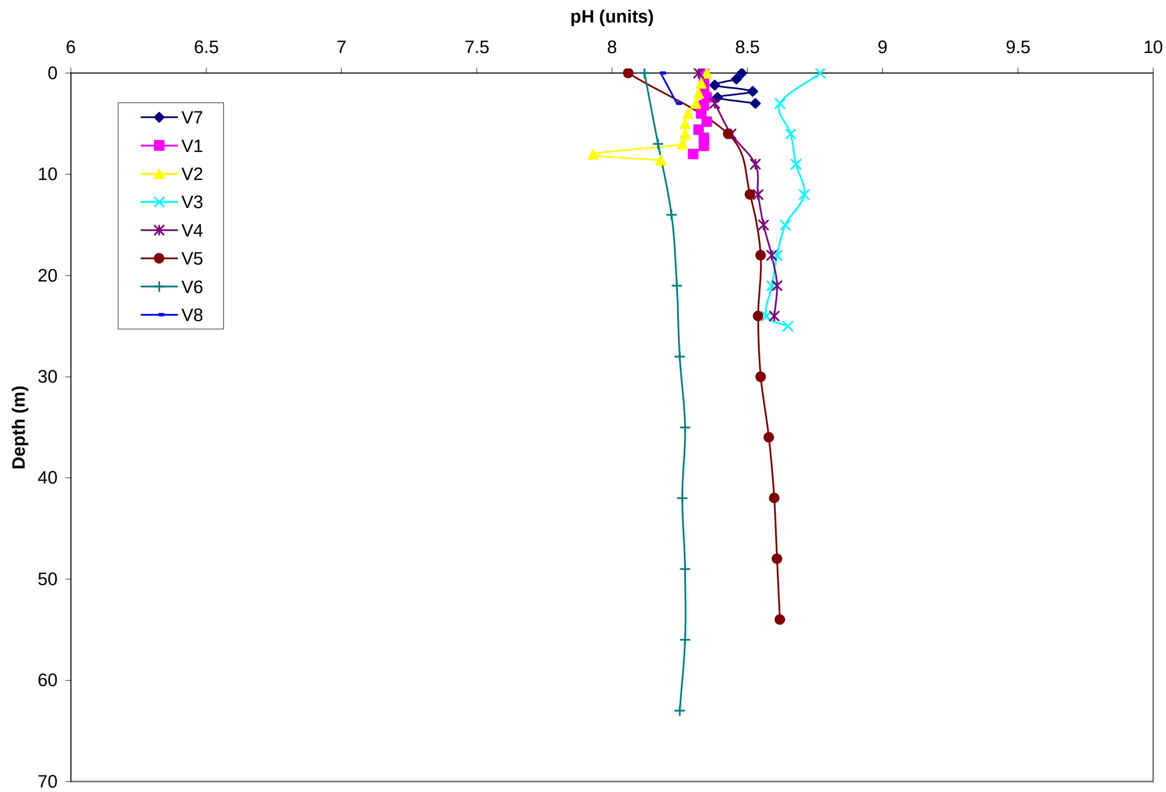

Figure 5.1-8. Boundary Reservoir pH profiles in June 2007.

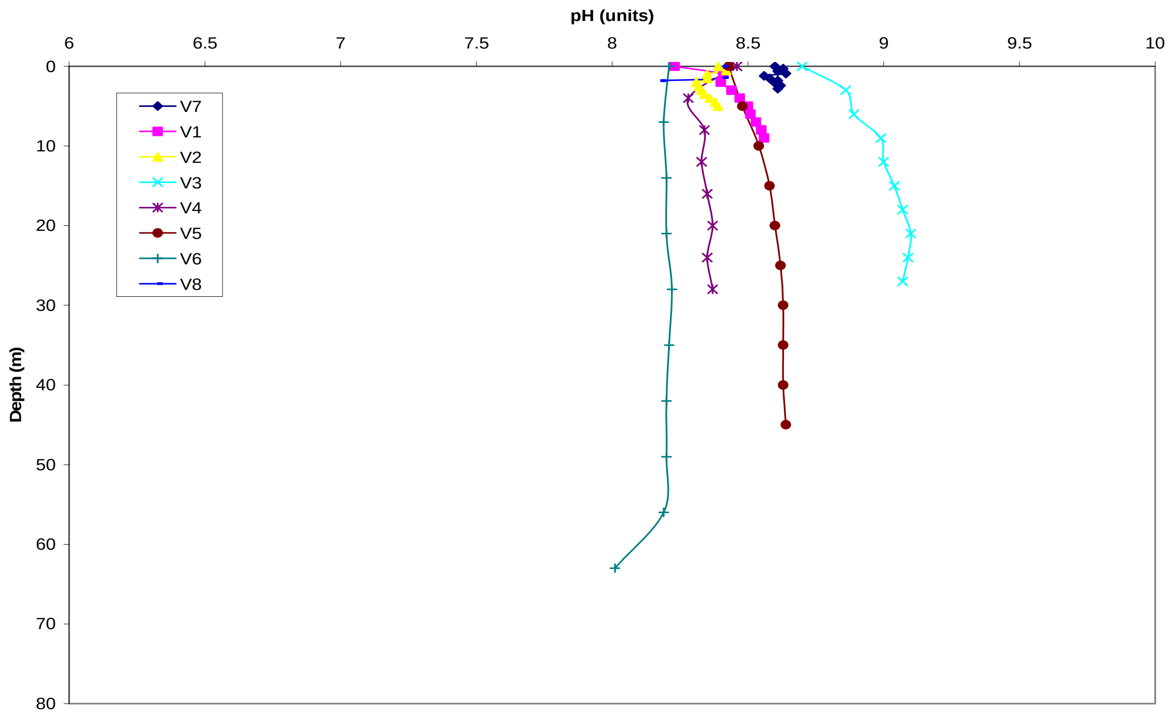

Figure 5.1-9. Boundary Reservoir pH profiles in July 2007.

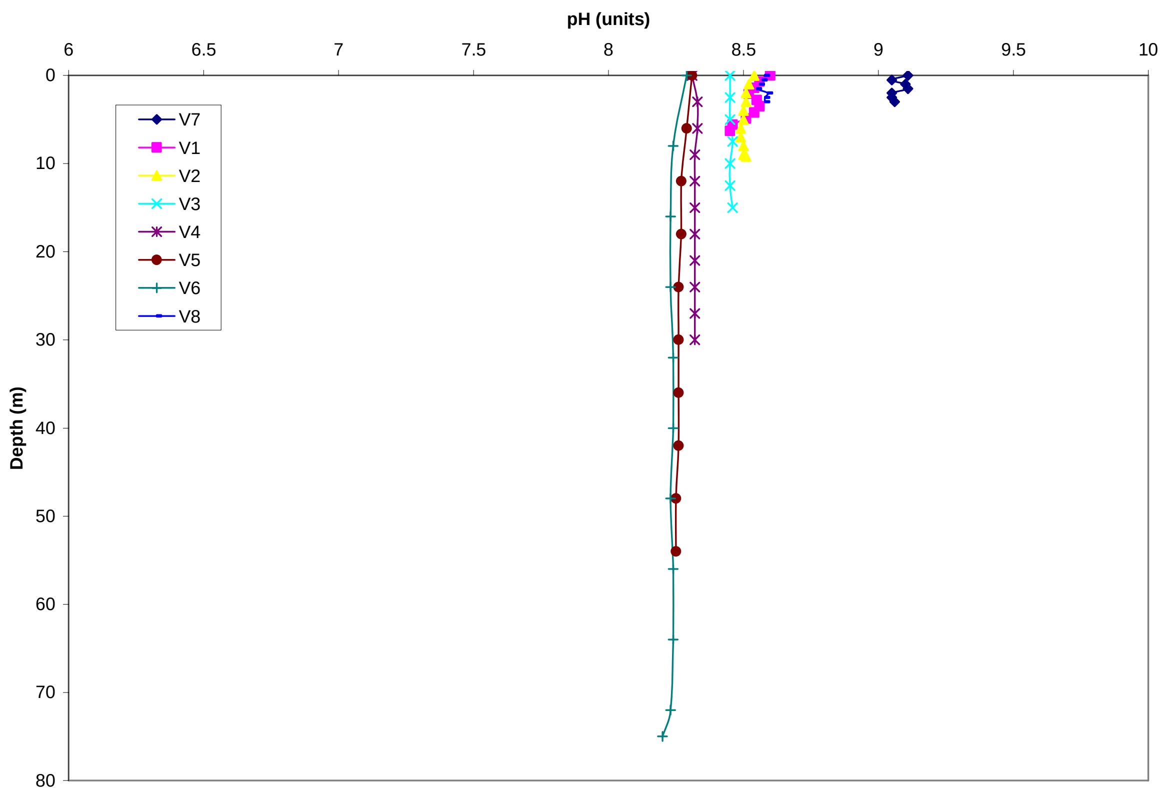

Figure 5.1-10. Boundary Reservoir pH profiles in August 2007.

5.1.4. Conductivity

Average, maximum, and minimum values of the conductivity profile data collected at every site for each month are presented in Table 5.1-4. The conductivity measurements ranged from 136.5 microsiemens per centimeter (µS/cm) at V7 in May to169.2 µS/cm at V8 in August (Figure 5.1-11). Values increased monthly from May to August.

Table 5.1-4. Conductivity data summary for each site (µS/cm).

Site	May			June			July			August		
	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min
V7	136.5	136.5	136.5	149.4	149.8	149.0	161.1	161.4	160.8	166.3	166.6	166.0
V1	136.3	136.3	136.3	149.5	149.9	149.1	161.1	161.6	160.7	164.0	164.6	163.5
V2	136.8	137.0	136.7	149.5	149.8	149.1	160.3	161.1	158.6	164.8	165.2	164.4
V3	140.0	140.0	140.0	147.1	148.0	147.0	162.2	162.5	161.9	166.6	166.9	166.4
V4	140.4	140.4	140.4	147.8	148.0	147.0	161.6	162.0	161.4	167.1	167.9	166.8
V5	140.4	140.4	140.4	147.9	148.0	147.0	161.7	161.9	161.5	167.3	167.6	167.0
V6	140.8	140.8	140.8	147.1	148.0	147.0	161.3	161.7	160.4	167.5	168.0	167.1
V8	139.1	139.1	139.1	146.1	146.1	146.0	161.3	161.7	161.1	169.2	169.4	169.1

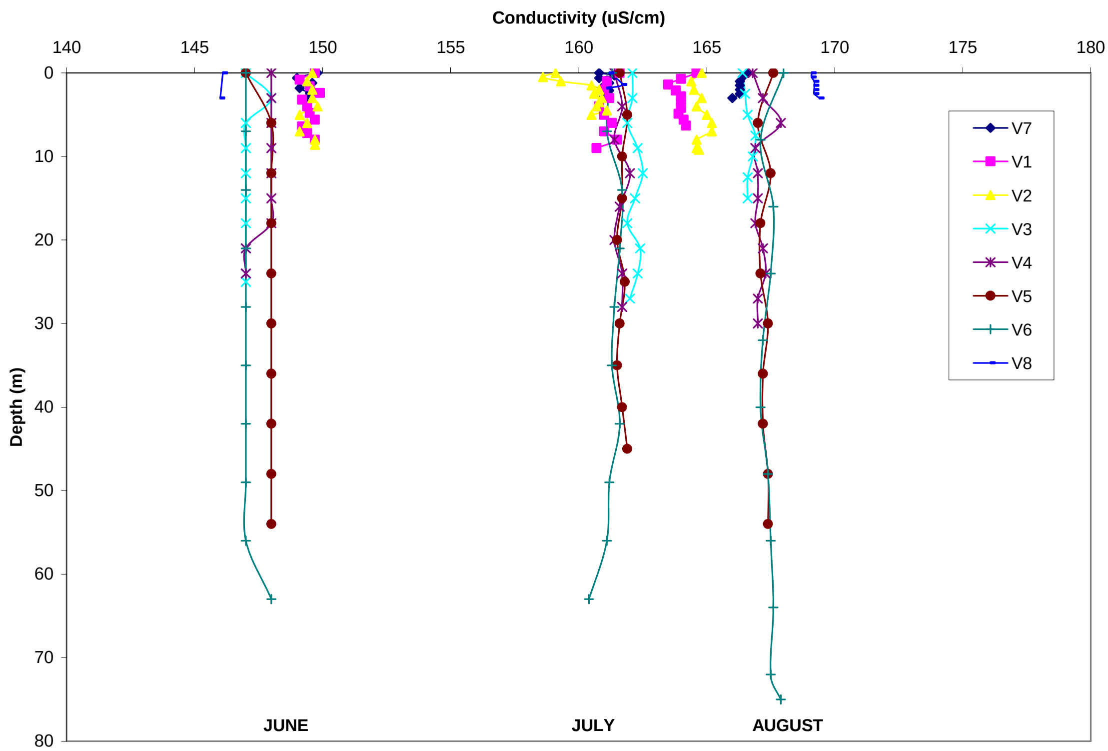

Figure 5.1-11. Boundary Reservoir conductivity measurements June–August 2007.

5.1.5. Turbidity

Turbidity measurements were collected in the littoral and pelagic regions of four sites (V1, V3, V6, and V8) within the Project area. Table 5.1-5 summarizes turbidity measurements at these sites as well as the reservoir means and standard deviations. Figure 5.1-12 presents reservoir pelagic and littoral turbidity averages and standard deviations.

Pelagic and littoral turbidity measurements were similar throughout the reservoir with a possible decreasing trend from May to August. The higher turbidity measurements seen in May and June as compared to July and August are most likely due to higher inflows during the spring months.

According to Ecology's criteria for salmonid spawning, rearing, and migration, turbidity shall not exceed 5 nephelometric turbidity units (NTUs) over background when background is 50 NTUs or less (Ecology 2006). No turbidity values over 5 NTU were measured during the in situ data collection.

Table 5.1-5. Boundary Reservoir turbidity measurements (May–August 2007).

Site	Turbidity (NTUs)			
	May	**June**	**July**	**August**
V1 Littoral	2.94	3.11	0.92	1.23
V1 Pelagic	3.4	3.17	1.34	1.22
V3 Littoral	4.45	2.48	0.26	1.04
V3 Pelagic	3.04	2.65	2.15	1.02
V6 Littoral	2.28	1.31	1.85	
V6 Pelagic	2.24	1.59	1.28	0.85
V8 Pelagic	2.55	0.83	1.02	1.34
Reservoir Littoral Mean	3.2	2.3	1.0	1.1
Reservoir Littoral STDEV	1.1	0.9	0.8	0.1
Reservoir Pelagic Mean	2.9	2.5	1.6	1.0
Reservoir Pelagic STDEV	0.59	0.81	0.49	0.19

Note:
NTU – nephelometric turbidity unit

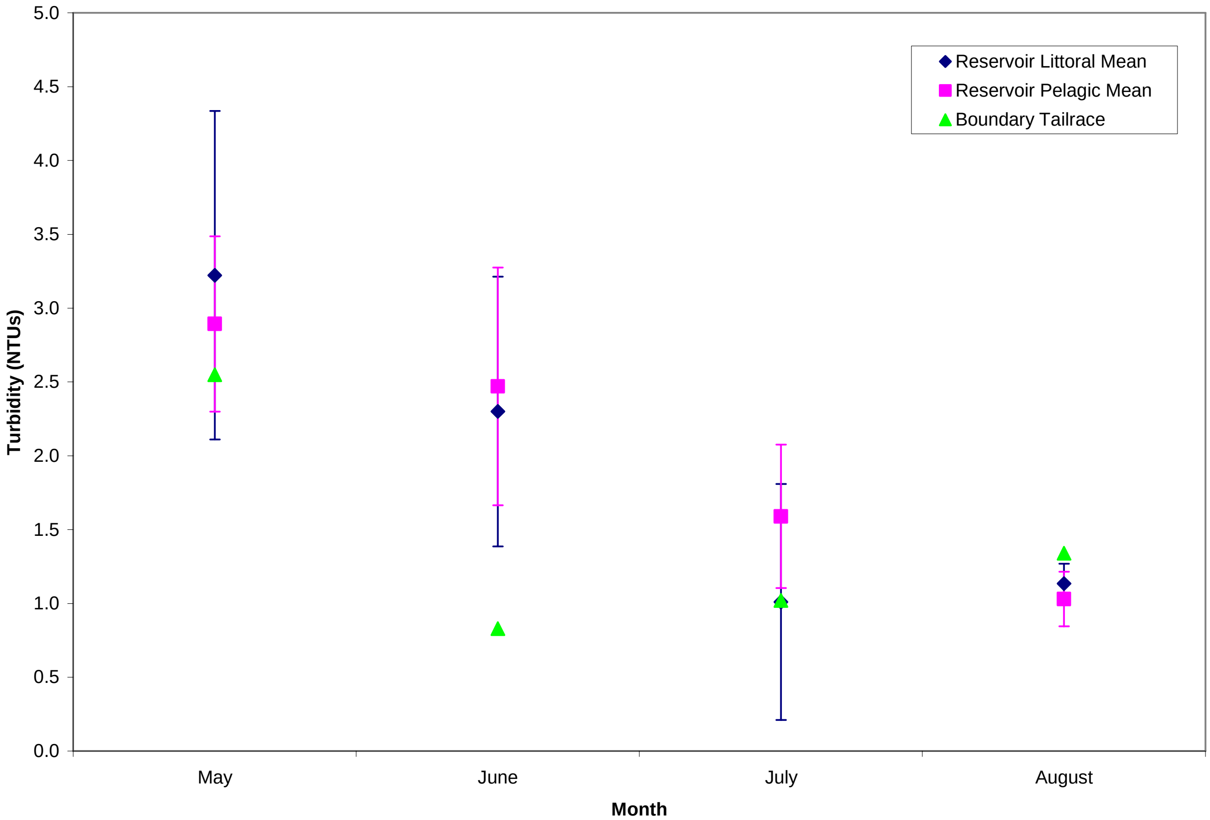

Figure 5.1-12. Boundary Reservoir turbidity measurements (May–August 2007).

5.1.6. Nutrients

Grab samples were collected at all sites within the Project area and analyzed for phosphorous (total phosphorus [Total-P] and soluble reactive phosphorus [SRP]) and total Kjeldahl nitrogen (TKN) (i.e., the combination of organic and ammonia nitrogen). Figures 5.1-13 through 5.1-15 display the results of the nutrient analyses for Total-P, SRP, and TKN, respectively. Samples that were below the detection limits were graphed at the detection limits (i.e., <0.001 microgram per liter [µg/L] for SRP and 0.2 µg/L for TKN). Concentrations of phosphorous and nitrogen were low and often below detection limits for SRP and TKN. SRP was especially limited and near or below detection all the time, indicating a phosphorous-limited system. Total-P was higher in June in both tailraces than anywhere else in the reservoir.

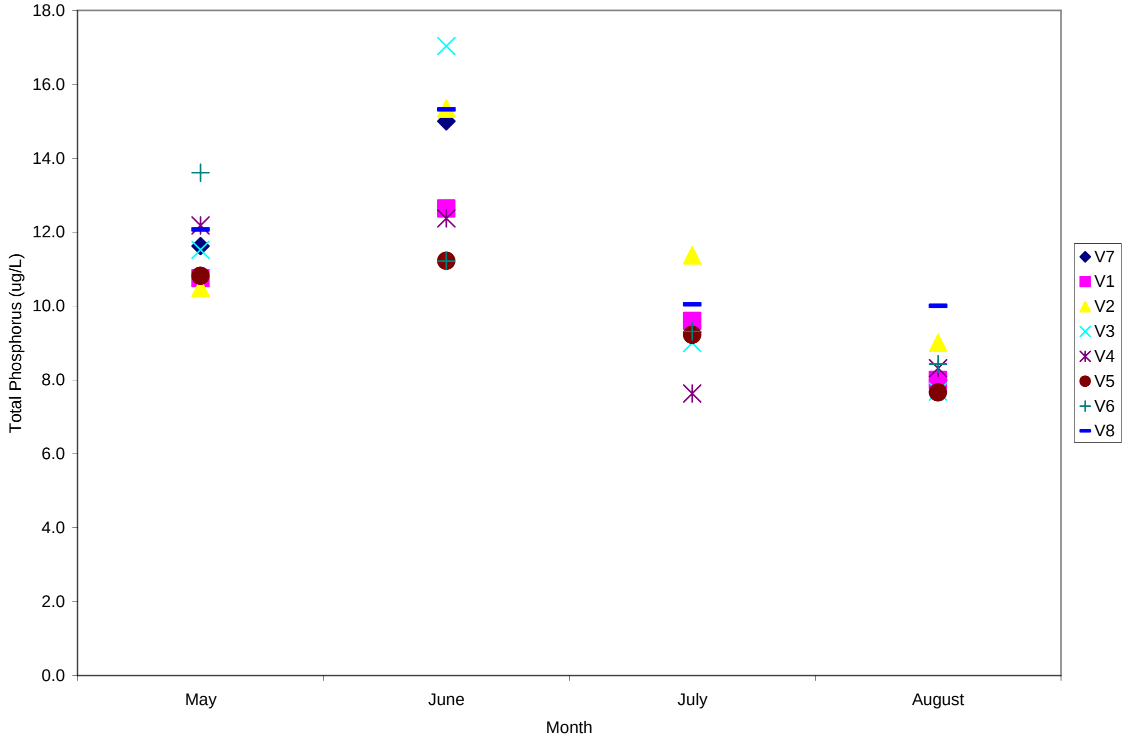

Figure 5.1-13. Total-phosphorus concentrations at Boundary Reservoir sites (May-August 2007).

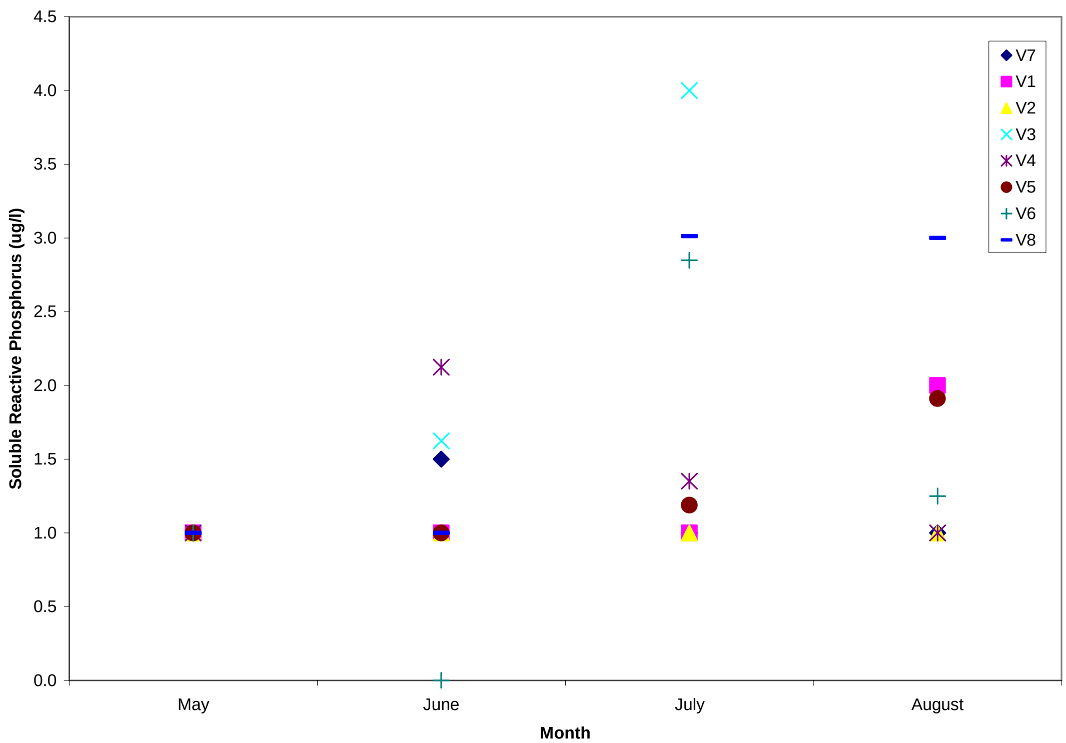

Figure 5.1-14. SRP (soluble reactive phosphorus) concentrations at Boundary Reservoir sites (May-August, 2007).

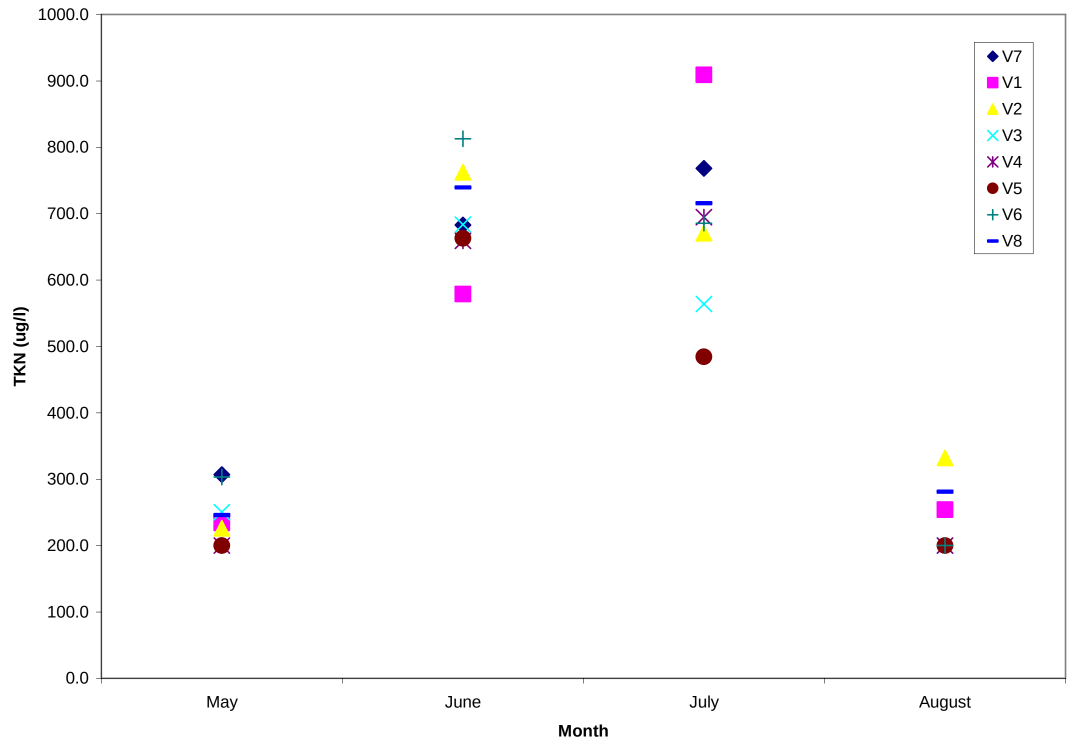

Figure 5.1-15. TKN (total Kjeldahl nitrogen) concentrations at Boundary Reservoir sites (May-August, 2007).

5.1.7. Hardness

Grab samples were collected at all sites within the Project area and analyzed for water hardness. The RSP stated that the hardness samples would be collected 1 meter from the bottom of the river. Due to equipment malfunction, hardness samples were collected at the surface during May for all sites, at the surface for sites V5 and V6 during June, and at 40 feet for sites V3, V4, V5, and V6 in August. All of July's hardness samples were collected at the bottom.

Hardness varied from 64.7 milligrams per liter (mg/L) as calcium carbonate ($CaCO_3$) at site V7 in May to 80.5 mg/L as $CaCO_3$ at site V5 in August. Overall, hardness within the Project area increased slightly from May to August. This increase may reflect a situation in which, as temperatures rise and flows decrease, the groundwater influence increases and elevates the rate of limestone dissolution, thus raising the hardness level.

During July sampling, surface and bottom hardness samples were collected at sites V3 and V6 to determine if there was any difference in hardness throughout the water column. After looking at the data, there appears to be no difference between surface and bottom hardness within the Project area. This result also corresponds to the finding that the Project is a completely mixed system thermally throughout the summer (see Section 5.1.1). Table 5.1-6 summarizes hardness concentrations for the Project area.

Table 5.1-6. Boundary Reservoir hardness concentrations (May–August 2007).

Site	Date	Depth	Hardness (mg/L as $CaCO_3$)
V1	5/23/2007	Surface	65.1
	6/25/2007	Bottom	70.2
	7/23/2007	Bottom	75.0
	8/16/2007	Bottom	77.2
V2	5/23/2007	Surface	65.1
	6/25/2007	Bottom	71.5
	7/23/2007	Bottom	75.2
	8/16/2007	Bottom	76.8
V3	5/22/2007	Surface	66.1
	6/19/2007	Bottom	69.2
	7/24/2007	Surface	76.6
	7/24/2007	Bottom	77.4
	8/25/2007	40 feet	79.7
V4	5/22/2007	Surface	66.6
	6/20/2007	Bottom	69.4
	7/24/2007	Bottom	76.2
	8/25/2007	40 feet	80.1
V5	5/22/2007	Surface	66.8
	6/20/2007	Surface	69.0
	7/24/2007	Bottom	75.8
	8/25/2007	40 feet	80.5
V6	5/22/2007	Surface	67.2
	6/20/2007	Surface	69.2
	7/24/2007	Surface	76.6
	7/24/2007	Bottom	74.9
	8/25/2007	40 feet	79.9
V7	5/23/2007	Surface	64.7
	6/25/2007	Bottom	69.6
	7/23/2007	Bottom	74.9
	8/14/2007	Bottom	76.6
V8	5/23/2007	Surface	66.4
	6/25/2007	Bottom	68.8
	7/23/2007	Surface	75.6
	8/14/2007	Bottom	77.0

Notes:
$CaCO_3$ – calcium carbonate
mg/L – milligram per liter

5.2. Production

Factors limiting aquatic productivity—specifically light, nutrient concentrations, and reservoir retention time—were compared to chlorophyll *a* concentrations and zooplankton densities to address potential limiting conditions and also to determine the relative influences of Pend Oreille River inflows and Boundary Reservoir operations on primary and secondary productivity. Detailed results from zooplankton drift sampling can be found in Appendix 5.

5.2.1. Limiting Factors to Production

5.2.1.1. Light

Secchi disk depth, an index of water clarity, was measured at each site within the Project area during each sampling event. Table 5.2-1 summarizes the Secchi disk depths for May through August for each site, as well as the reservoir mean and standard deviation. Secchi disk depth did not vary greatly throughout the reservoir during a sampling period; hence, an average Secchi disk depth is representative of the system on a given day. Figure 5.2-1 presents the reservoir mean Secchi disk depth and standard deviations as well as the Secchi disk depth for each tailrace.

There is a definite trend of increasing Secchi disk depth throughout the reservoir from May to August. The Secchi disk was visible at Site V7 in August even though it rested on the channel bottom. The increasing trend in Secchi disk depth is most likely due to a decrease in chlorophyll *a* concentrations entering Boundary Reservoir from upstream. Figure 5.2-2 shows the relationship between Secchi disk depth and chlorophyll *a* concentrations in Boundary Reservoir and tailrace.

The mean Secchi disk depth measurements indicate that Boundary Reservoir is an oligotrophic to mesotrophic system, or a low to medium productive system. Carlson (1977) states that a summer mean Secchi disk depth of greater than 3.6 meters is characteristic of an oligotrophic waterbody.

Table 5.2-1. Boundary Reservoir Secchi disk depths (May-August 2007).

Site	Secchi Disk Depth (m)			
	May	June	July	August
V7	2.0	1.2	3.3	3.5
V1	1.9	1.4	4.5	4.9
V2	2.0	1.4	3.1	5.3
V3	1.7	1.5	4.7	5.0
V4	2.2	2.1	4.8	5.5
V5	1.9	2.1	3.9	5.5
V6	2.1	2.2	5.5	4.7
V8	2.0	1.5	-	3.9
Reservoir Mean	2.0	1.8	4.4	5.1
Reservoir STDEV	0.18	0.41	0.83	0.35

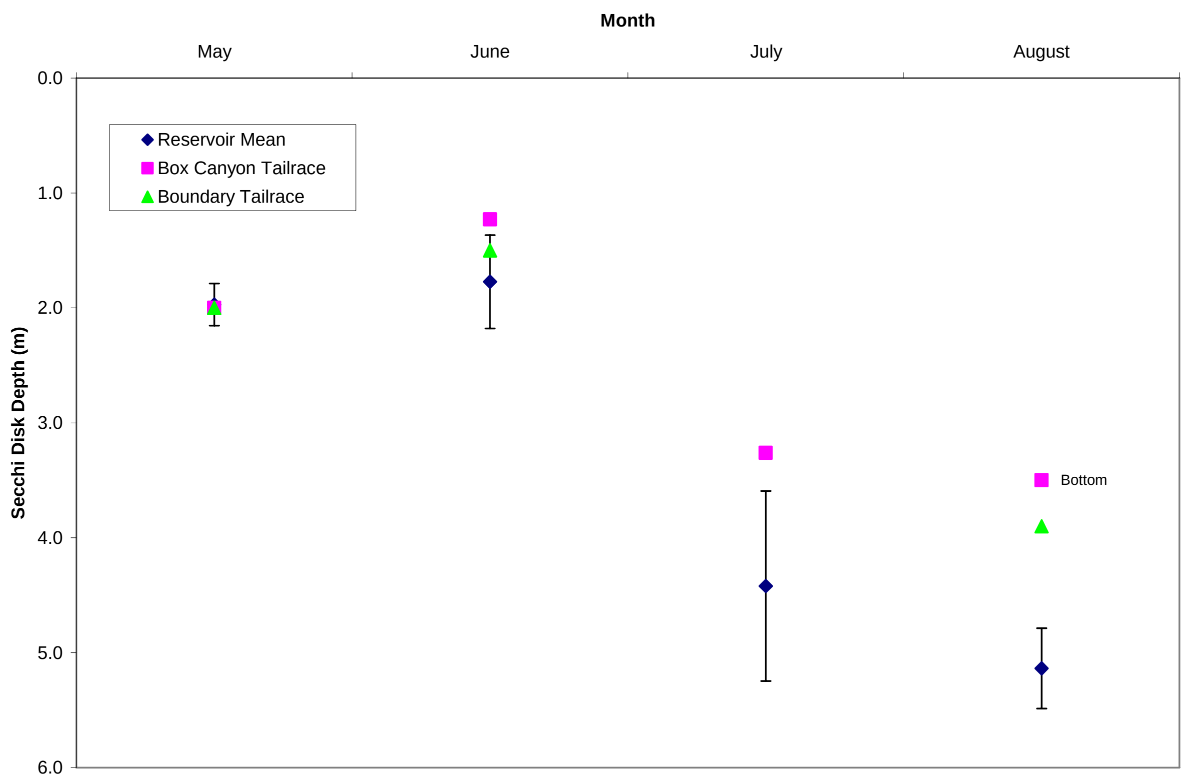

Figure 5.2-1. Boundary Reservoir Secchi disk depths (May-August 2007).

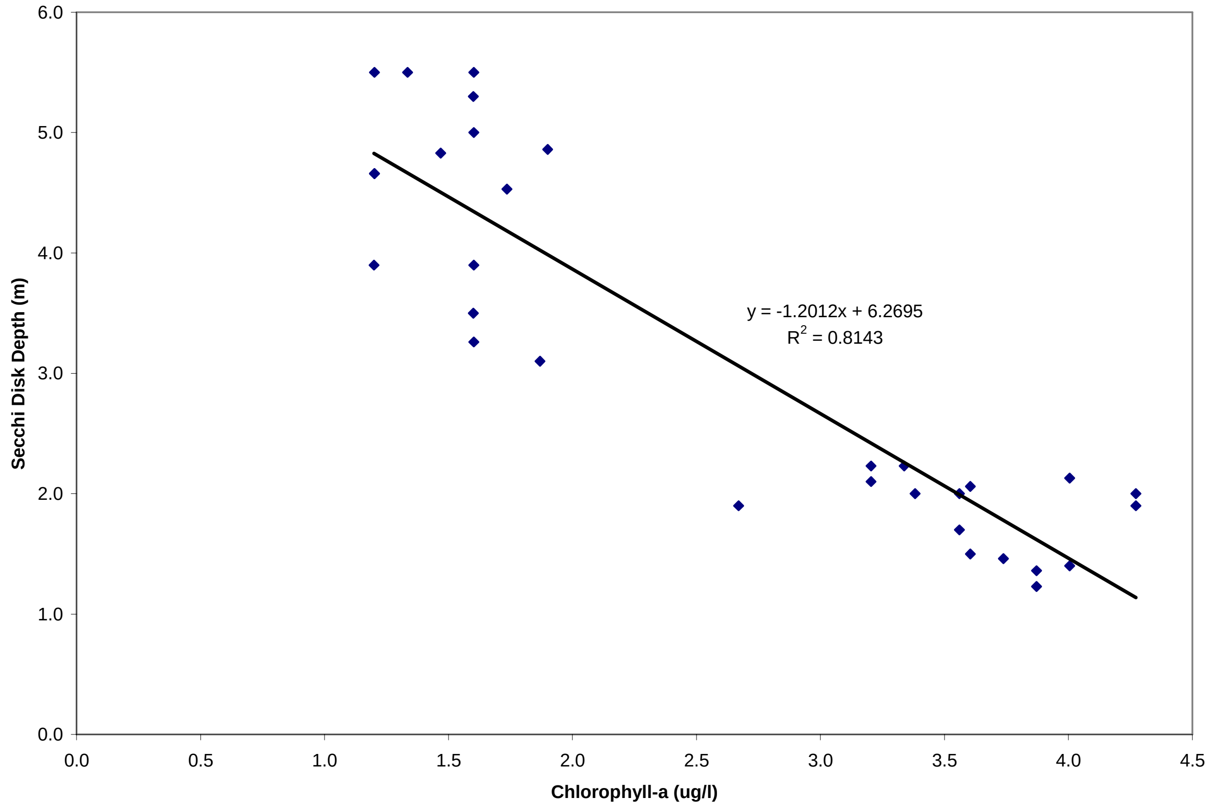

Figure 5.2-2. Relationship between Secchi disk depth and chlorophyll *a* concentration based on data collected in the Boundary Reservoir and tailrace.

5.2.1.2. Nutrients

A preliminary analysis was completed to determine the limiting nutrient concentrations within Boundary Reservoir. Nutrient samples were collected at the surface of all eight sites within the Project area (see Section 5.1.7). Determining the nitrogen to phosphorus (N:P) ratio of a waterbody is an acceptable method for determining the limiting nutrient of a system. If the N:P ratio is greater than the Redfield ratio (7.2:1 by weight), then a system is assumed to be phosphorus-limited. Freshwater systems are usually phosphorus-limited unless they are located within very arid regions. Eutrophic lakes, those lakes with high productivity, tend to have low N:P ratios, around 10. Oligotrophic lakes, lakes with low productivity, have higher N:P ratios, around 70. Mesotrophic lakes, lakes with intermediate productivity, have N:P ratios around 20 to 30.

Boundary Reservoir N:P ratios were calculated based on the Total-P concentration and the TKN concentration at the surface of each site. Table 5.2-2 summarizes the N:P ratios calculated for each site within the Project area.

N:P ratios within Boundary Reservoir and the tailrace varied from 16.4 to 94.7. Applying the Redfield ratio to the observed N:P ratios would indicate that Boundary Reservoir phytoplankton production is limited by the availability of phosphorus. This is especially true when considering the low concentrations of soluble reactive phosphorus observed. In a few instances, nitrogen concentrations were found to be below the lab detection limit of 200 µg/L. For these cases, the nitrogen concentration was set to the detection limit and the N:P ratio was calculated.

Boundary Reservoir N:P ratios indicate that phosphorus is the limiting nutrient within the system. N:P ratios calculated for the Project also indicate that the system is mesotrophic to oligotrophic, or has medium to low productivity.

Table 5.2-2. Boundary Reservoir N:P ratios from May to August 2007.

Site	Date	N:P Ratio
V1	5/23/2007	21.8
	6/25/2007	45.8
	7/23/2007	94.7
	8/16/2007	31.8
V2	5/23/2007	19.5 [1]
	6/25/2007	49.7
	7/23/2007	59.0
	8/16/2007	36.9
V3	5/22/2007	21.7
	6/19/2007	40.1
	7/24/2007	79.7
	8/25/2007	25.9 [1]
V4	5/22/2007	16.4 [1]
	6/20/2007	53.3
	7/24/2007	91.1
	8/25/2007	24.1 [1]
V5	5/22/2007	18.5 [1]
	6/20/2007	59.1
	7/24/2007	52.5
	8/25/2007	26.1 [1]
V6	5/22/2007	22.3
	6/20/2007	72.5
	7/24/2007	73.6
	8/25/2007	23.7 [1]
V7	5/23/2007	26.4
	6/25/2007	37.3
	7/23/2007	82.8
	8/15/2007	25.0 [1]
V8	5/23/2007	20.4
	6/25/2007	48.2
	7/25/2007	71.2
	8/14/2007	28.1

Notes:
1 Nitrogen was reported at below the detection limit; for calculation purposes the concentration of N was set to detection limit of 200 µg/L.

5.2.1.3. Retention Time

Phytoplankton production, measured as chlorophyll *a* in this study, is limited when reservoir retention time is less than 3 days (Uhlmann 1971). Boundary Reservoir on average has a retention time of less than 2 days. Given this, it would appear that two of the major limiting factors for production within the Project are the hydrologic conditions and the retention time of the reservoir.

After the sample collection period is complete in March of 2008 a more detailed evaluation of the retention time of Boundary Reservoir will be conducted. After the average retention time is calculated for the sampling period, the effects of Project operations and hydrologic conditions on primary production in the reservoir will be evaluated.

5.2.2. Measures of Production

5.2.2.1. Chlorophyll a

Chlorophyll *a* samples were collected at all sampling sites within the Project area. At Sites V1 to V6, chlorophyll *a* samples were collected at the surface, 15 feet in the pelagic region, and at the surface in the littoral region. Figure 5.2-3 presents chlorophyll *a* concentrations within the Project area at pelagic and littoral regions for May to August 2007.

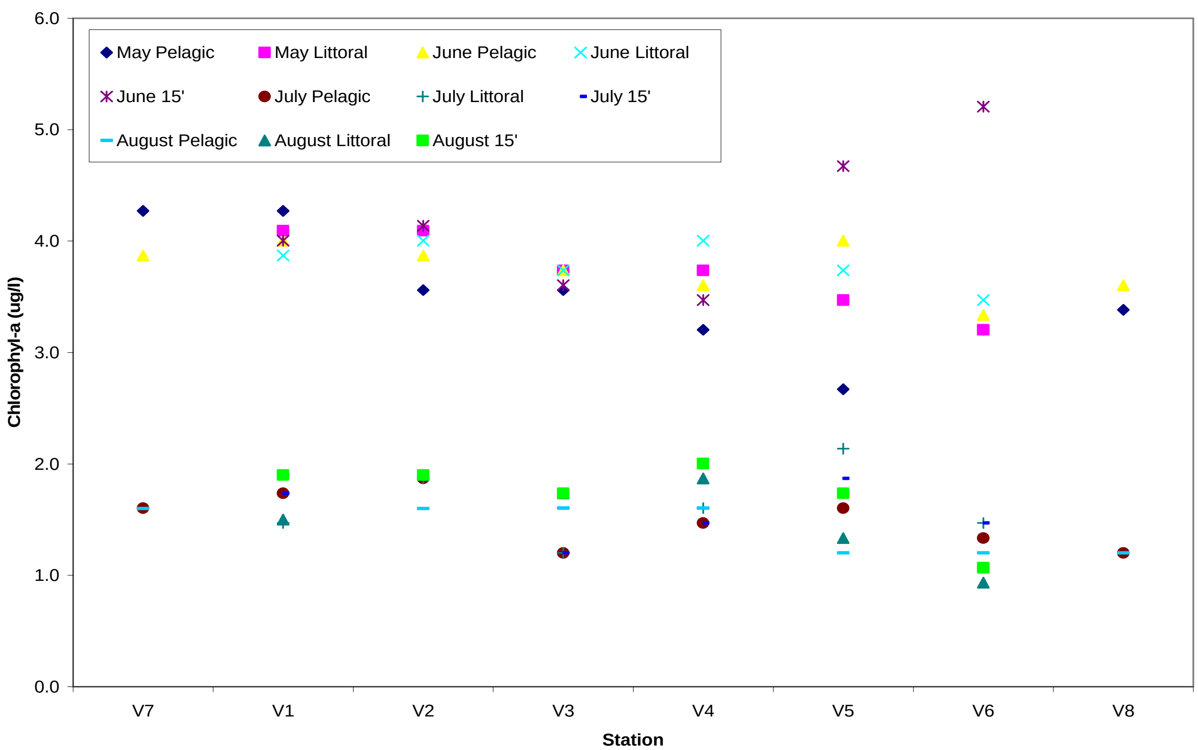

Figure 5.2-3. Boundary Reservoir chlorophyll *a* concentrations (May–August 2007).

Chlorophyll *a* concentrations ranged from 0.9 µg/L in the littoral zone at Site V6 during August to 5.2 µg/L at 15-feet in the pelagic zone at Site V6 in June. There appears to be a decrease in chlorophyll *a* concentrations throughout the reservoir from June to July. This decrease is most likely due to a decline in inflow nutrient concentrations related to a decrease in flow or simply a decrease in inflow of phytoplankton from upstream. (see Section 5.1.7). After preliminary analysis, chlorophyll *a* concentrations in the pelagic regions of the reservoir do not seem to vary from concentrations found in the littoral regions of the reservoir. There also does not seem to be a drastic change in chlorophyll *a* concentrations longitudinally in the reservoir.

Chlorophyll *a* concentrations found within Boundary Reservoir suggest that the system is oligotrophic to mesotrophic. High flows and associated nutrients result in higher chlorophyll *a* concentrations in May and June than in July and August, suggesting higher productivity within the reservoir during the spring runoff months or higher transfer from upstream production. During July and August, chlorophyll *a* concentrations decreased to below 2.8 µg/L, indicating that the reservoir is an oligotrophic or low productivity system.

5.2.2.2. Zooplankton

Monthly zooplankton samples were collected in both the pelagic and littoral zones of the reservoir. Seasonal zooplankton drift data were collected in June and August. Seasonal drift samples from June have been processed for one site (V8). The results of this are presented in Table 5.2-3. Further analysis of the zooplankton data will be conducted as more data become available.

Between 12 and 17 species were found in six samples. Overall total biomass is very low, varying between 15,042 and 33,946 µg/L. Total density is dominated by Rotifers as they make up on average 97.67 percent of the samples. Rotifers also dominate the total dry weight biomass of the samples as they make up, on average, 51.30 percent of the samples. These numbers indicate that a bacterial detrital food source is available to the Project from the Box Canyon Reservoir, but very low primary productivity of phytoplankton is available as a food source.

Table 5.2-3. Average percent of zooplankton density and biomass

Taxonomic Groups	Total Density (%)	Total Dry Weight Biomass (%)
Calanoid Copepods	0.08	9.92
Cyclopoid Copepods	0.26	22.10
Nauplii	1.97	14.24
Cladocerans	0.02	2.44
Rotifers	97.67	51.30

The population of zooplankton is limited by what comes into the Project from the Box Canyon Reservoir. In addition, the populations are limited by low retention time in two ways: (1) the limited available food supply (phytoplankton primary producers) and (2) inadequate time available for zooplankton reproduction.

6 SUMMARY

6.1. Existing Water Quality

Temperature data show that the reservoir is not thermally stratified. In addition, no clear pattern of thermal gain was observed along the longitudinal profile of the reservoir. Temperature and pH values often exceed water quality criteria in June, July, and August (20 ^{o}C and 8.5 pH). The pH levels entering Boundary reservoir from Box Canyon reservoir exceed the pH 8.5 standard in June, July and August probably due to geochemical conditions within the Pend Oreille River Basin. Some fluctuations in the pH values are observed moving through the system as a result of localized geochemistry (sources of limestone in direct contact with reservoir water and to a lesser extent the cement kiln dust treatment effluent). In addition, since the DO measurements are at or above saturation during July and August, the low DO values not meeting water quality criteria are due to the elevated temperatures entering the Project from Box Canyon reservoir.

Turbidity, conductivity, and nutrient concentrations were low. Concentrations of phosphorous and nitrogen were often below detection limits for SRP and TKN. Overall, hardness within the Project area increased slightly from May to August. This increase may reflect a situation in which, as temperatures rise and flows decrease, the groundwater influence may increase elevating the rate of limestone dissolution thus raising the hardness level, or as flows decrease there is less dilution of the calcium hydroxide for the limestone.

6.2. Production

Limiting factors to production—specifically light, nutrient concentrations, and reservoir retention time—were compared to chlorophyll *a* concentrations and zooplankton densities.

Light may be limiting productivity seasonally and in deeper zones of the reservoir. Nutrients (specifically phosphorus) are limited within the system; N:P ratios calculated for the Project indicate that the system is phosphorus limited and mesotrophic to oligotrophic. Retention time also appears to be a major limiting factor to production in the Project area. When reservoir retention time is less than 3 days, phytoplankton production is limited based on reproduction rates (Uhlmann 1971); Boundary Reservoir has an average retention time of less than 2 days.

Chlorophyll *a* concentrations measured within Boundary Reservoir also indicate that the system is oligotrophic to mesotrophic. During spring runoff in May and June, increased nutrients and phytoplankton cells from upstream of the Project area cause chlorophyll *a* concentrations to be higher than in July and August. During July and August, chlorophyll *a* concentrations decrease to below 2.8 μg/L, which is indicative of an oligotrophic or low productivity system.

The zooplankton community is limited by food availability in the Project area, which is dictated to a large degree by input from Box Canyon reservoir. Population size is also limited by low retention time in Boundary Reservoir, which limits food supply (phytoplankton primary producers) and flushes zooplankton from the reservoir at a rate faster than they can reproduce.

In summary, the productivity of Boundary Reservoir appears to be governed by the physical characteristic: hydrology and limited nutrients in the reservoir. Phytoplankton production is limited by the low retention time, low nutrients, and limited light, and the zooplankton production is then limited by the reduced primary production.

7 VARIANCES FROM FERC-APPROVED STUDY PLAN AND PROPOSED MODIFICATIONS

At the time of this interim report there have been three variances from the FERC-approved RSP. One variance was the depth at which hardness grab samples were collected. The RSP stated that hardness samples would be collected 1 meter from the bottom of the reservoir. Due to equipment malfunction, hardness samples were collected at the surface during May for all sites, at the surface for sites V5 and V6 during June, and at 40 feet for sites V3, V4, V5, and V6 in August. All of July's hardness samples were collected at the bottom. In order to determine whether surface and bottom hardness concentrations were similar or significantly different, both surface and bottom samples were collected in July for sites V3 and V6.

Another variance was the inability of field crews to collect the 15-foot pelagic chlorophyll *a* sample during May because of an equipment malfunction. Field crews were able to collect a sample at 15-foot depth during all other sampling events.

There was a small schedule variance from the RSP concerning the zooplankton diurnal drift sample collection. The RSP calls for spring drift zooplankton data to be collected during May. However, high flows in the reservoir during May 2007 precluded proper operation of the sampling equipment, i.e., high flows prevented field crews from conducting vertical tows because sampling equipment moved diagonally through the water column. As a result, spring zooplankton samples were collected in June 2007.

There are no planned modifications for 2008 study effort.

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Appendix 1. Quality Assurance Project Plan

Boundary Hydroelectric Project
FERC No. 2144

Study 5

Water Quality Constituent and Productivity Monitoring in Boundary Reservoir, Pend Oreille County, Washington

Quality Assurance Project Plan

Prepared for:
Seattle City Light

August 2007

Prepared by
Darlene Siegel, David Cline, Kari Kimura, Shannon Brattebo,
Eugene Welch, and Harry Gibbons
Tetra Tech, Inc.

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Study No. 5: Water Quality Constituent and Productivity Monitoring
Quality Assurance Project Plan
Boundary Hydroelectric Project (FERC No. 2144)

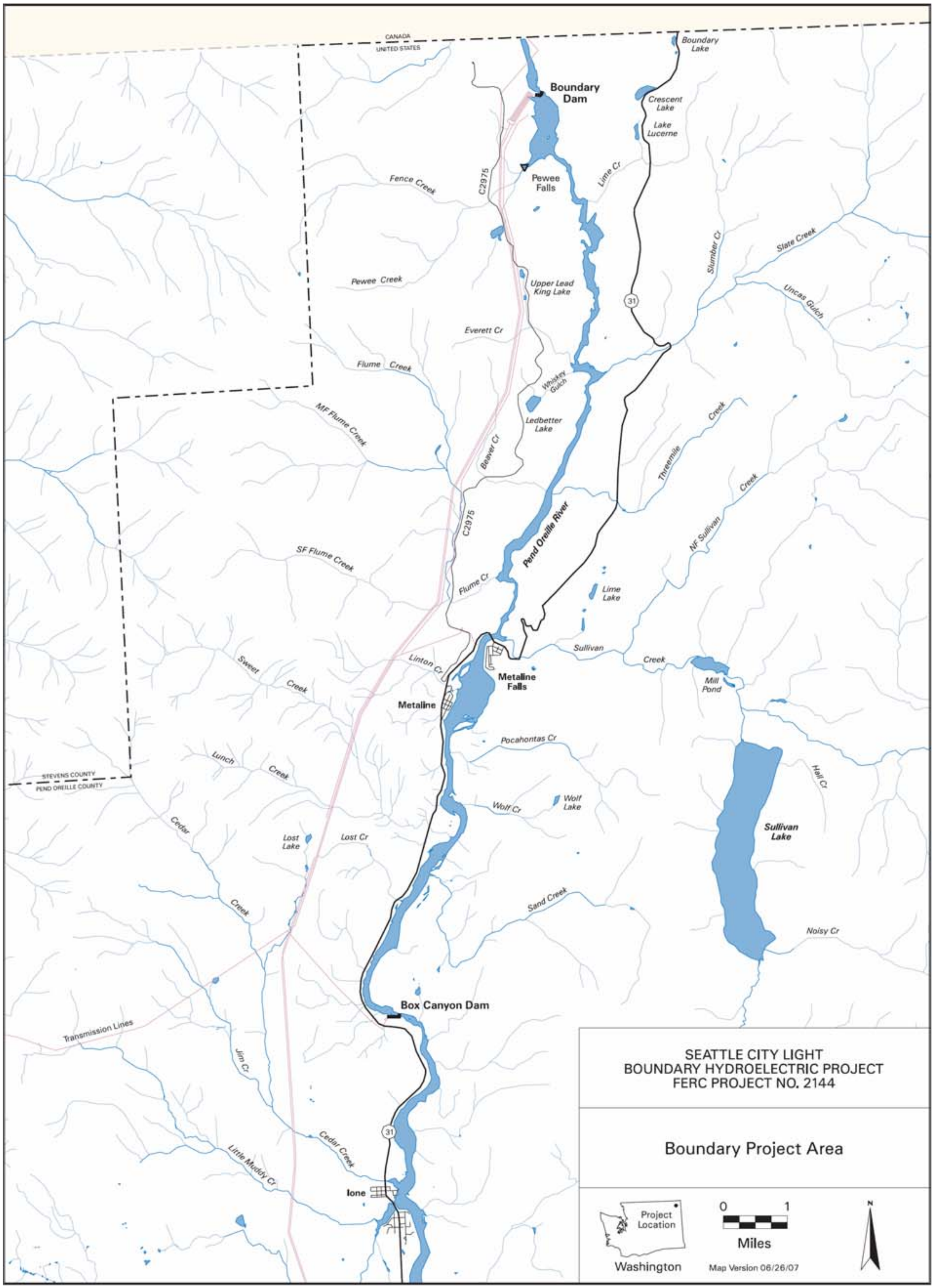
1 BACKGROUND

As part of the Federal Energy Regulatory Commission (FERC) relicensing requirements, Seattle City Light (SCL) must apply for certification under Section 401 of the Clean Water Act. The application for 401 certification requires characterization of existing water quality conditions in the Boundary Hydroelectric Project (Project) and an assessment of whether water quality meets Washington Department of Ecology (Ecology) regulatory standards. Water quality issues in Boundary Reservoir appear to be limited to pH, total dissolved gas (TDG), water temperature, and toxics. Existing information does not indicate exceedences of Ecology criteria for other water quality parameters.

The operation of the Project has the potential to impact water quality in the Pend Oreille River within the Project area. In support of 401 certification and FERC relicensing, potential impacts must be evaluated. Although some historical information exists, additional and ongoing data on specific water quality constituents are needed to evaluate potential Project operational effects. In addition, data on the productivity of the reservoir are needed to support evaluations of potential Project operational effects on aquatic habitat and fauna. Boundary Project studies are specifically designed to meet FERC relicensing requirements, but may also be relevant to recent or ongoing management activities by other entities.

This quality assurance project plan (QAPP) is being prepared to document the quality assurance (QA) and quality control (QC) measures to be observed to ensure that the following objectives are met: data are consistent, correct, and complete, with no errors or omissions; QC sample results have been reviewed and are included; established criteria for QC results are met; measurement quality objectives have been met, or data qualifiers are properly assigned where necessary; and data specified in the sampling process design are obtained. Data collection methods will follow established Ecology and U.S. Environmental Protection Agency (EPA) guidelines.

The Boundary Project is located on the Pend Oreille River in northeastern Washington, one of a total of eleven hydroelectric and storage projects within the Clark Fork - Pend Oreille River basin. Boundary Dam is located 1 mile south of the Canadian border, 16 miles west of the Idaho border, 107 miles north of Spokane, and 10 miles north of Metaline Falls (Figure 1). The dam is at Project river mile (PRM) 17.0 on the Pend Oreille River.


SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Boundary Project Area
Project Location
Washington
Miles
Map Version 06/26/07
Boundary Dam
Box Canyon Dam
Metaline Falls
Metaline
Ione
Pend Oreille River
Sullivan Lake
Pewee Falls
Boundary Lake
Crescent Lake
Lake Lucerne
Upper Lead King Lake
Ledbetter Lake
Lime Lake
Wolf Lake
Lost Lake
Mill Pond
Transmission Lines
CANADA
UNITED STATES
STEVENS COUNTY
PEND OREILLE COUNTY

2 PROJECT DESCRIPTION

The goals of Study No. 5, *Water Quality Constituent and Productivity Monitoring*, are to evaluate existing water quality conditions in and immediately downstream of Boundary Reservoir in support of the application for 401 certification and fish and aquatic resource studies under the FERC relicensing efforts. These goals will be accomplished by two objectives. The first is to characterize water quality conditions in and immediately downstream of the reservoir to determine if the Project meets Ecology's water quality standards in support of the 401 certification application. The second is to collect nutrient, primary productivity, and zooplankton data in support of the assessment of reservoir productivity being conducted as part of the Fish and Aquatic resource studies. To meet these objectives, data will be collected in both the pelagic and littoral zones of the reservoir.

Although SCL has been collecting water quality data since 2004, nutrient (nitrogen and phosphorus) data have been collected only in 2006 and only limited chlorophyll *a*, phytoplankton, and zooplankton data have been collected; these parameters will be addressed as part of the study. Water quality parameters, including pH, dissolved oxygen (DO), nutrients, and phytoplankton/zooplankton abundance are important factors determining the quality of fish habitat and food supply. Additional data are needed to characterize these and other parameters in and immediately downstream of Boundary Reservoir to assess fish habitat suitability. In addition, water quality data are needed to assess Project effects on primary and secondary production in the reservoir.

The water quality monitoring will consist of two components one year of water quality and productivity data collection, and seasonal zooplankton drift data collection. The water quality constituent monitoring will consist of data collection at eight sampling stations during eight months of a one-year period. Monthly samples (grab and *in situ* samples) will be collected from May through September 2007, in November 2007, and in January and March 2008. Water quality monitoring will include the following parameters: temperature, pH, DO, conductivity, Secchi depth, chlorophyll *a*, nutrients, zooplankton, hardness, and turbidity.

The second component of the study includes collection of seasonal zooplankton drift data downstream of Box Canyon and Boundary dams to quantify the movement of zooplankton into and out of Boundary Reservoir. Downstream of both dams, samples will be collected before, during, and after Project startup to quantify the impact of Project operations on zooplankton movement. Data will be collected in the summer, winter, and spring, and sampling will coincide with other water quality monitoring. Summer sampling will be conducted in either July or August, winter sampling in January, and spring sampling in May. Work products for the Water Quality Constituent and Productivity Monitoring Study consist of this QAPP, a productivity data compilation, an interim study report, and a final study report.

3 ORGANIZATION AND SCHEDULE

This section provides an overview of the staffing organization and schedule. The key personnel involved in the Water Quality Constituent and Productivity Monitoring Study in Boundary Reservoir are listed in Table 1.

Table 1: Project/task organization and responsibility summary.

Personnel	Responsibility	Address/E-Mail	Phone Number
Christine Pratt, Seattle City Light	Responsible for project coordination with local, county, state, and federal government officials; and for reviewing drafts of the study plan, QAPP and summary data reports	Seattle City Light City Municipal Building Suite 3300 P.O. Box 34023 700 Fifth Avenue Seattle, Washington 98104	206-386-4571
Harry Gibbons Tetra Tech, Inc	Responsible for managing the project, preparing the project QAPP, coordinating and completing sampling activities, analyzing project data, and preparing the draft and final data reports. Serves as the principal project team contact for the technical aspects of the study	Tetra Tech, Inc. 1420 5th Ave. Suite 550 Seattle, WA 98101 Harry.Gibbons@tetratech.com	206-728-9655
Shannon Brattebo, Project Field Lead, Tetra Tech, Inc.	Responsible for field sampling assistance, quality assurance and quality control of field protocols.	Tetra Tech, Inc. 1420 5th Ave. Suite 550 Seattle, WA 98101	509-442-2135
Gene Welch, Tetra Tech, Inc.	Reviews QAPP and all Ecology quality assurance programs. Provides technical assistance on QA/QC issues during the implementation and assessment of the project.	Tetra Tech, Inc. 1420 5th Ave. Suite 550 Seattle, WA 98101	206-728-9655
Steve Lazoff, Aquatic Research Inc.	Responsible for coordinating requests for analysis, scheduling sample processing, and providing access to project water quality data.	Aquatic Research, Inc. 2927 Aurora Ave. N Seattle, WA 98103	206-632-2715
Maribeth Gibbons, WATER Environmental Services, Inc.	Responsible for coordinating request for analysis, scheduling sample processing, and providing access to zooplankton data.	WATER Environmental Services, Inc. 9515 Windsong Loop NE Bainbridge Island, WA 98110	206-842-9382

The Water Quality Constituent and Productivity Monitoring at Boundary Reservoir will begin in May 2007 and will continue through March 2008. The exact scheduling of the monthly and seasonal sampling will be coordinated between SCL and Tetra Tech staff. Table 2 gives the projected schedule of activities and deliverables.

Table 2: Projected schedule of activities and deliverables.

Phase	Target Date
QAPP	March 31, 2007
Site reconnaissance	April 2007
Field collection of water quality and productivity data	May 2007 – March 2008
Prepare interim study report (first-year results)	November – December 2007
Distribute interim study report	January 2008
Meet with relicensing participants to review first year efforts and results and discuss plans for any second year efforts	February 2008
Include interim study report in Initial Study Report (ISR) filed with FERC	March 2008
Hold ISR meeting and file meeting summary with FERC	March 2008
Data review and report preparation	May–June 2008
Prepare “draft” final study report	October – November 2008
Distribute “draft” final study report for relicensing participant review	December 2008
Meet with relicensing participants to review study efforts and results and “cross-over” study results	January 2009
Include final study report in Updated Study Report (USR) filed with FERC	March 2009
Hold USR meeting and file meeting summary with FERC	March 2009

4 QUALITY OBJECTIVES

Measurement quality objectives (MQOs) are the performance or acceptance criteria for individual data quality indicators, including precision, bias, and sensitivity (Ecology, 2004). The MQOs[1] for this project are presented in Table 3. Industry standard field methods will be used throughout this project to minimize measurement bias (systematic error) and to improve precision (to reduce random error). All laboratory-bound samples will be collected, preserved, stored, and otherwise managed using accepted procedures for maintaining sample integrity prior to analysis (Ecology, 1993).

Table 3: Measurement quality objectives.

Parameter	Check Standard (LCS) % Recovery Limits	Duplicate Samples RPD	Matrix Spikes % Recovery Limits	Matrix Spike Duplicates RPD	Lowest Concentration of Interest Units of Concentration
pH (field)[(a)]	± 0.2 pH units	± 0.1 pH units	NA	NA	0.1
Conductivity (field)[(a)]	± 10 µmhos/cm	± 10 %	NA	NA	25 µmhos/cm @ 25 ºC
Temperature (field) [(a)]	± 0.1 ºC	± 5 %	NA	NA	0.1 ºC
Dissolved Oxygen (field) [(a)]	± 0.2 mg/L	NA	NA	NA	0.2 mg/L
Turbidity (field) [(a)]	5 TU	±10%	±10%	±10%	5 TU
Laboratory analyses					
Chlorophyll a	0.0001 mg/L	±20%	±20%	±20%	0.0001 mg/L
Kjeldahl nitrogen	0.010 mg/L	±20%	±20%	±20%	0.010 mg/L
Total phosphorus	0.002 mg/L	±20%	±20%	±20%	0.002 mg/L
Orthophosphorus	0.001 mg/L	±20%	±20%	±20%	0.001 mg/L
Hardness	3.0 mg/L as $CaCO_3$	±20%	±20%	±20%	3.0 as mg/L $CaCO_3$
Zooplankton	# organisms/L	±20%	NA	NA	# organisms/L

(a) = pH, conductivity, DO, temperature, and turbidity are field measured parameters. Values are stated in terms of maximum allowable differences from the field check standards. Accuracy will be ensured by twice per day (pre and post-sampling) calibration and standard checks. Field temperatures will be verified by comparing difference in pre-calibrated instrument thermistors.

Frequency of Quality Control Samples - For samples analyzed at a commercial laboratory, the type and frequency of the quality control samples to be analyzed are summarized in Table 4 (Chlorophyll *a*, nutrients, and hardness).

Table 4: Quality control samples.

Type of Quality Control Sample	Description	Frequency
Method Blank	Reagent grade sample matrix analyzed to provide an indication of laboratory contamination.	One per sample batch. Maximum sample batch equals 20 samples.
Check Sample	Generally purchased, prepared independently from analytical standards and used to provide an indication of the accuracy of the analytical determination.	Random through the study, but not more than twice annually.
Laboratory Duplicate	A second aliquot of a sample, processed in exactly the same manner.	One per sample batch. Maximum sample batch equals 20 samples.
Matrix Spike	An aliquot of a sample to which known quantities of analytes are added, processed in exactly the same manner.	One per sample batch. Maximum sample batch equals 20 samples.
Field Replicate	A split sample, labeled in a similar manner as regular samples, submitted to laboratory, and processed in exactly the same manner.	One per sample batch. Maximum sample batch equals 20 samples.

Precision - Precision is defined as the degree to which a set of observations or measurements of the same property, obtained under similar conditions, conform to themselves. Precision is usually expressed as standard deviation, variance, or range, in either absolute or relative terms. Laboratory replicates for assessment of precision will be analyzed at no less than a 5 percent frequency of the total number of samples submitted to the laboratory.

For sample results that exceed the reporting detection limit (RDL), the relative percent difference (RPD) will be less than or equal to 20 percent, see Table 4 for details. No criteria are presented for duplicates that are below the RDL, as these data are provided for informational purposes only. When one or more of the results is below the RDL, professional judgment will be used in determining the compliance of the data to project requirements.

Bias - Bias provides an indication of the accuracy of the analytical data. To assess analytical bias, method blanks that are below detection limits, reporting limits, and percent recovery of target analytes from reagent matrix will be employed. Check samples will be used to provide compliance criteria for bias. The percent recovery of the matrix spikes and standard reference materials will be less than or equal to ± 20 percent. The use of matrix spike recovery will provide additional information regarding method performance on actual samples. The laboratory and Tetra Tech's Project Manager, Harry Gibbons, will use professional judgment regarding reanalysis triggered by matrix spike recovery.

Representativeness - Sample representativeness is the degree to which data accurately and precisely represent a characteristic of a population. Representativeness will be addressed at two distinct points in the data collection process. During sample collection, the use of generally accepted sampling procedures applied in a consistent manner throughout the project will help ensure that samples are representative of conditions at the point where the sample was taken. During subsampling (sample aliquot removal) in the laboratory, samples will be inverted several times to ensure that the analytical subsample is well mixed and therefore representative of the sample container's contents. Depending upon the sampling parameter, samples will be collected at different depths as discussed in the sampling plan.

Completeness - Completeness is a measure of the amount of valid data needed to meet the project's objectives. Completeness will be judged by the amount of valid data compared to the data expected. Valid data are those data in compliance with the data quality criteria as presented in this section, and in compliance with required holding times. While the goal for the criteria described above is 100 percent completeness, a level of 95 percent completeness will be considered acceptable. However, any time data are incomplete, decisions regarding resampling and/or reanalysis will be made. These decisions will take into account the project data quality objectives as presented above.

Comparability - Comparability is a measure of the confidence with which one dataset can be compared to another. This is a qualitative assessment and is addressed primarily by sampling design through use of comparable sampling procedures or, for monitoring programs, through consistent sampling of stations over time. In the laboratory, comparability is assured through the use of comparable analytical procedures and ensuring that project staff are trained in the proper application of the procedures. Within-study comparability will be assessed through analytical performance (quality control samples).

Detection Limits - Method detection limits, field measurement resolution and laboratory methods for water quality variables analyzed for the Boundary Reservoir monitoring program are listed in Table 5.

Table 5: Detection limits, field measurement resolution, reporting detection limits and analytical methods for water quality data.

Water Quality Parameter	Units	Detection Limit	Field Measurement Resolution	Reporting Detection Limits	Method
Temperature	ºC	0.01	0.5	0.5	Thermometer
Dissolved Oxygen	mg/L	0.2	0.2	0.2	Winkler titration or dissolved oxygen meter
pH	pH units	0.01	0.1	0.1	pH meter
Conductivity	µmhos/cm	5	5	5	Conductivity meter
Turbidity	Nephelo-metric Turbidity Units (NTUs)	5	5	5	Hach turbidimeter
Secchi Disk Transparency	m	0.1	0.1	0.1	Black/White Secchi Disk
Chlorophyll-*a*	mg/L	0.0002		0.0002	SM-10200H
Nutrients -					
Kjeldahl nitrog	mg/L				EPA-351.1, SM-4500NORGC
Total Phosphorus, TP	mg/L	0.0002		0.0002	Automated, ascorbic acid SM-4500P
Ortho-phosphorus	SRP in mg/l	0.0001		0.0002	SM-4500PF
Hardness	mg/L	3.0 as $CaCO_3$		3.0 as $CaCO_3$	EDTA Titration or Calculation - SM 2340C
Zooplankton	organisms/L	1		1	Microscope examination

5 SAMPLING PROCESS DESIGN

Water quality monitoring will include three primary types of sampling: in-situ water quality data collection, point or interval specific grab samples requiring lab analysis, and vertical “tow” integrated samples requiring lab analysis. Table 6 is a summary of the water quality monitoring parameters of interest, sampling methods, depth position, equipment, sensor or measurement range, and measurement and reporting accuracy. Table 7 is a summary of sampling locations and identification of which parameters will be sampled. The sampling locations are shown in Figures 2 through 9. The samples will be collected during the schedule period identified in Table 8.

Table 6: Water quality monitoring parameters.

Parameter	Units	Sampling Method	Sampling Depth Position	Measurement Equipment	Sensor or Measurement Range	Measurement and Reporting Accuracy
Temperature (Temp)	Degrees Celsius (°C)	Vertical profile of entire water column	10 measurements (minimum) at evenly spaced intervals	Hydrolab MS5	-5.0°C to 50.0°C	±0.1 °C
pH	Negative logarithm of the hydrogen ion concentration	Vertical profile of entire water column	10 measurements (minimum) at evenly spaced intervals	Hydrolab MS5	0.0 to 14.0 pH units	±0.2 Units
Dissolved oxygen (DO)[1]	Milligrams per liter (mg/l)	Vertical profile of entire water column	10 measurements (minimum) at evenly spaced intervals (5m intervals)	Hydrolab MS5	0.0 to 20.0 mg/l	±0.1 mg/l @ <8mg/l ±0.2 mg/l @ >8mg/l
Conductivity (Cond)	Micro Siemens per centimeter (mS/cm)	Vertical profile of entire water column	10 measurements (minimum) at evenly spaced intervals	Hydrolab MS5	0.0 to 100.0 mg/l	±0.001mS/cm
Secchi depth (Secchi)	Meters (m)	Single measurement at maximum visual depth[2]	Hand line w/ demarcation and Secchi disk	Hand line w/ demarcation and Secchi disk	n/a	±0.1m
Turbidity (Turb)	Nephelometric Turbidity Units (NTUs)	Grab sample	(1) surface pelagic (1) surface littoral	Field turbidimeter	0.0 to 1,000.0 NTU	± 1 NTU
Chlorophyll *a* (Chl *a*)	Micrograms per liter (µg/l)	Grab sample	(1) surface pelagic (Surf-Pel) (1) 15ft pelagic (15ft-Pel)[3] (4.5m) (1) surface littoral @ zooplankton stations (Surf-Litt)	Pump system sampler	N/A	±0.0001 mg/L
Nutrients (TKN, TP, SRP)	Kjeldahl nitrogen (TKN-N in mg/l), Total Phosphorus (TP in µg/l) , Orthophosphorus (SRP in µg/l)	Grab sample	(1) surface pelagic	Pump system sampler	N/A	± 0.010 mg/L
Hardness (Hard)	Parts per million (PPM)	Grab sample	(1) 1 meter above bottom pelagic (Bot-Pel)	Pump system sampler	N/A	± 3.0 as $CaCO_3$
Zooplankton (Zoo)	N/A	Vertical tows (Tow) of full profile starting 1 meter above bottom	4 tows total per section* (2) tows in littoral (Litt) region and (2) tows in	Pump system sampler	N/A	1 organism/L

Parameter	Units	Sampling Method	Sampling Depth Position	Measurement Equipment	Sensor or Measurement Range	Measurement and Reporting Accuracy
		80 micron net	pelagic (Pel) region, * (2) mid-channel tows only at tailrace locations (Mid)			
Zooplankton (Zoo)	N/A	Drift (Drift) sample, (1) sample for 20 minute period, every 2 hours, over 24 hour period	Sample taken at 1-2m depth	Pump system sampler	N/A	1 organism/L

Notes:

1 Sensor uses a trademark Hach LDO.

2 Secchi depth sampling protocols included in Section 6.

3 Need to determine if sampling at 5 meters can replace criteria of 15 feet

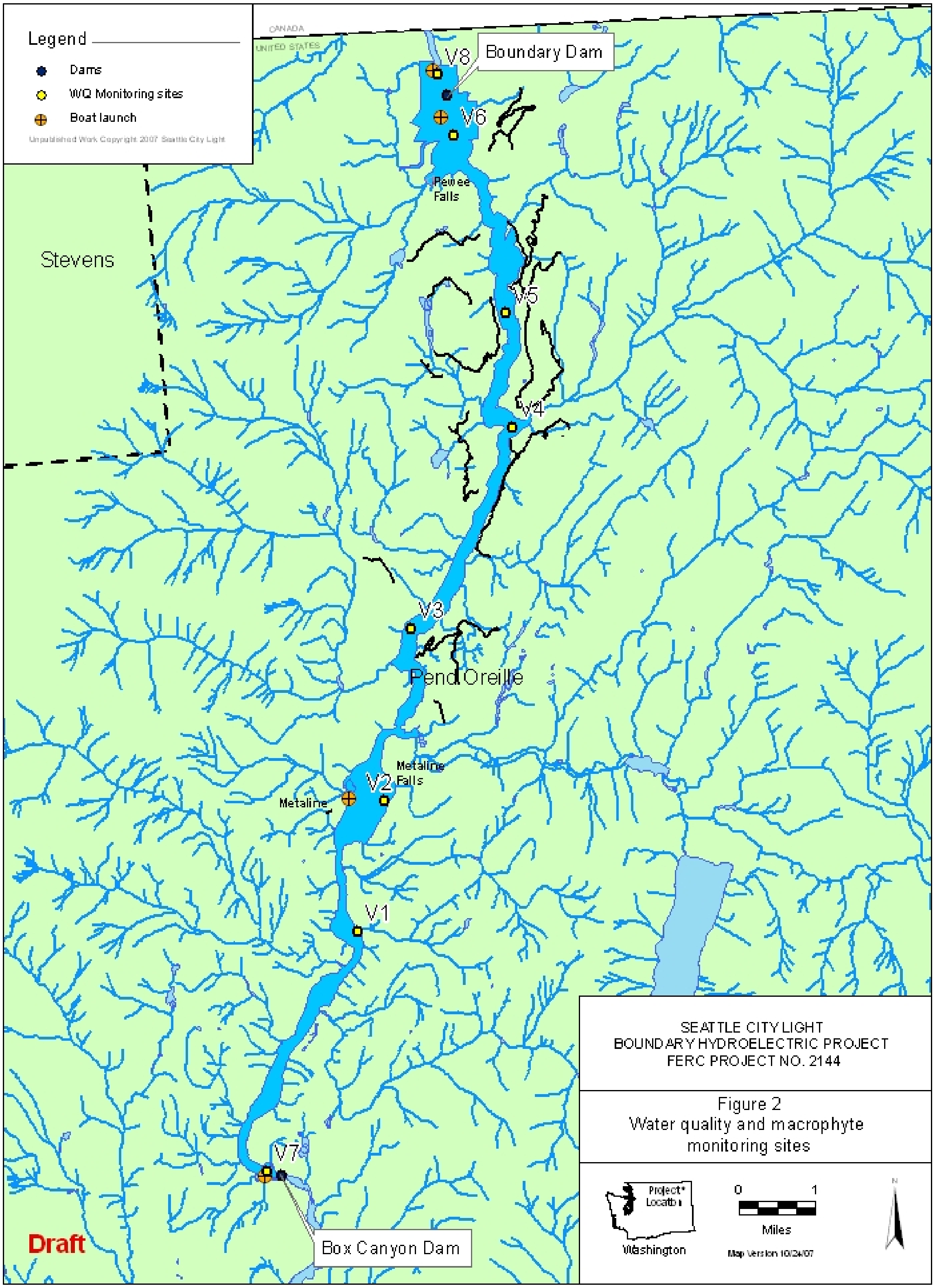
Table 7: Water quality sampling locations.

Station ID	Station Name	In-situ WQ Data Collection					WQ Grab Samples for Lab Analysis									Zooplankton Samples for Lab Analysis			
		Temp (°C)	pH	D.O. (mg/l)	Cond (mS/cm)	Secchi (m)	Chl *a* (µg/l)			Nutrients			Hard (PPM)	Turb (NTUs)		Tows			Drift
							Surf-Litt (Mid)	15ft-Pel (4.5m)	Surf-Pel	TKN (mg/l)	TP (µg/l)	SRP (µg/l)	Bot-Pel	Surf-Litt	Surf-Pel	Litt	Pel	Mid	Litt
V7	Box Canyon Tailrace	●	●	●	●	●	●			●	●	●	●					◊	●
V1	Wolf Creek	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
V2	Metaline Old	●	●	●	●	●	●	●	●	●	●	●	●						
V3	Pend Oreille Mine	●	●	●	●	●	●	●	●	●	●	●	●	●	●				
V4	Slate Creek	●	●	●	●	●	●	●	●	●	●	●	●			●	●		
V5	Everett Creek Island	●	●	●	●	●	●	●	●	●	●	●	●			○	○		
V6	Boundary Reservoir Forebay	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
V8	Boundary Tailrace	●	●	●	●	●	●			●	●	●	●	●	●			◊	●

○ Everett Island is listed in zooplankton sampling schedule Table 2.5-3.

● Tailraces chlorophyll *a* data collected at surface, mid-channel.

◊ Indicates sampling set for 20 minutes every 2 hrs for 24 hr period at mid-channel (pelagic) station.


Legend
Dams
WQ Monitoring sites
Boat launch
Unpublished Work Copyright 2007 Seattle City Light
CANADA
UNITED STATES
V8
Boundary Dam
V6
Pewee Falls
Stevens
V5
V4
V3
Pend Oreille
Metaline Falls
V2
Metaline
V1
V7
Box Canyon Dam
Draft
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure 2
Water quality and macrophyte monitoring sites
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Miles
Map Version 10/24/07
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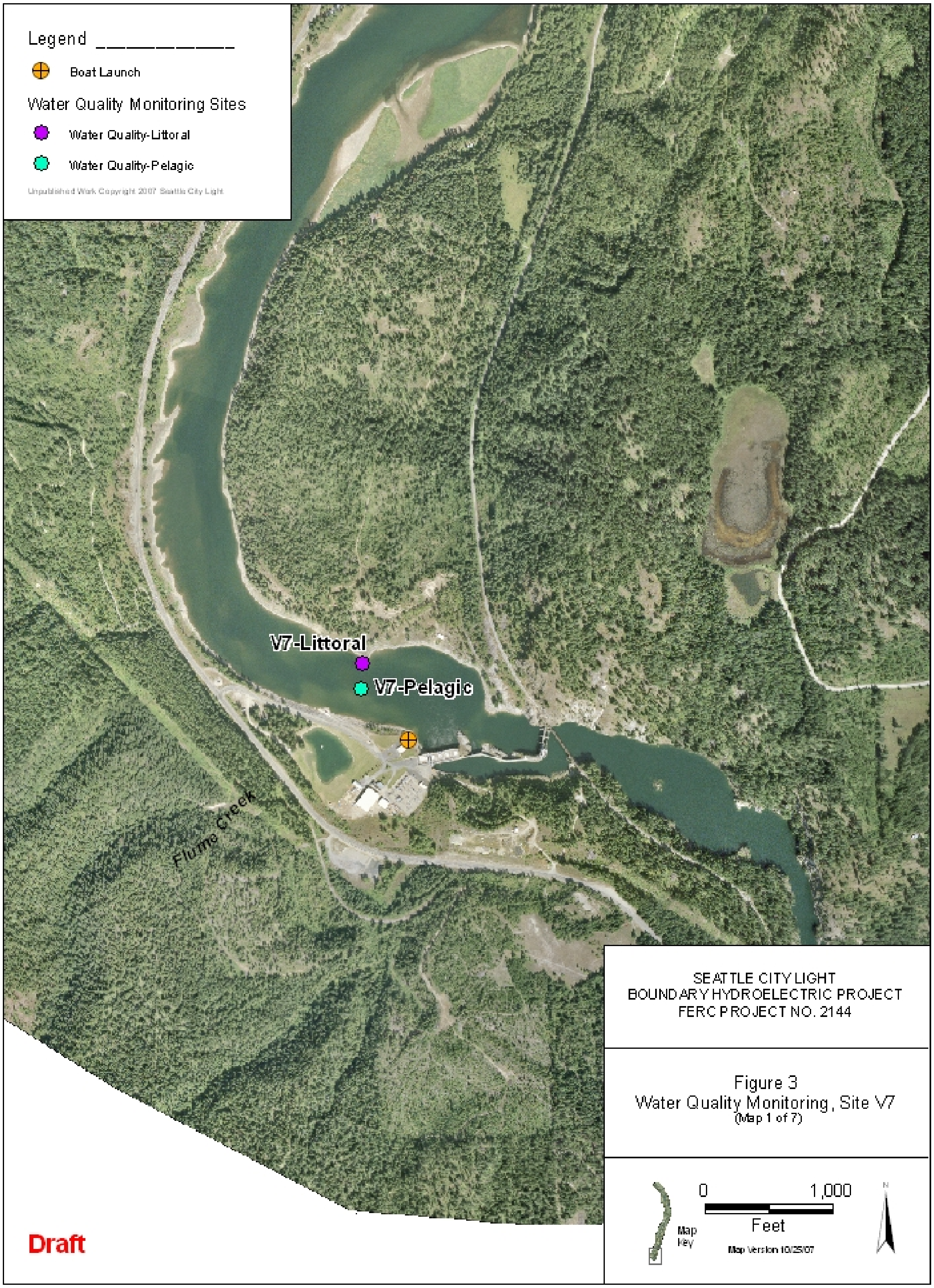
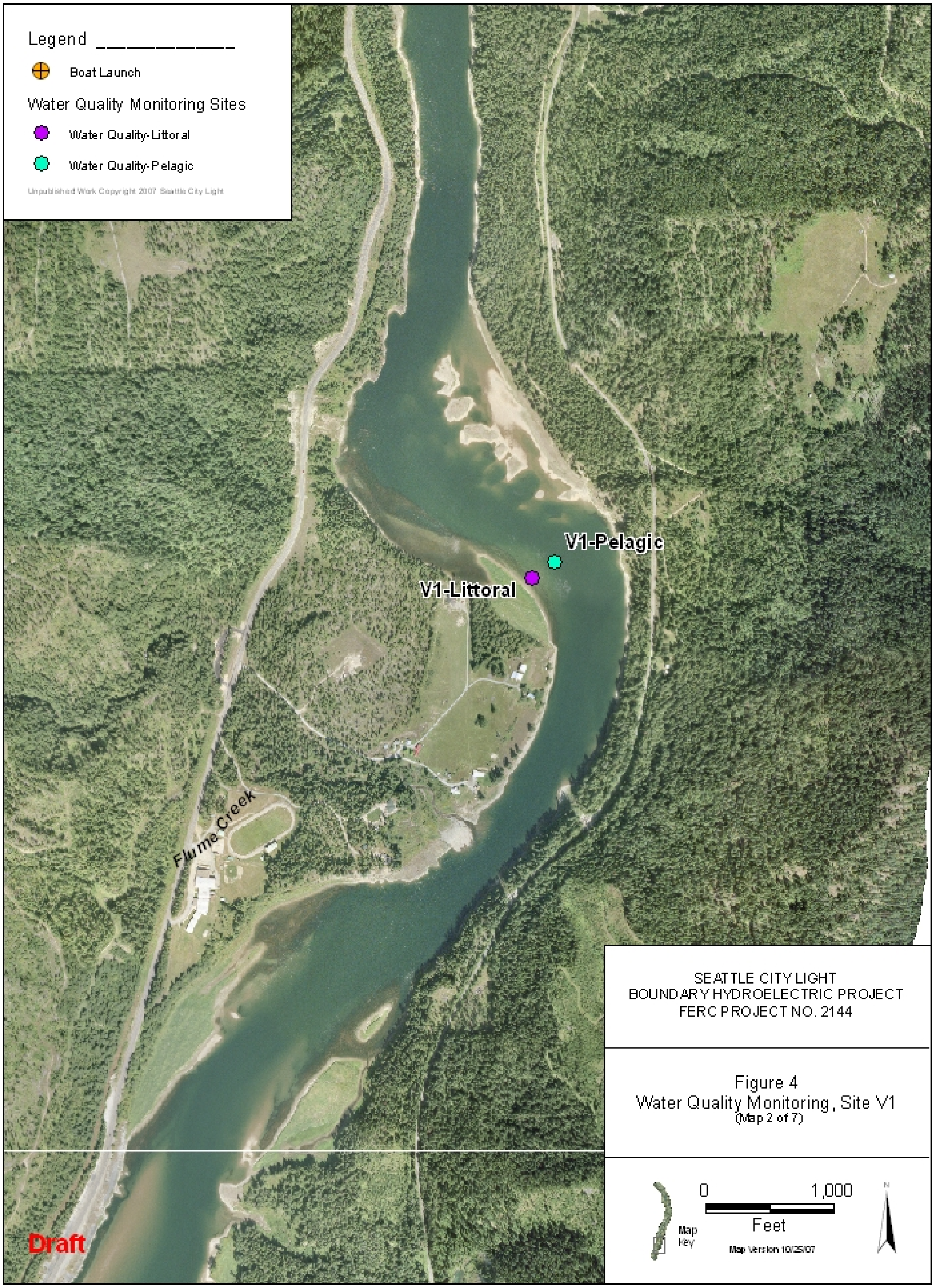
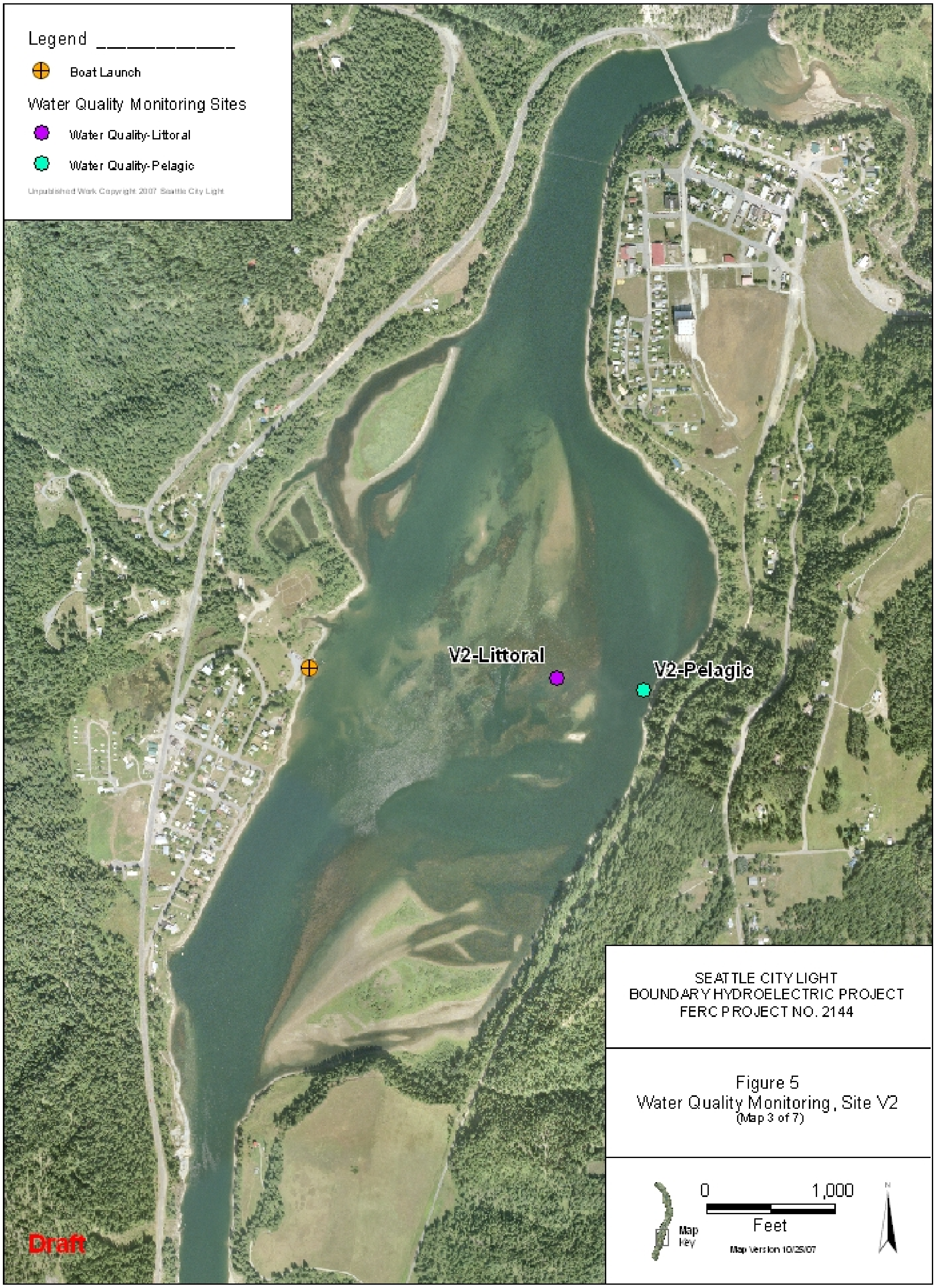
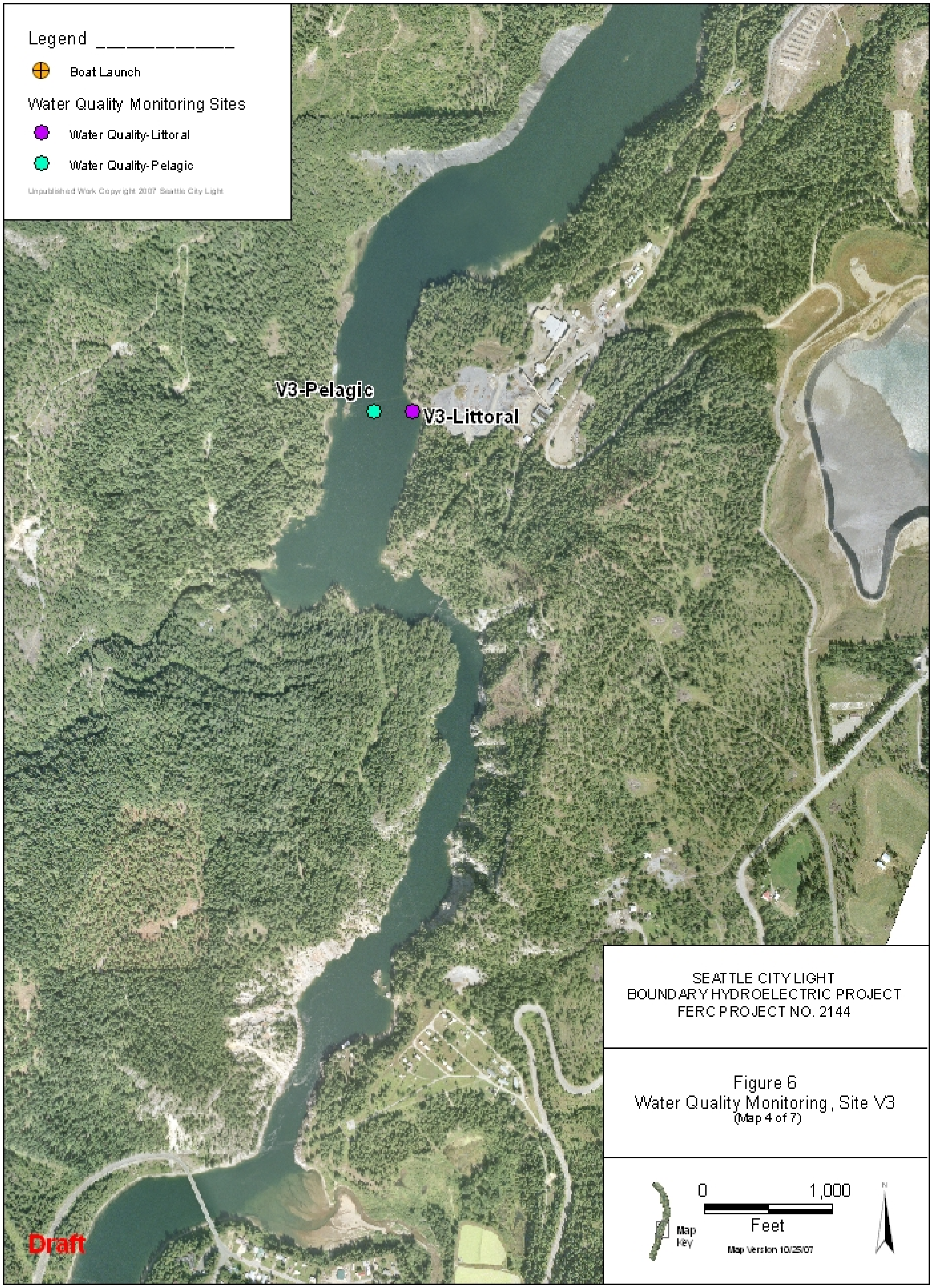
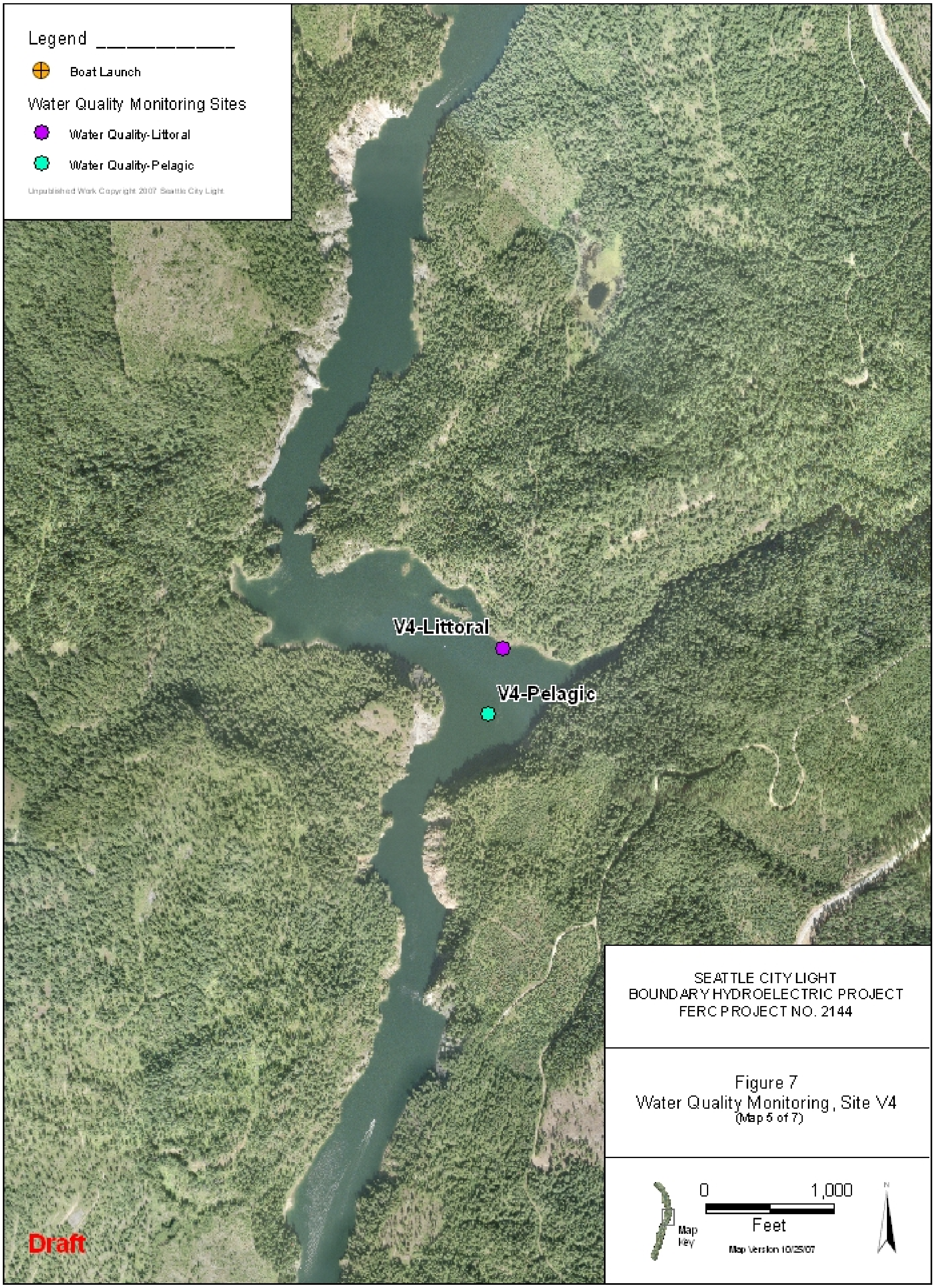


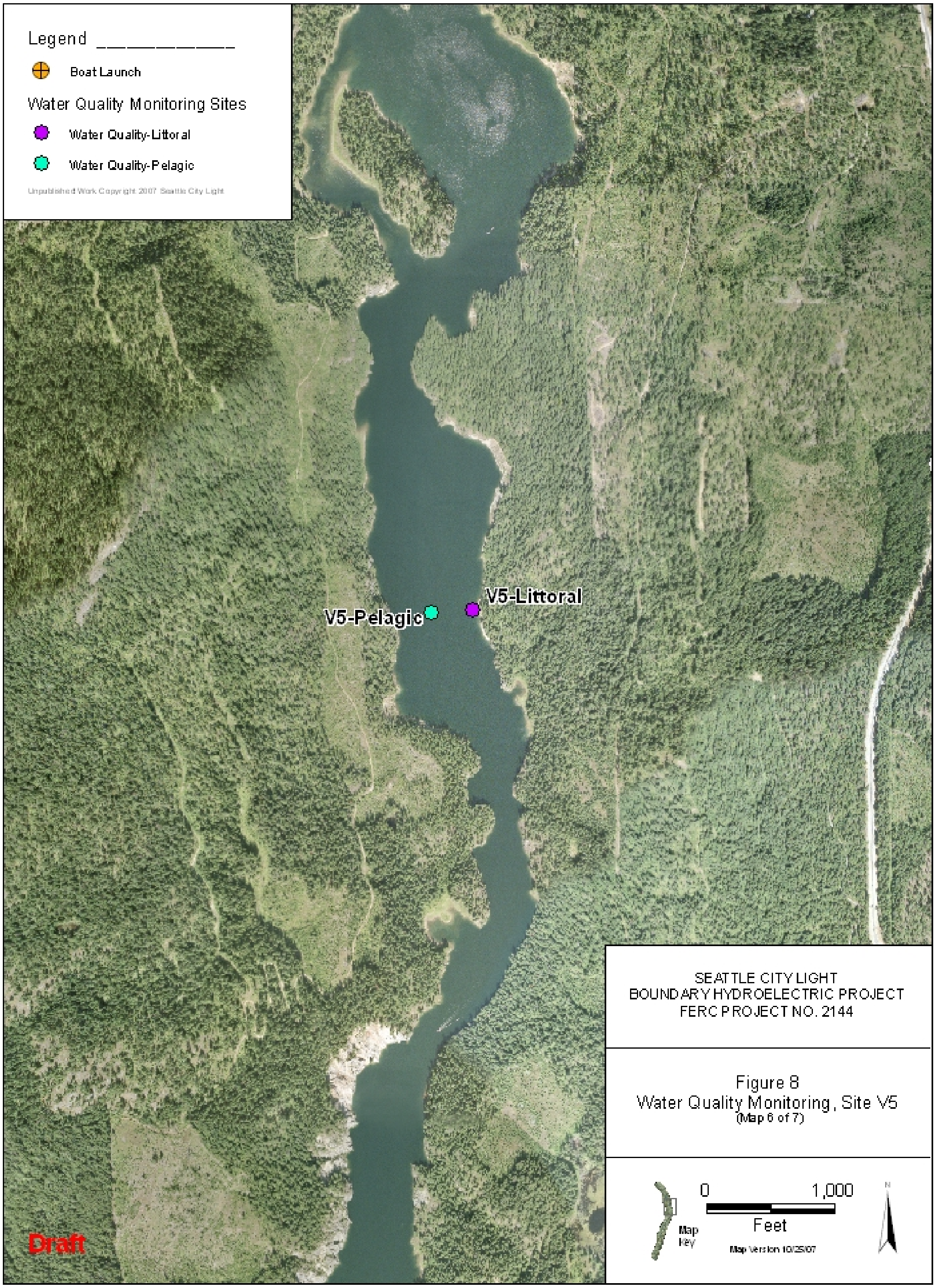
Legend
Boat Launch
Water Quality Monitoring Sites
Water Quality-Littoral
Water Quality-Pelagic
V7-Littoral
V7-Pelagic
Flume Creek
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure 3
Water Quality Monitoring, Site V7
(Map 1 of 7)
0
1,000
Feet
Map Key
Draft


Legend
Boat Launch
Water Quality Monitoring Sites
Water Quality-Littoral
Water Quality-Pelagic
Unpublished Work Copyright 2007 Seattle City Light
V1-Pelagic
V1-Littoral
Flume Creek
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure 4
Water Quality Monitoring, Site V1
(Map 2 of 7)
0
1,000
Feet
Map Key
Map Version 10/25/07
Draft


Legend
Boat Launch
Water Quality Monitoring Sites
Water Quality-Littoral
Water Quality-Pelagic
Unpublished Work Copyright 2007 Seattle City Light
V2-Littoral
V2-Pelagic
Draft
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure 5
Water Quality Monitoring, Site V2
(Map 3 of 7)
0
1,000
Feet
Map Key
Map Version 10/25/07
N


Legend
Boat Launch
Water Quality Monitoring Sites
Water Quality-Littoral
Water Quality-Pelagic
Unpublished Work Copyright 2007 Seattle City Light
V3-Pelagic
V3-Littoral
Draft
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure 6
Water Quality Monitoring, Site V3
(Map 4 of 7)
0
1,000
Feet
Map Key
Map Version 10/25/07


Legend
Boat Launch
Water Quality Monitoring Sites
Water Quality-Littoral
Water Quality-Pelagic
Unpublished Work Copyright 2007 Seattle City Light
V4-Littoral
V4-Pelagic
Draft
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure 7
Water Quality Monitoring, Site V4
(Map 5 of 7)
0
1,000
Feet
Map Key
Map Version 10/25/07


Legend
Boat Launch
Water Quality Monitoring Sites
Water Quality-Littoral
Water Quality-Pelagic
Unpublished Work Copyright 2007 Seattle City Light
V5-Littoral
V5-Pelagic
Draft
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure 8
Water Quality Monitoring, Site V5
(Map 6 of 7)
0
1,000
Feet
Map Key
Map Version 10/25/07

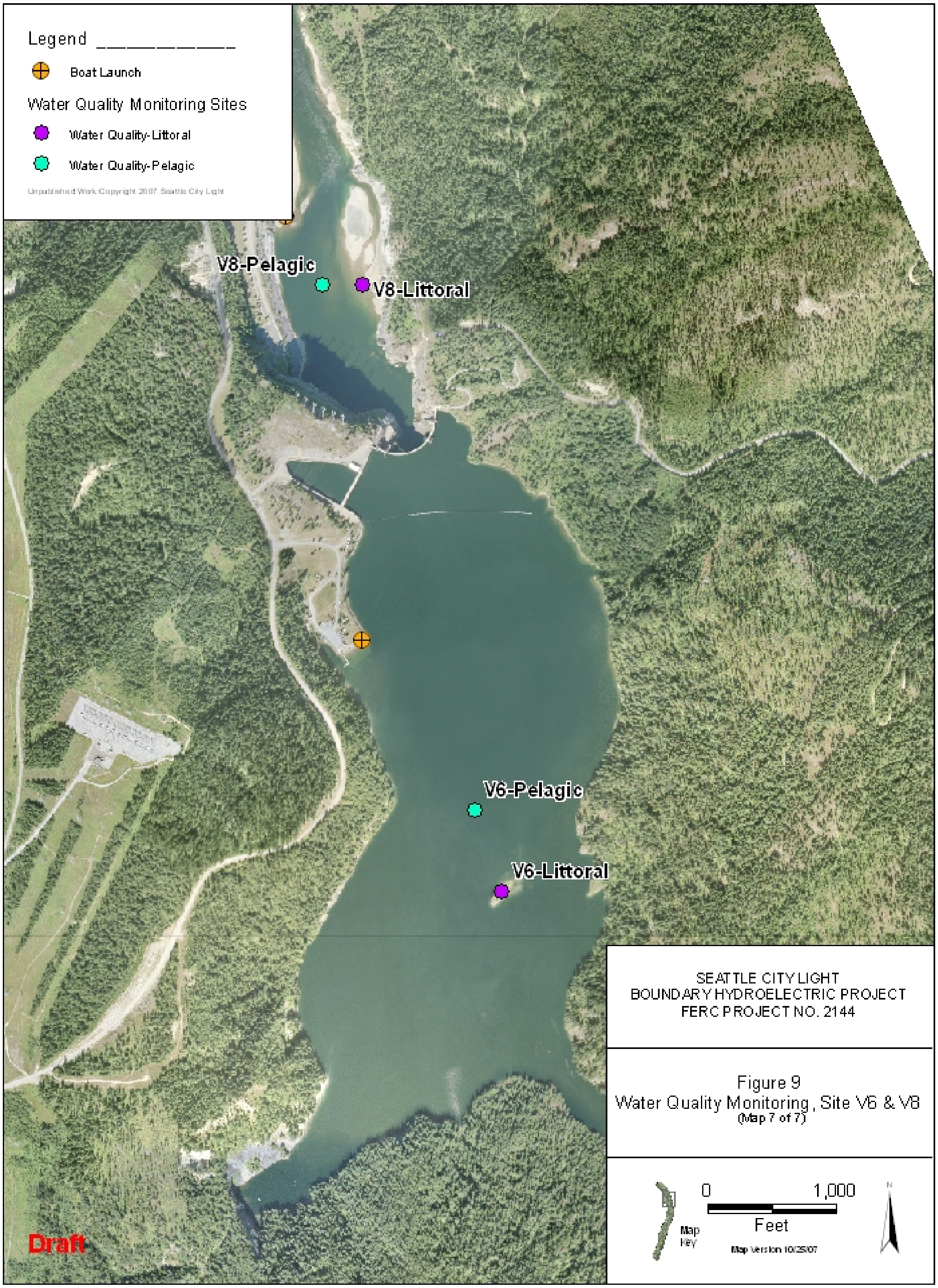

Legend
Boat Launch
Water Quality Monitoring Sites
Water Quality-Littoral
Water Quality-Pelagic
Unpublished Work Copyright 2007 Seattle City Light
V8-Pelagic
V8-Littoral
V6-Pelagic
V6-Littoral
Draft
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure 9
Water Quality Monitoring, Site V6 & V8
(Map 7 of 7)
0
1,000
Feet
Map key
Map Version 10/25/07

Table 8: Water quality monitoring schedule.

	2007								2008		
WQ Sampling and Zooplankton Tow Stations	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**
Box Canyon Tailrace (V7)	●	●	●	●	●		●		●		●
Wolf Creek (V1)	●	●	●	●	●		●		●		●
Slate Creek (V4)	●	●	●	●	●		●		●		●
Everett Creek Island (V5)	●	●	●	●	●		●		●		●
Boundary Forebay (V6)	●	●	●	●	●		●		●		●
Boundary Tailrace (V8)	●	●	●	●	●		●		●		●
Zooplankton Drift Stations (24-hr)											
Box Canyon Tailrace (V7)	○			○					○		
Boundary Tailrace (V8)	○			○					○		

○ Indicates sampling set for 20 minutes every 2hrs for 24 hr period at mid-channel (pelagic) station.

6 SAMPLING AND MEASUREMENT PROCEDURES

When visiting a sampling station, field data technicians will record the following information on a waterproof field datasheet (Figure 10).

In-situ Water Quality Data Collection **-** In-situ data on temperature, pH, DO and conductivity will be collected using a Hydrolab MS5, a multiprobe water quality sampling instrument. Calibration and sampling will be performed per the manufacturer specifications. Field data technicians will be trained for sampling and calibrating equipment, and a copy of the Hydrolab manual will be kept with the field crew during sampling operations. The Hydrolab MS5 multiprobe will be lowered through the water column either by hand or a reel system. The Hydrolab data cable will have demarcations using colored electrical tape and permanent markings for depth taken as the distance from the tip of the data sensors within the probe.

Secchi depth will be measured using Ecology's Citizen's Guide to Understanding and Monitoring Lakes and Streams (Michaud, 1994). Field data technicians will be trained in taking Secchi depth measurements and a copy of the Lake Monitoring manual will be kept with the field crew during sampling operations (Michaud, 1994).

Water Quality Grab Samples for Lab Analysis **-** Water quality grab samples to be analyzed in the laboratory will be collected with a mechanical pump system to draw samples from specific water column depths, as well as take in water through an integrated depth sampler. The automatic pump system is composed of a perforated PVC intake pipe, anchor weight, ½-in clear surgical tubing for the intake hose, a ½-in water pump, electrical connections and hand reel. Samples will be collected in polyethylene or glass containers at the pump outlet. Upon each setup, the pump will be run for a period of time to flush the hose system. Table 9 summarizes the containers, preservation techniques, and recommended and maximum sample holding times. Total phosphorus, soluble reactive phosphorus and chlorophyll-*a* samples will be collected in polyethylene bottles that have been cleaned with an acid (HCl) wash and rinsed with distilled water. A small amount of magnesium carbonate will be added to the chlorophyll-*a* sample bottles for preservation.

Turbidity will be analyzed on site using a Hach, 2100P portable turbidimeter. Sample analysis and calibration will follow the manufacturer specifications. A Hach turbidimeter laboratory manual will be kept with the field data collection crew during field sampling.

Zooplankton Samples for Lab Analysis **-** Recommended sample sizes, containers, preservation techniques, and holding times for measurement of the conventional water quality parameters are listed in Table 9. Sample containers will be kept closed and in a cooler until each set of sample containers is to be filled. Lake water samples will be collected using a pump sampler. Where flow velocities preclude use of a pump mechanism for zooplankton drift sampling the zooplankton net will be attached to a weighted cable for suspension at a defined depth.

Seattle City Light - Boundary Hydroelectric Project (FERC No. 2144)						
Study No. 5, Water Quality Constituent and Productivity Monitoring						
I. General Information						
Party:					Time:	
Date:					Weather/Temp:	
Station I.D.					Photo Numbers:	
II. WQ In-Situ Sampling Information						
Reservoir Depth (m):						
Secchi Depth (m):						
WQ In-Situ Meas. Interval (Depth/10ft):						
Interval	**Meas. Depth** (m)	**Temp** (°C)	**pH**	**D.O.** (mg/l)	**Cond** (mS/cm)	**Notes**
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

III. WQ Grab Samples

Turbidity		**Chlorophyl *a***	
Location	Reading (NTU)	Location	Sample ID
Surf-Litt		Surf-Litt	
Surf-Pel		Surf-Pel	
		15ft-Pel	

Nutrients			**Hardness**	
Location		Sample ID	Location	Sample ID
Surf-Pel	TKN-TP		Bot-Pel	
Surf-Pel	SRP			

Zooplankton			
Location	Sample ID	Location	Sample ID
Litt1		Pel (Mid)1	
Litt2		Pel (Mid)2	

IV. General Notes/Observations

Figure 10: Water quality sampling field data sheets.

Table 9: Containers, preservation techniques, and holding times for measurement of water quality parameters.

Parameters	Sample Container	Sample Volume	Preservation	Recommended Holding Time	Maximum Holding Time
Chlorophyll-*a*	Polyethylene, Glass	1,000 ml	Saturated MgCO3 in sample w/o filter. Filter (0.5-0.6mm) and freeze sample	24 hours for filtration/freezing	28 days frozen/filtered sample (hold in dark)
Nutrients (TKN, TP)	Polyethylene, Glass	100-250 ml	Cool, 4 ºC	48 hours	28 days
Nutrients (SRP)	Polyethylene, Glass	100-250 ml	Cool, 4 ºC	24 hours	24 hours
Hardness	Polyethylene, Glass	100-250 ml	Cool, 4 ºC	28 days	28 days
Zooplankton	Polyethylene	250 ml	Cool, 4 ºC Preserve 5% solution 100 parts isopropyl_10 parts formulin_10 parts glycerin	60 days	6 months

Field Sampling Decisions

Inevitably, the type of data collection described in this QAPP requires judgment and decision making in the field. The protocol for making field-based decisions will be as follows. Field sampling decisions to modify field sampling locations or methods will be made only with the approval of the field study lead. The field crew chief will document the decision on the field note sheets, and email a copy of the sheet or telephone the information to the study manager. If the field decision is large enough in scale to significantly affect the study's data, scope, schedule or budget, the field crew chief is authorized to stop work until further contact and coordination with the study lead can be performed.

During the initial site investigation in late April, the Tetra Tech study manager worked closely with the lead field crew chief and technical support engineer to layout and verify the study plan and sampling methods in the field. A discussion of potential sampling problems and a trouble shooting session was performed during the initial site investigation. During the initial site investigation work, the study team identified and characterized potential field decisions and what type of decision the field crew chief is allowed to make in the field, and what type of decisions need to be coordinated with the study manager.

Completeness

Completeness is a measure of the amount of valid data needed to meet the project's objectives. Completeness will be judged by the amount of valid data compared to the amount of data expected, as detailed in the QAPP. Valid data are those data in compliance with the data quality criteria as presented in this section, and in compliance with required holding times. While the goal for the criteria above is 100 percent completeness, a level of 95 percent completeness will be considered acceptable. However, any time data are incomplete, decisions regarding resampling and/or reanalysis will be made by Tetra Tech, Inc. These decisions will take into account the project data quality objectives as presented above.

Comparability

Comparability is a measure of the confidence with which one dataset can be compared to another. This is a qualitative assessment and is addressed primarily in sampling design through use of comparable sampling procedures or, for monitoring programs, through consistent sampling of stations over time. In the laboratory, comparability is assured through the use of comparable analytical procedures and ensuring that project staff are trained in the proper application of the procedures. Within-study comparability will be assessed through analytical performance (quality control samples).

7 SAMPLING CHAIN OF CUSTODY

Each sample bottle will have a waterproof sample identification label, tag, or permanent marker identification. All sample bottles will be labeled with an indelible marker before the time of collection. Sample labels will include station designation, date, time, collector's initials, and sample/analysis type. Special analyses to be performed and any pertinent remarks will also be recorded on the label. Total phosphorus, soluble reactive phosphorus and chlorophyll-*a* samples will be sent overnight via UPS (or other comparable carrier) to the contract commercial laboratory by Tetra Tech staff. Samples will be accompanied by the sample tracking forms with sample numbers, requested analyses, number of bottles, bottle sizes and contact information. An example of the sample tracking (or chain-of-custody) form is presented in Figure 11.

Aquatic Research Incorporated
3927 Aurora Ave. N / Seattle, WA 98103 / (206) 632-2715

CHAIN-OF-CUSTODY RECORD

CLIENT: ____________________
SAMPLING DATE: ____________________
SAMPLERS: ____________________

SHEET ________ OF ________
PROJECT ID: ____________________
CASE FILE NO.: ____________________
DATA RECORDED BY: ____________________

SAMPLE INFORMATION

SAMPLE ID	DATE/TIME COLLECTED	PARAMETERS	BOTT #	NOTES

	Relinquished By	Date/Time	Received By	Date/Time
Printed Name				
Signature				
Affiliation				

	Relinquished By	Date/Time	Received By	Date/Time
Printed Name				
Signature				
Affiliation				

Miscellaneous Notes (Hazardous Materials, Quick turn-around time, etc.): ____________________

Figure 11: Chain-of-custody record.

8 MEASUREMENT PROCEDURES

This study will employ both field measurements and collection of samples to be analyzed in the laboratory. Field and laboratory analytical procedures will follow APHA *et al*. (1998) methods. The expected detection or reporting limits for field parameters and laboratory analyses are listed in Table 5 along with the anticipated analytical method.

9 QUALITY CONTROL

Field Quality Control Procedures - Standard protocols for measuring surface water will be followed throughout this study (Ecology, 1993). All measurement equipment will be cleaned and inspected prior to use to verify that it is working properly. All field meters will be calibrated according to the manufacturers' instructions before and after each monitoring event. All pertinent information about each field meter will be recorded in field notebooks.

Accurate records of dates, times, sampler name(s), sampling location, measuring point descriptions, and other observations will be assured through the use of standardized field forms specifically designed for this activity. All field forms will be checked by the field crew chief at the completion of sampling and prior to leaving the site to ensure all measurements and sampling-related data were accurately recorded.

Field replicates will consist of a split sample, labeled in a similar manner as a regular sample. The replicate will be submitted to the laboratory and processed in exactly the same manner as a regular sample. Field replicates will be collected at one per sample batch, with a sample batch maximum of 20 samples.

Equipment and instrument logs will also be maintained and will include serial numbers, manufacturer, model number, and date of production. All maintenance and calibration protocols will be documented and their service checks will be recorded. Any deviations from written protocol will be recorded by the field technician. Calibration of equipment and instruments will be conducted by comparison with standards from the National Bureau of Standards.

Laboratory Quality Control Procedures - All samples will be analyzed by an accredited commercial laboratory. Currently, Aquatic Research Inc.'s environmental laboratory in Seattle, WA is retained by Tetra Tech to provide analytical services. Aquatic Research is accredited by the Washington Department of Ecology, and participates in audits and inter-laboratory studies by Ecology and EPA. Performance and system audits have verified the performance of the laboratory standard operating procedures, which include preventative maintenance and data reduction procedures.

Aquatic Research routinely performs QC procedures for a variety of projects. These procedures include but are not limited to: duplicates (relative percent difference), spikes (percent recovery), duplicate samples, and laboratory blanks. These routine laboratory, QC procedures will be used to demonstrate laboratory precision and accuracy and that the projects MQO's have been met. If QC requirements are not met, then all those analyses will be repeated with fresh reagents and new standards. If analysis still fails to meet QC requirements that sample will be declared invalid and not used in the data analysis.

Precision can be estimated from duplicate and check standards, duplicate sample analysis, and duplicate spiked sample analyses. Bias will be estimated from spikes, spike duplicates, and check standards. Recoveries from check standards provide an estimate of bias due to calibration. Mean percent recoveries of spiked sample analyses provide an estimate of bias due to interference. Results of quality control analyses will be reported in the same units as those expressed for the MQOs. Laboratory staff will conduct a quality assurance review of all analytical data generated at Aquatic Research, Inc. prior to releasing the data to the study lead along with a standard case narrative of laboratory QA/QC results and data qualifiers or caveats, if any. Chain-of-custody procedures will be followed throughout the project.

Records and Documentation - All analytical methods will be completely documented and referenced. Any deviation or modification from the written protocol will be noted and explained. The laboratory log will contain information that allows analytical results to be traced to specific samples and their appropriate field logs. Equipment, reagents, and other materials used will be recorded by the laboratory analyst.

Records of calculation will be maintained by the field technician and the analytical laboratory. The calculation records such as data adjustments due to QA results will include the name and signature of the person performing the calculations. The sources of all data and assumptions in the calculations will also be noted. Any corrections to the calculation will be signed and dated with explanatory notes. Equipment and instrument logs will also be maintained and will include serial numbers, manufacturer, model number, and date of production. All maintenance and calibration protocols will be documented and their service checks will be recorded. Any deviations from written protocol will be recorded by the analyst. Calibration of equipment and instruments will be conducted by comparison with standards from the National Bureau of Standards.

AQUATIC RESEARCH INCORPORATED

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: SNO001-62 **PAGE 3**
REPORT DATE: 09/11/02
DATE SAMPLED: 08/17,18/02 **DATE RECEIVED:** 08/18/02
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM SNOHOMISH COUNTY SWM

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/l)	CHLOR_a (ug/l)	PHAEO_a (ug/l)
METHOD	SM18 4500PF	SM18 10200H	SM18 10200H
DATE PREPARED	09/04/02	08/19/02	08/19/02
DATE ANALYZED	09/09/02	09/10/02	09/10/02
DETECTION LIMIT	0.002	0.1	0.1
DUPLICATE			
SAMPLE ID	SHOECRAFT IM	MARTHA N IM	MARTHA N IM
ORIGINAL	0.007	0.5	1.3
DUPLICATE	0.007	0.3	1.8
RPD	6.59%	66.67%	29.06%
SPIKE SAMPLE			
SAMPLE ID	SHOECRAFT IM		
ORIGINAL	0.007		
SPIKED SAMPLE	0.064		
SPIKE ADDED	0.050		
% RECOVERY	115.40%	NA	NA
QC CHECK			
FOUND	0.097		
TRUE	0.092		
% RECOVERY	105.27%	NA	NA
BLANK	<0.002	NA	NA

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

Figure 12. Sample QA/QC report from Aquatic Research Inc.

10 DATA MANAGEMENT PROCEDURES

At the completion of each sampling event, all field and laboratory analytical data will be compiled and evaluated against the project measurement quality objectives. Field and laboratory results will be checked for improbable or missing data. Analytical precision will be evaluated using standard statistical techniques [relative percent difference (RPD), standard deviation (s), pooled standard deviation (sp), or percent relative standard deviation (%RSD)] as appropriate. The % RSD for duplicates will be used to assess data quality relative to that listed in Table 3.

11 DATA VERIFICATION AND VALIDATION

Data verification requires confirmation by examination or provision of objective evidence that the requirements of these specified QC acceptance criteria are met. Each step of the data collection and analysis process must be evaluated and its conformance to the protocols established in this QAPP verified, including:

- Sampling design
- Sample collection procedures
- Analytical procedures
- Quality control
- Data format reduction and processing data

Validation involves detailed examination of the complete data package using professional judgment to determine whether the established procedures were followed. Validation will be done by the study lead.

Aquatic Research Inc. and Water Environmental Services, Inc. staff will review all laboratory analyses for the project to verify that the methods and protocols specified in the QAPP were followed; that all instrument calibrations, quality control checks, and intermediate calculations were performed appropriately; and that the final reported data are consistent, correct, and complete, with no omissions or errors.

Evaluation criteria will include the acceptability of instrument calibrations, procedural blanks, spike sample analysis, precision data, laboratory control sample analysis, and the appropriateness of assigned data qualifiers, if any.

The study lead ill review the laboratory data packages and case narratives to determine if the results met the MQOs for bias, precision, and accuracy for that sampling episode and to ensure that all analyses specified on the "Chain of Custody" form were performed. Field duplicate and filter blank results will be evaluated and compared to the quality objectives shown in Table 3. Based on these assessments, the data will either be accepted, accepted with appropriate qualifications, or rejected.

After the laboratory and field data have been reviewed and verified by the study lead, they will be independently reviewed as a standard procedure by a QA officer from the contract laboratory for errors before closing out the study. The initial data review will consist of a 10 percent random sampling of the project data. If any errors are discovered during the initial data review, a full independent review will be undertaken by the QA officer.

12 DATA QUALITY (USABILITY) ASSESSMENT

The data collected during this project will be used to assess surface water quality and productivity conditions within Boundary Reservoir. Assuming the project MQOs are ultimately met, the data will be deemed acceptable for use (except as qualified during the data review and validation process).

A draft data report in 2008 will be prepared and forwarded to the Seattle City Light for the data analysis completed during the summer of 2007, the remaining data for 2007 and 2008 will be reported in the final report in 2009 The report will include the following:

- Description of the project purpose, goals, and objectives.
- Map(s) of the study area and sampling sites.
- Descriptions of field and laboratory methods.
- Discussion of data quality and the significance of any problems encountered in the analyses.
- Summary tables of field and laboratory chemical data.
- Observations regarding significant or potentially significant findings.
- Recommendations based on project goals.

The final data report should be ready for inclusion into the FERC filing documents by March 2009.

13 REFERENCES

APHA, 1998. Standard Methods for the Examination of Water and Wastewater, 20th edition. American Public Health Association, Washington, D.C.

Michaud, Joy, et al., 1994. A Citizen's Guide to Understanding and Monitoring Lakes and Streams.

Seattle City Light, 2006. Revised Study Plan Boundary Hydroelectric Project (FERC No. 2144).

Washington State Department of Ecology (Ecology). 1993. Field Sampling and Measurement Protocols for the Watershed Assessment Section, Washington State Department of Ecology. 72. Publication No. 93-e04.

Ecology. 2004. Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies. July 2004. No. 04-03-030. Olympia, WA.

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Appendix 1. Field Checklist and Data Sheets

Study No. 5: Water Quality Monitoring

Field Equipment

- Pump Sampler and extra PVC intake
- Weights
- Quicklinks
- Deep Cell Batteries (2)
- Secchi Disk with rope
- Hydrolab
- Turbidimeter
- Zooplankton Nets
- VanDorn Sampler
- Depth Sounder
- Cooler
- Ice packs
- Set of Sample Bottles (21-1 liter chla bottles, 9-500ml nutrient bottles, 9-250ml hardness bottles, 21-250ml zooplankton bottles)
- Set of Extra Sample Bottles
- Ethanol Solution, 70%
- Permanent Markers, Fine Point
- Rinse Bottles
- Deionized Water
- Maps with Station Locations: Pelagic, Littoral
- Field Notebook
- Radio
- 5-gallon bucket
- Laminated Sampling Procedures
- GPS
- Digital Camera

Data to be Collected

- In-situ Water Quality Data
  - Temperature, Dissolved Oxygen, pH, conductivity
  - Secchi Disk Depth

- Grab Water Quality Data
  - Turbidity
  - Chlorophyll-*a*
  - Nutrients; TKN, TP, SRP
  - Hardness

- Vertical Tow Water Quality Data
  - Zooplankton

Seattle City Light - Boundary Hydroelectric Project (FERC No. 2144)

Study No. 5, Water Quality Constituent and Productivity Monitoring

I. General Information

Samplers:	Time:
Date:	Weather/Temp:
Station I.D.: V1 Wolf Creek	Photo Numbers:

II. WQ In-Situ Sampling Information

Reservoir Depth at Station (m):

Secchi Depth (m):	1st:		2nd:		3rd:		Avg:	

WQ In-Situ Meas. Interval (Depth/10ft):

Interval	Meas. Depth (m)	Temp (°C)	pH	D.O. (mg/l)	Cond (mS/cm)	Notes
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

III. WQ Grab Samples

Turbidity		**Chlorophyl *a***	
Location	Reading (NTU)	Location	Sample ID
Surf-Litt		Surf-Litt	
Surf-Pel		Surf-Pel	
		15ft-Pel	

Nutrients			**Hardness**	
Location		Sample ID	Location	Sample ID
Surf-Pel	TKN-TP		Bot-Pel	
Surf-Pel	SRP-filtrate			

Zooplankton			
Location	Sample ID	Location	Sample ID
Litt1		Pel (Mid)1	
Litt2		Pel (Mid)2	

IV. General Notes/Observations

Seattle City Light - Boundary Hydroelectric Project (FERC No. 2144)								
Study No. 5, Water Quality Constituent and Productivity Monitoring								
I. General Information								
Samplers:					Time:			
Date:					Weather/Temp:			
Station I.D.:	**V2 Metaline Old**				Photo Numbers:			
II. WQ In-Situ Sampling Information								
Reservoir Depth at Station (m):								
Secchi Depth (m):		1st:		2nd:		3rd:		Avg:
WQ In-Situ Meas. Interval (Depth/10ft):								

Interval	Meas. Depth (m)	Temp (°C)	pH	D.O. (mg/l)	Cond (mS/cm)	Notes
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

III. WQ Grab Samples

Turbidity		Chlorophyl *a*	
Location	Reading (NTU)	Location	Sample ID
Surf-Litt	not collected	Surf-Litt	
Surf-Pel	not collected	Surf-Pel	
		15ft-Pel	

Nutrients			Hardness	
Location		Sample ID	Location	Sample ID
Surf-Pel	TKN-TP		Bot-Pel	
Surf-Pel	SRP-filtrate			

Zooplankton			
Location	Sample ID	Location	Sample ID
Litt1	not collected	Pel (Mid)1	not collected
Litt2	not collected	Pel (Mid)2	not collected

IV. General Notes/Observations

Seattle City Light - Boundary Hydroelectric Project (FERC No. 2144)

Study No. 5, Water Quality Constituent and Productivity Monitoring

I. General Information

Samplers:	Time:
Date:	Weather/Temp:
Station I.D.: V3 Pend Oreille Mine	Photo Numbers:

II. WQ In-Situ Sampling Information

Reservoir Depth at Station (m):

Secchi Depth (m):	1st:		2nd:		3rd:		Avg:	

WQ In-Situ Meas. Interval (Depth/10ft):

Interval	Meas. Depth (m)	Temp (°C)	pH	D.O. (mg/l)	Cond (mS/cm)	Notes
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

III. WQ Grab Samples

Turbidity		**Chlorophyl *a***	
Location	Reading (NTU)	Location	Sample ID
Surf-Litt		Surf-Litt	
Surf-Pel		Surf-Pel	
		15ft-Pel	

Nutrients			**Hardness**	
Location		Sample ID	Location	Sample ID
Surf-Pel	TKN-TP		Bot-Pel	
Surf-Pel	SRP-filtrate			

Zooplankton

Location	Sample ID	Location	Sample ID
Litt1	not collected	Pel (Mid)1	not collected
Litt2	not collected	Pel (Mid)2	not collected

IV. General Notes/Observations

Seattle City Light - Boundary Hydroelectric Project (FERC No. 2144)							
Study No. 5, Water Quality Constituent and Productivity Monitoring							
I. General Information							
Samplers:					Time:		
Date:					Weather/Temp:		
Station I.D.: V4 Slate Creek					Photo Numbers:		
II. WQ In-Situ Sampling Information							
Reservoir Depth at Station (m):							
Secchi Depth (m):	1st:		2nd:		3rd:		Avg:
WQ In-Situ Meas. Interval (Depth/10ft):							

Interval	Meas. Depth (m)	Temp (°C)	pH	D.O. (mg/l)	Cond (mS/cm)	Notes
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

III. WQ Grab Samples

Turbidity		Chlorophyl *a*	
Location	Reading (NTU)	Location	Sample ID
Surf-Litt	not collected	Surf-Litt	
Surf-Pel	not collected	Surf-Pel	
		15ft-Pel	

Nutrients			Hardness	
Location		Sample ID	Location	Sample ID
Surf-Pel	TKN-TP		Bot-Pel	
Surf-Pel	SRP-filtrate			

Zooplankton			
Location	Sample ID	Location	Sample ID
Litt1		Pel (Mid)1	
Litt2		Pel (Mid)2	

IV. General Notes/Observations

Seattle City Light - Boundary Hydroelectric Project (FERC No. 2144)								
Study No. 5, Water Quality Constituent and Productivity Monitoring								
I. General Information								
Samplers:					Time:			
Date:					Weather/Temp:			
Station I.D.: V5 Everett Creek Island					Photo Numbers:			
II. WQ In-Situ Sampling Information								
Reservoir Depth at Station (m):								
Secchi Depth (m):	1st:		2nd:		3rd:		Avg:	
WQ In-Situ Meas. Interval (Depth/10ft):								
Interval	**Meas. Depth** (m)	**Temp** (°C)	**pH**	**D.O.** (mg/l)	**Cond** (mS/cm)	**Notes**		
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

III. WQ Grab Samples

Turbidity		**Chlorophyl *a***	
Location	Reading (NTU)	Location	Sample ID
Surf-Litt	not collected	Surf-Litt	
Surf-Pel	not collected	Surf-Pel	
		15ft-Pel	

Nutrients			**Hardness**	
Location		Sample ID	Location	Sample ID
Surf-Pel	TKN-TP		Bot-Pel	
Surf-Pel	SRP-filtrate			

Zooplankton			
Location	Sample ID	Location	Sample ID
Litt1		Pel (Mid)1	
Litt2		Pel (Mid)2	

IV. General Notes/Observations

Seattle City Light - Boundary Hydroelectric Project (FERC No. 2144)	
Study No. 5, Water Quality Constituent and Productivity Monitoring	
I. General Information	
Samplers:	Time:
Date:	Weather/Temp:
Station I.D.: V6 Boundary Reservoir Forebay	Photo Numbers:

II. WQ In-Situ Sampling Information

Reservoir Depth at Station (m):							
Secchi Depth (m):	1st:		2nd:		3rd:		Avg:
WQ In-Situ Meas. Interval (Depth/10ft):							

Interval	Meas. Depth (m)	Temp (°C)	pH	D.O. (mg/l)	Cond (mS/cm)	Notes
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

III. WQ Grab Samples

Turbidity		**Chlorophyl *a***	
Location	Reading (NTU)	Location	Sample ID
Surf-Litt		Surf-Litt	
Surf-Pel		Surf-Pel	
		15ft-Pel	

Nutrients			**Hardness**	
Location		Sample ID	Location	Sample ID
Surf-Pel	TKN-TP		Bot-Pel	
Surf-Pel	SRP-filtrae			

Zooplankton			
Location	Sample ID	Location	Sample ID
Litt1		Pel (Mid)1	
Litt2		Pel (Mid)2	

IV. General Notes/Observations

Seattle City Light - Boundary Hydroelectric Project (FERC No. 2144)									
Study No. 5, Water Quality Constituent and Productivity Monitoring									
I. General Information									
Samplers:					Time:				
Date:					Weather/Temp:				
Station I.D.: V7 Box Canyon Tailrace					Photo Numbers:				
II. WQ In-Situ Sampling Information									
Reservoir Depth at Station (m):									
Secchi Depth (m):		1st:		2nd:		3rd:		Avg:	
WQ In-Situ Meas. Interval (Depth/10ft):									

Interval	**Meas. Depth** (m)	**Temp** (°C)	**pH**	**D.O.** (mg/l)	**Cond** (mS/cm)	**Notes**
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

III. WQ Grab Samples

Turbidity		**Chlorophyl *a***	
Location	Reading (NTU)	Location	Sample ID
Surf-Litt	not collected	Surf-MID	
Surf-Pel	not collected	Surf-Pel	not collected
		15ft-Pel	not colleted

Nutrients			**Hardness**	
Location		Sample ID	Location	Sample ID
Surf-Pel	TKN-TP		Bot-Pel	
Surf-Pel	SRP-filtrate			

Zooplankton			
Location	Sample ID	Location	Sample ID
Litt1	not collected	Pel (Mid)1	
Litt2	not collected	Pel (Mid)2	

IV. General Notes/Observations

Seattle City Light - Boundary Hydroelectric Project (FERC No. 2144)									
Study No. 5, Water Quality Constituent and Productivity Monitoring									
I. General Information									
Samplers:						Time:			
Date:						Weather/Temp:			
Station I.D.:	**V8 Boundary Dam Tailrace**					Photo Numbers:			
II. WQ In-Situ Sampling Information									
Reservoir Depth at Station (m):									
Secchi Depth (m):		1st:		2nd:		3rd:		Avg:	
WQ In-Situ Meas. Interval (Depth/10ft):									
Interval	**Meas. Depth** (m)	**Temp** (°C)	**pH**	**D.O.** (mg/l)	**Cond** (mS/cm)	**Notes**			
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

III. WQ Grab Samples

Turbidity		Chlorophyl *a*	
Location	Reading (NTU)	Location	Sample ID
Surf-Litt		Surf-MID	
Surf-Pel		Surf-Pel	not collected
		15ft-Pel	not collected

Nutrients			Hardness	
Location		Sample ID	Location	Sample ID
Surf-Pel	TKN-TP		Bot-Pel	
Surf-Pel	SRP-filtrate			

Zooplankton			
Location	Sample ID	Location	Sample ID
Litt1	not collected	Pel (Mid)1	
Litt2	not collected	Pel (Mid)2	

IV. General Notes/Observations

Study No. 5: 24-Hour Zooplankton Monitoring

Field Equipment

- Pump Sampler and extra PVC intake
- Weights
- Quick Links
- Deep Cell Batteries (2)
- Secchi Disk with rope
- Zooplankton Nets
- VanDorn Sampler
- Depth Sounder
- Cooler
- Ice packs
- Set of Sample Bottles (25-250ml zooplankton bottles)
- Set of Extra Sample Bottles
- Ethanol Solution, 70%
- Permanent Markers, Fine Point
- Rinse Bottles
- Deionized Water
- Maps with Station Locations
- Field Notebook
- Radio
- 5-gallon bucket
- Laminated Sampling Procedures
- GPS
- Digital Camera

Data to be Collected

- In-situ Water Quality Data
  - Secchi Disk Depth

- Vertical Tow Water Quality Data
  - Zooplankton

Seattle City Light - Boundary Hydroelectric Project (FERC No. 2144)								
Study No. 5, Water Quality Constituent and Productivity Monitoring								
I. General Information								
Samplers:				Time 24-HR Period Began:				
Date:				Weather/Temp:				
Station I.D.: V7 Box Canyon Tailrace				Photo Numbers:				
II. WQ In-Situ Sampling Information								
Reservoir Depth at Station (m):								
Secchi Depth (m):	1st:		2nd:		3rd:		Avg:	
III. WQ Grab Samples								
Zooplankton								

Sample	Start Time	End Time	Sample ID
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

IV. General Notes/Observations

Seattle City Light - Boundary Hydroelectric Project (FERC No. 2144)								
Study No. 5, Water Quality Constituent and Productivity Monitoring								
I. General Information								
Samplers:				Time 24-HR Period Began:				
Date:				Weather/Temp:				
Station I.D.: V8 Boundary Dam Tailrace				Photo Numbers:				
II. WQ In-Situ Sampling Information								
Reservoir Depth at Station (m):								
Secchi Depth (m):	1st:		2nd:		3rd:		Avg:	

III. WQ Grab Samples			
Zooplankton			
Sample	Start Time	End Time	Sample ID
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

IV. General Notes/Observations

Appendix 2. Water Quality Data

Table A.2-1. In situ field data observations in Boundary Reservoir (May–August 2007).

Sample Location	Date	Depth (m)	Temperature (ºC)	pH (units)	DO (mg/L)	Conductivity (µS/cm)
V1	5/23/2007	0.5	13.00	7.98	11.35	136.3
V1	6/25/2007	0.0	17.35	8.34	10.06	149.7
V1	6/25/2007	0.8	17.35	8.34	10.03	149.1
V1	6/25/2007	1.6	17.36	8.34	10.02	149.5
V1	6/25/2007	2.4	17.34	8.35	10.03	149.9
V1	6/25/2007	3.2	17.35	8.34	10.00	149.2
V1	6/25/2007	4.0	17.35	8.33	9.97	149.4
V1	6/25/2007	4.8	17.35	8.35	9.99	149.5
V1	6/25/2007	5.6	17.35	8.32	9.98	149.7
V1	6/25/2007	6.4	17.35	8.34	9.96	149.2
V1	6/25/2007	7.2	17.35	8.34	9.95	149.4
V1	6/25/2007	8.0	17.35	8.30	9.94	149.7
V1	7/23/2007	0.0	24.30	8.23	8.80	161.6
V1	7/23/2007	1.0	24.31	8.41	8.75	161.1
V1	7/23/2007	2.0	24.31	8.40	8.78	161.0
V1	7/23/2007	3.0	24.27	8.44	8.77	161.2
V1	7/23/2007	4.0	24.25	8.47	8.74	160.8
V1	7/23/2007	5.0	24.25	8.50	8.72	161.0
V1	7/23/2007	6.0	24.25	8.51	8.72	161.3
V1	7/23/2007	7.0	24.25	8.53	8.69	161.0
V1	7/23/2007	8.0	24.23	8.55	8.68	161.5
V1	7/23/2007	9.0	24.24	8.56	8.66	160.7
V1	8/16/2007	0.0	22.07	8.60	8.12	164.6
V1	8/16/2007	0.7	22.03	8.56	8.13	164.0
V1	8/16/2007	1.4	22.01	8.54	8.12	163.5
V1	8/16/2007	2.1	22.00	8.52	8.11	163.8
V1	8/16/2007	2.8	22.00	8.55	8.10	164.0
V1	8/16/2007	3.5	22.00	8.56	8.11	164.0
V1	8/16/2007	4.2	22.00	8.54	8.08	164.0
V1	8/16/2007	4.9	22.00	8.51	8.09	163.9
V1	8/16/2007	5.6	22.00	8.46	8.07	164.1
V1	8/16/2007	6.3	22.00	8.45	8.06	164.2
V2	5/23/2007	0.5	12.99	7.92	11.17	136.7
V2	5/23/2007	2.0	12.79	8.00	11.26	137.0
V2	5/23/2007	5.0	12.80	8.01	11.32	136.8
V2	6/25/2007	0.0	17.61	8.35	10.10	149.6
V2	6/25/2007	1.0	17.49	8.33	10.07	149.4
V2	6/25/2007	2.0	17.52	8.32	10.06	149.6
V2	6/25/2007	3.0	17.39	8.31	10.02	149.6

Table A.2-1. continued…

Sample Location	Date	Depth (m)	Temperature (ºC)	pH (units)	DO (mg/L)	Conductivity (µS/cm)
V2	6/25/2007	4.0	17.41	8.28	10.00	149.8
V2	6/25/2007	5.0	17.36	8.27	9.98	149.1
V2	6/25/2007	6.0	17.34	8.27	9.97	149.4
V2	6/25/2007	7.0	17.32	8.26	9.94	149.1
V2	6/25/2007	8.0	17.32	7.93	9.91	149.7
V2	6/25/2007	8.6	17.31	8.18	9.90	149.7
V2	7/23/2007	0.0	25.12	8.39	9.58	159.1
V2	7/23/2007	0.5	25.19	8.42	9.74	158.6
V2	7/23/2007	1.0	24.55	8.35	9.74	159.3
V2	7/23/2007	1.5	24.48	8.35	9.29	160.5
V2	7/23/2007	2.0	24.44	8.31	9.18	160.8
V2	7/23/2007	2.5	24.39	8.32	9.05	160.6
V2	7/23/2007	3.0	24.41	8.33	9.03	160.9
V2	7/23/2007	3.5	24.39	8.34	8.96	160.8
V2	7/23/2007	4.0	24.32	8.36	8.94	160.7
V2	7/23/2007	4.5	24.33	8.38	8.99	161.1
V2	7/23/2007	5.0	24.32	8.39	8.98	160.5
V2	8/16/2007	0.0	22.17	8.54	7.98	164.8
V2	8/16/2007	1.0	22.11	8.52	7.98	164.4
V2	8/16/2007	2.0	22.01	8.51	7.99	164.5
V2	8/16/2007	3.0	21.95	8.51	7.97	164.8
V2	8/16/2007	4.0	21.95	8.50	7.96	164.6
V2	8/16/2007	5.0	21.92	8.50	7.94	165.0
V2	8/16/2007	6.0	21.91	8.49	7.94	165.2
V2	8/16/2007	7.0	91.90	8.49	7.91	165.2
V2	8/16/2007	8.0	21.91	8.50	7.90	164.6
V2	8/16/2007	9.0	21.91	8.50	7.89	164.6
V2	8/16/2007	9.2	21.91	8.51	7.88	164.7
V3	5/23/2007	0.5	13.08	7.88	11.42	140.0
V3	6/25/2007	0.0	15.86	8.77	9.55	147.0
V3	6/25/2007	3.0	15.82	8.62	9.64	148.0
V3	6/25/2007	6.0	15.81	8.66	9.60	147.0
V3	6/25/2007	9.0	15.81	8.68	9.53	147.0
V3	6/25/2007	12.0	15.81	8.71	9.48	147.0
V3	6/25/2007	15.0	15.80	8.64	9.46	147.0
V3	6/25/2007	18.0	15.80	8.61	9.42	147.0
V3	6/25/2007	21.0	15.80	8.59	9.38	147.0
V3	6/25/2007	24.0	15.80	8.57	9.36	147.0
V3	6/25/2007	25.0	15.79	8.65	9.44	147.0
V3	7/23/2007	0.0	24.08	8.70	8.39	162.1

Table A.2-1. continued…

Sample Location	Date	Depth (m)	Temperature (ºC)	pH (units)	DO (mg/L)	Conductivity (µS/cm)
V3	7/23/2007	3.0	23.89	8.86	8.40	162.1
V3	7/23/2007	6.0	23.88	8.89	8.33	161.9
V3	7/23/2007	9.0	23.86	8.99	8.28	162.3
V3	7/23/2007	12.0	23.85	9.00	8.22	162.5
V3	7/23/2007	15.0	23.85	9.04	8.19	162.2
V3	7/23/2007	18.0	23.85	9.07	8.14	161.9
V3	7/23/2007	21.0	23.85	9.10	8.11	162.4
V3	7/23/2007	24.0	23.84	9.09	8.08	162.3
V3	7/23/2007	27.0	23.85	9.07	8.05	162.0
V3	8/28/2007	0.0	20.22	8.45	9.06	166.4
V3	8/28/2007	2.5	19.95	8.45	8.99	166.5
V3	8/28/2007	5.0	19.94	8.45	8.95	166.6
V3	8/28/2007	7.5	19.96	8.46	8.94	166.9
V3	8/28/2007	10.0	19.94	8.45	8.89	166.8
V3	8/28/2007	12.5	19.94	8.45	8.85	166.6
V3	8/28/2007	15.0	19.94	8.46	8.82	166.6
V4	5/23/2007	0.5	13.01	8.05	11.30	140.4
V4	6/20/2007	0.0	15.47	8.32	9.32	148.0
V4	6/20/2007	3.0	15.45	8.38	9.33	148.0
V4	6/20/2007	6.0	15.45	8.44	9.29	148.0
V4	6/20/2007	9.0	15.45	8.53	9.23	148.0
V4	6/20/2007	12.0	15.44	8.54	9.19	148.0
V4	6/20/2007	15.0	15.44	8.56	9.14	148.0
V4	6/20/2007	18.0	15.44	8.59	9.16	148.0
V4	6/20/2007	21.0	15.44	8.61	9.14	147.0
V4	6/20/2007	24.0	15.44	8.60	9.12	147.0
V4	7/24/2007	0.0	24.51	8.46	8.52	161.4
V4	7/24/2007	4.0	24.38	8.28	8.70	161.7
V4	7/24/2007	8.0	24.37	8.34	8.63	161.4
V4	7/24/2007	12.0	24.38	8.33	8.59	162.0
V4	7/24/2007	16.0	24.33	8.35	8.49	161.6
V4	7/24/2007	20.0	24.33	8.37	8.46	161.4
V4	7/24/2007	24.0	24.34	8.35	8.40	161.7
V4	7/24/2007	28.0	24.34	8.37	8.36	161.7
V4	8/28/2007	0.0	20.33	8.31	8.99	166.8
V4	8/28/2007	3.0	20.16	8.33	8.93	167.2
V4	8/28/2007	6.0	20.10	8.33	8.85	167.9
V4	8/28/2007	9.0	20.12	8.32	8.82	166.9
V4	8/28/2007	12.0	20.11	8.32	8.80	167.0
V4	8/28/2007	15.0	20.11	8.32	8.74	167.0

Table A.2-1. continued…

Sample Location	Date	Depth (m)	Temperature (ºC)	pH (units)	DO (mg/L)	Conductivity (µS/cm)
V4	8/28/2007	18.0	20.11	8.32	8.72	166.9
V4	8/28/2007	21.0	20.11	8.32	8.68	167.2
V4	8/28/2007	24.0	20.11	8.32	8.64	167.3
V4	8/28/2007	27.0	20.10	8.32	8.61	167.0
V4	8/28/2007	30.0	20.09	8.32	8.58	167.0
V5	5/23/2007	0.5	13.00	7.93	11.22	140.4
V5	6/20/2007	0.0	15.69	8.06	9.22	147.0
V5	6/20/2007	6.0	15.55	8.43	9.32	148.0
V5	6/20/2007	12.0	15.55	8.51	9.22	148.0
V5	6/20/2007	18.0	15.54	8.55	9.14	148.0
V5	6/20/2007	24.0	15.53	8.54	9.16	148.0
V5	6/20/2007	30.0	15.52	8.55	9.20	148.0
V5	6/20/2007	36.0	15.52	8.58	9.12	148.0
V5	6/20/2007	42.0	15.52	8.60	9.09	148.0
V5	6/20/2007	48.0	15.52	8.61	9.07	148.0
V5	6/20/2007	54.0	15.52	8.62	9.06	148.0
V5	7/24/2007	0.0	24.91	8.43	8.39	161.6
V5	7/24/2007	5.0	24.16	8.48	8.50	161.9
V5	7/24/2007	10.0	24.07	8.54	8.34	161.7
V5	7/24/2007	15.0	24.07	8.58	8.24	161.7
V5	7/24/2007	20.0	24.06	8.60	8.16	161.5
V5	7/24/2007	25.0	24.00	8.62	8.04	161.8
V5	7/24/2007	30.0	23.99	8.63	7.98	161.6
V5	7/24/2007	35.0	23.98	8.63	7.92	161.5
V5	7/24/2007	40.0	23.96	8.63	7.83	161.7
V5	7/24/2007	45.0	23.95	8.64	7.74	161.9
V5	8/28/2007	0.0	20.88	8.31	8.87	167.6
V5	8/28/2007	6.0	20.31	8.29	8.79	167.0
V5	8/28/2007	12.0	20.25	8.27	8.67	167.5
V5	8/28/2007	18.0	20.23	8.27	8.58	167.1
V5	8/28/2007	24.0	20.23	8.26	8.47	167.1
V5	8/28/2007	30.0	20.22	8.26	8.40	167.4
V5	8/28/2007	36.0	20.23	8.26	8.34	167.2
V5	8/28/2007	42.0	20.21	8.26	8.22	167.2
V5	8/28/2007	48.0	20.20	8.25	8.17	167.4
V5	8/28/2007	54.0	20.20	8.25	8.08	167.4
V6	5/23/2007	0.5	13.22	8.34	11.23	140.8
V6	6/20/2007	0.0	15.95	8.12	9.22	147.0
V6	6/20/2007	7.0	15.61	8.17	9.27	147.0
V6	6/20/2007	14.0	15.56	8.22	9.13	147.0

Table A.2-1. continued…

Sample Location	Date	Depth (m)	Temperature (ºC)	pH (units)	DO (mg/L)	Conductivity (µS/cm)
V6	6/20/2007	21.0	15.58	8.24	9.06	147.0
V6	6/20/2007	28.0	15.51	8.25	9.01	147.0
V6	6/20/2007	35.0	15.47	8.27	8.99	147.0
V6	6/20/2007	42.0	15.40	8.26	8.90	147.0
V6	6/20/2007	49.0	15.30	8.27	8.83	147.0
V6	6/20/2007	56.0	15.26	8.27	8.84	147.0
V6	6/20/2007	63.0	15.24	8.25	8.78	148.0
V6	7/24/2007	0.0	24.50	8.21	8.43	161.3
V6	7/24/2007	7.0	24.29	8.19	8.28	161.1
V6	7/24/2007	14.0	24.19	8.20	8.11	161.7
V6	7/24/2007	21.0	24.15	8.20	7.98	161.6
V6	7/24/2007	28.0	24.16	8.22	7.87	161.4
V6	7/24/2007	35.0	24.15	8.21	7.80	161.3
V6	7/24/2007	42.0	24.11	8.20	7.66	161.6
V6	7/24/2007	49.0	24.09	8.20	7.53	161.2
V6	7/24/2007	56.0	24.07	8.19	7.42	161.1
V6	7/24/2007	63.0	23.83	8.01	7.03	160.4
V6	7/24/2007	70.0	21.74	7.19	0.66	162.6
V6	8/28/2007	0.0	21.95	8.29	8.44	168.0
V6	8/28/2007	8.0	20.89	8.24	8.29	167.1
V6	8/28/2007	16.0	20.86	8.23	8.12	167.6
V6	8/28/2007	24.0	20.77	8.23	8.06	167.5
V6	8/28/2007	32.0	20.70	8.24	8.06	167.2
V6	8/28/2007	40.0	20.65	8.24	8.03	167.1
V6	8/28/2007	48.0	20.59	8.23	7.93	167.4
V6	8/28/2007	56.0	20.58	8.24	7.88	167.5
V6	8/28/2007	64.0	20.57	8.24	7.81	167.6
V6	8/28/2007	72.0	20.55	8.23	7.74	167.5
V6	8/28/2007	75.0	20.55	8.20	7.62	167.9
V7	5/23/2007	0.0	12.86	7.76	10.98	136.5
V7	6/20/2007	0.0	17.24	8.48	10.00	149.8
V7	6/20/2007	0.6	17.25	8.46	10.02	149.0
V7	6/20/2007	1.2	17.25	8.38	10.03	149.6
V7	6/20/2007	1.8	17.25	8.52	10.03	149.1
V7	6/20/2007	2.4	17.25	8.39	9.99	149.5
V7	6/20/2007	3.0	17.25	8.53	10.00	149.4
V7	7/24/2007	0.0	24.30	8.60	8.45	160.8
V7	7/24/2007	0.3	24.03	8.63	8.61	161.4
V7	7/24/2007	0.6	24.01	8.61	8.62	160.8
V7	7/24/2007	0.9	24.01	8.64	8.60	161.1

Table A.2-1. continued…

Sample Location	Date	Depth (m)	Temperature (ºC)	pH (units)	DO (mg/L)	Conductivity (µS/cm)
V7	7/24/2007	1.2	24.00	8.56	8.61	161.2
V7	7/24/2007	1.5	23.99	8.58	8.62	161.1
V7	7/24/2007	1.8	23.99	8.61	8.61	160.9
V7	7/24/2007	2.1	23.98	8.60	8.60	161.2
V7	7/24/2007	2.4	23.99	8.62	8.62	161.1
V7	7/24/2007	2.8	23.99	8.61	8.61	161.0
V7	8/15/2007	0.0	22.02	9.11	8.40	166.6
V7	8/15/2007	0.5	22.02	9.05	8.40	166.4
V7	8/15/2007	1.0	22.02	9.10	8.39	166.3
V7	8/15/2007	1.5	22.02	9.11	8.39	166.3
V7	8/15/2007	2.0	22.02	9.05	8.36	166.3
V7	8/15/2007	2.5	22.02	9.05	8.37	166.3
V7	8/15/2007	3.0	22.03	9.06	8.36	166.0
V8	5/23/2007	0.5	12.95	8.40	11.20	139.1
V8	6/20/2007	0.0	13.90	8.18	-	146.1
V8	6/20/2007	6.0	15.40	8.24	9.45	146.0
V8	7/25/2007	0.0	24.12	8.41	8.19	161.2
V8	7/25/2007	1.4	24.11	8.41	8.19	161.7
V8	7/25/2007	1.8	24.10	8.18	8.18	161.1
V8	8/14/2007	0.0	22.73	8.58	7.68	169.1
V8	8/14/2007	0.5	22.72	8.57	7.68	169.1
V8	8/14/2007	1.0	22.72	8.56	7.65	169.2
V8	8/14/2007	1.5	22.71	8.55	7.68	169.2
V8	8/14/2007	2.0	22.71	8.59	7.68	169.2
V8	8/14/2007	2.5	22.71	8.58	7.65	169.2
V8	8/14/2007	3.0	22.71	8.58	7.65	169.4

Table A.2-2. In situ turbidity and Secchi disk depth measurements in Boundary Reservoir (May–August 2007).

Sample Location	Date	Sample ID	Turbidity (NTUs)	Secchi Disk Depth (m)
V1	5/23/2007	SURF-LITT	2.94	-
V1	5/23/2007	SURF-PEL	3.4	1.9
V1	6/25/2007	SURF-PEL	3.17	1.4
V1	6/25/2007	SURF-LITT	3.11	-
V1	7/23/2007	SURF-PEL	1.34	4.53
V1	7/23/2007	SURF-LITT	0.92	-
V1	8/16/2007	SURF-LITT	1.23	-
V1	8/16/2007	SURF-PEL	1.22	4.86
V2	5/23/2007	SURF-PEL	-	2
V2	6/25/2007	SURF-PEL	-	1.36
V2	7/23/2007	SURF-PEL	-	3.1
V2	8/16/2007	SURF-PEL	-	5.3
V3	5/22/2007	SURF-LITT	4.45	-
V3	5/22/2007	SURF-PEL	3.04	1.7
V3	6/19/2007	SURF-PEL	2.65	1.46
V3	6/19/2007	SURF-LITT	2.48	-
V3	7/24/2007	SURF-PEL	2.15	4.66
V3	7/24/2007	SURF-LITT	0.26	-
V3	8/25/2007	SURF-PEL	1.02	5
V3	8/25/2007	SURF-LITT	1.04	-
V4	5/22/2007	SURF-PEL	-	2.23
V4	6/20/2007	SURF-PEL	-	2.06
V4	7/24/2007	SURF-PEL	-	4.83
V4	8/25/2007	SURF-PEL	-	5.5
V5	5/22/2007	SURF-PEL	-	1.9
V5	6/20/2007	SURF-PEL	-	2.13
V5	7/24/2007	SURF-PEL	-	3.9
V5	8/25/2007	SURF-PEL	-	5.5
V6	5/22/2007	SURF-LITT	2.28	-
V6	5/22/2007	SURF-PEL	2.24	2.1
V6	6/20/2007	SURF-PEL	1.59	2.23
V6	6/20/2007	SURF-LITT	1.31	-
V6	7/24/2007	SURF-PEL	-	5.5
V6	7/24/2007	SURF-LITT	1.85	-
V6	7/24/2007	SURF-PEL	1.28	-
V6	8/25/2007	SURF-PEL	0.85	4.66

Table A.2-2 continued…

Sample Location	Date	Sample ID	Turbidity (NTUs)	Secchi Disk Depth (m)
V7	5/23/2007	SURF-PEL	-	2
V7	6/25/2007	SURF-PEL	-	1.23
V7	7/23/2007	SURF-PEL	-	3.26
V7	8/14/2007	SURF-PEL	-	3.5
V8	5/23/2007	SURF-PEL	2.55	2
V8	6/25/2007	SURF-PEL	0.83	1.5
V8	7/25/2007	SURF-SHORE	1.02	not collected
V8	8/14/2007	SURF-PEL	1.34	3.9

Table A.2-3. Laboratory water quality data from Boundary Reservoir (May-August 2007).

Sample Location	Date	Sample ID	Total P (mg/L)	SRP (mg/L)	TKN (mg/L)	Hardness (mg/L as $CaCO_3$)	Chloro *a* (µg/L)	Phaeo_a (µg/L)
V1	5/23/2007	SURF-LITT	--	--	--	--	4.094	1.4
V1	5/23/2007	SURF-PEL	0.011	<0.001	0.234	65.1	4.272	1.1
V1	6/25/2007	15FT-PEL	--	--	--	--	4.005	1.4
V1	6/25/2007	BOT-PEL	--	--	--	70.2	--	--
V1	6/25/2007	SURF-LITT	--	--	--	--	3.872	1.3
V1	6/25/2007	SURF-PEL	0.013	<0.001	0.579	--	4.005	1.7
V1	7/23/2007	15FT-PEL	--	--	--	--	1.736	1.2
V1	7/23/2007	BOT-PEL	--	--	--	75.0	--	--
V1	7/23/2007	SURF-LITT	--	--	--	--	1.469	1.3
V1	7/23/2007	SURF-PEL	0.010	<0.001	0.909	--	1.736	1.2
V1	8/16/2007	15FT-PEL	--	--	--	--	1.900	0.7
V1	8/16/2007	BOT-PEL	--	--	--	77.2	--	--
V1	8/16/2007	SURF-LITT	--	--	--	--	1.500	0.9
V1	8/16/2007	SURF-PEL	0.008	0.002	0.254	--	1.900	0.7
V2	5/23/2007	SURF-LITT	--	--	--	--	4.094	1.0
V2	5/23/2007	SURF-LITT DUP	--	--	--	--	3.916	0.9
V2	5/23/2007	SURF-PEL	0.010	<0.001	<0.200	65.1	3.560	1.4
V2	5/23/2007	SURF-PEL DUP	0.011	<0.001	0.226	64.9	3.560	1.5
V2	6/25/2007	15FT-PEL	--	--	--	--	4.139	1.6
V2	6/25/2007	BOT-PEL	--	--	--	71.531	--	--
V2	6/25/2007	SURF-LITT	--	--	--	--	4.005	1.2
V2	6/25/2007	SURF-PEL	0.015	<0.001	0.762	--	3.872	1.0
V2	7/23/2007	15FT PEL	--	--	--	--	1.869	1.2
V2	7/23/2007	BOT-PEL	--	--	--	75.2	--	--
V2	7/23/2007	SURF-LITT	--	--	--	--	1.869	1.0
V2	7/23/2007	SURF-PEL	0.011	<0.001	0.670	--	1.869	0.7
V2	8/16/2007	15FT-PEL	--	--	--	--	1.900	0.8
V2	8/16/2007	BOT-PEL	--	--	--	76.8	--	--
V2	8/16/2007	SURF-LITT	--	--	--	--	1.900	0.6
V3	5/22/2007	SURF-LITT	--	--	--	--	3.738	1.0
V3	5/22/2007	SURF-PEL	0.012	<0.001	0.250	66.1	3.560	1.1
V3	6/19/2007	15FT-PEL	--	--	--	--	3.605	1.5
V3	6/19/2007	BOT-PEL	--	--	--	69.2	--	--
V3	6/19/2007	SURF-LITT	--	--	--	--	3.738	1.7
V3	6/19/2007	SURF-PEL	0.017	0.002	0.683	--	3.738	1.5
V3	7/24/2007	15FT-PEL	--	--	--	--	1.202	1.2
V3	7/24/2007	15FT-PEL DUP	--	--	--	--	1.335	1.1

Table A.2-3 continued…

Sample Location	Date	Sample ID	Total P (mg/L)	SRP (mg/L)	TKN (mg/L)	Hardness (mg/L as $CaCO_3$)	Chloro *a* (µg/L)	Phaeo_a (µg/L)
V3	7/24/2007	BOT-PEL	--	--	--	77.4	--	--
V3	7/24/2007	BOT-PEL DUP	--	--	--	77.0	--	--
V3	7/24/2007	SURF-LITT	--	--	--	--	1.202	1.2
V3	7/24/2007	SURF-LITT DUP	--	--	--	--	1.335	1.2
V3	7/24/2007	SURF-PEL	0.009	<0.001	0.728	76.6	1.202	1.1
V3	7/24/2007	SURF-PEL DUP	0.009	0.007	0.401	--	1.335	0.9
V3	8/25/2007	15FT-PEL	--	--	--	--	1.736	1.0
V3	8/25/2007	15FT-PEL-DUP	--	--	--	--	1.869	0.8
V3	8/25/2007	BOT-PEL	--	--	--	79.7	--	--
V3	8/25/2007	BOT-PEL-DUP	--	--	--	79.0	--	--
V3	8/25/2007	SURF-LITT	--	--	--	--	1.736	0.9
V3	8/25/2007	SURF-LITT-DUP	--	--	--	--	1.602	1.2
V3	8/25/2007	SURF-PEL	0.008	<0.001	<0.200	--	--	--
V3	8/25/2007	SURF-PEL	--	--	--	--	1.602	1.0
V3	8/25/2007	SURF-PEL-DUP	0.008	<0.001	<0.200	--	--	--
V3	8/25/2007	SURF-PEL-DUP	--	--	--	--	1.869	0.8
V4	5/22/2007	SURF-LITT	--	--	--	--	3.738	1.5
V4	5/22/2007	SURF-PEL	0.012	<0.001	<0.200	66.6	3.204	1.8
V4	6/20/2007	15FT-PEL	--	--	--	--	3.471	1.8
V4	6/20/2007	BOT-PEL	--	--	--	69.4	--	--
V4	6/20/2007	SURF-LITT	--	--	--	--	4.005	1.9
V4	6/20/2007	SURF-PEL	0.012	0.002	0.659	--	3.605	1.5
V4	7/24/2007	15FT-PEL	--	--	--	--	1.469	1.3
V4	7/24/2007	BOT-PEL	--	--	--	76.2	--	--
V4	7/24/2007	SURF-LITT	--	--	--	--	1.602	0.8
V4	7/24/2007	SURF-PEL	0.008	0.001	0.695	--	--	--
V4	7/24/2007	SURF-PEL	--	--	--	--	1.469	1.1
V4	8/25/2007	15FT-PEL	--	--	--	--	2.003	0.7
V4	8/25/2007	BOT-PEL	--	--	--	80.1	--	--
V4	8/25/2007	SURF-LITT	--	--	--	--	1.869	0.7
V4	8/25/2007	SURF-PEL	0.008	<0.001	<0.200	--	--	--
V4	8/25/2007	SURF-PEL	--	--	--	--	1.602	0.9
V5	5/22/2007	SURF-LITT	--	--	--	--	3.471	1.0
V5	5/22/2007	SURF-PEL	0.011	<0.001	<0.200	66.8	2.670	1.8
V5	6/20/2007	15FT-PEL	--	--	--	--	4.673	1.7
V5	6/20/2007	BOT-PEL	--	--	--	69.0	--	--

Table A.2-3 continued…

Sample Location	Date	Sample ID	Total P (mg/L)	SRP (mg/L)	TKN (mg/L)	Hardness (mg/L as $CaCO_3$)	Chloro *a* (µg/L)	Phaeo_a (µg/L)
V5	6/20/2007	SURF-LITT	--	--	--	--	3.738	1.4
V5	6/20/2007	SURF-PEL	0.011	<0.001	0.663	--	4.005	1.3
V5	7/24/2007	15FT-PEL	--	--	--	--	1.869	1.1
V5	7/24/2007	BOT-PEL	--	--	--	75.8	--	--
V5	7/24/2007	SURF-LITT	--	--	--	--	2.136	0.9
V5	7/24/2007	SURF-PEL	0.009	0.001	0.484	--	--	--
V5	7/24/2007	SURF-PEL	--	--	--	--	1.602	1.4
V5	8/25/2007	15FT-PEL	--	--	--	--	1.736	0.8
V5	8/25/2007	BOT-PEL	--	--	--	80.5	--	--
V5	8/25/2007	SURF-LITT	--	--	--	--	1.335	0.5
V5	8/25/2007	SURF-PEL	0.008	0.002	<0.200	--	1.202	0.8
V6	5/22/2007	SURF-LITT	--	--	--	--	3.204	0.9
V6	5/22/2007	SURF-PEL	0.014	<0.001	0.303	67.2	3.204	0.7
V6	6/20/2007	15FT-PEL	--	--	--	--	5.207	1.7
V6	6/20/2007	SURF-LITT	--	--	--	--	3.471	1.1
V6	6/20/2007	SURF-PEL	0.011	--	0.813	69.2	3.338	1.5
V6	7/24/2007	15FT-PEL	--	--	--	--	1.469	1.3
V6	7/24/2007	BOT-PEL	--	--	--	74.9	--	--
V6	7/24/2007	SURF-LITT	--	--	--	--	1.469	0.9
V6	7/24/2007	SURF-PEL	0.009	0.003	0.686	--	--	--
V6	7/24/2007	SURF-PEL	--	--	--	76.6	--	--
V6	7/24/2007	SURF-PEL	--	--	--	--	1.335	1.1
V6	8/25/2007	15FT-PEL	--	--	--	--	1.068	0.3
V6	8/25/2007	BOT-PEL	--	--	--	79.9	--	--
V6	8/25/2007	SURF-LITT	--	--	--	--	0.935	0.3
V6	8/25/2007	SURF-PEL	0.008	0.001	<0.200	--	1.202	0.6
V7	5/23/2007	SURF-MID	--	--	--	--	4.272	1.1
V7	5/23/2007	SURF-PEL	0.012	<0.001	0.307	64.7	--	--
V7	6/25/2007	BOT-PEL	--	--	--	69.6	--	--
V7	6/25/2007	BOT-PEL DUP	--	--	--	70.2	--	--
V7	6/25/2007	SURF-MID	--	--	--	--	3.872	1.8
V7	6/25/2007	SURF-MID DUP	--	--	--	--	4.272	1.4
V7	6/25/2007	SURF-PEL	0.016	<0.001	0.608	--	--	--
V7	6/25/2007	SURF-PEL DUP	0.014	0.002	0.759	--	--	--
V7	7/23/2007	BOT-PEL	--	--	--	74.9	--	--
V7	7/23/2007	SURF-MID	--	--	--	--	1.602	1.3
V7	7/23/2007	SURF-PEL	0.009	<0.001	0.768	--	--	--
V7	8/14/2007	BOT-PEL	--	--	--	76.6	--	--

Table A.2-3 continued…

Sample Location	Date	Sample ID	Total P (mg/L)	SRP (mg/L)	TKN (mg/L)	Hardness (mg/L as $CaCO_3$)	Chloro *a* (µg/L)	Phaeo_a (µg/L)
V8	5/23/2007	SURF-MID	--	--	--	--	3.382	1.1
V8	5/23/2007	SURF-PEL	0.012	<0.001	0.246	66.4	--	--
V8	6/19/2007	BOT-PEL	--	--	--	68.795	--	--
V8	6/25/2007	SURF-MID	--	--	--	--	3.605	1.5
V8	6/25/2007	SURF-PEL	0.015	<0.001	0.739	--	--	--
V8	7/25/2007	SURF-SHORE	0.010	0.003	0.716	75.6	1.202	1.4
V8	8/14/2007	BOT-PEL	--	--	--	77	--	--

Appendix 3. Vertical Profile Water Quality Data

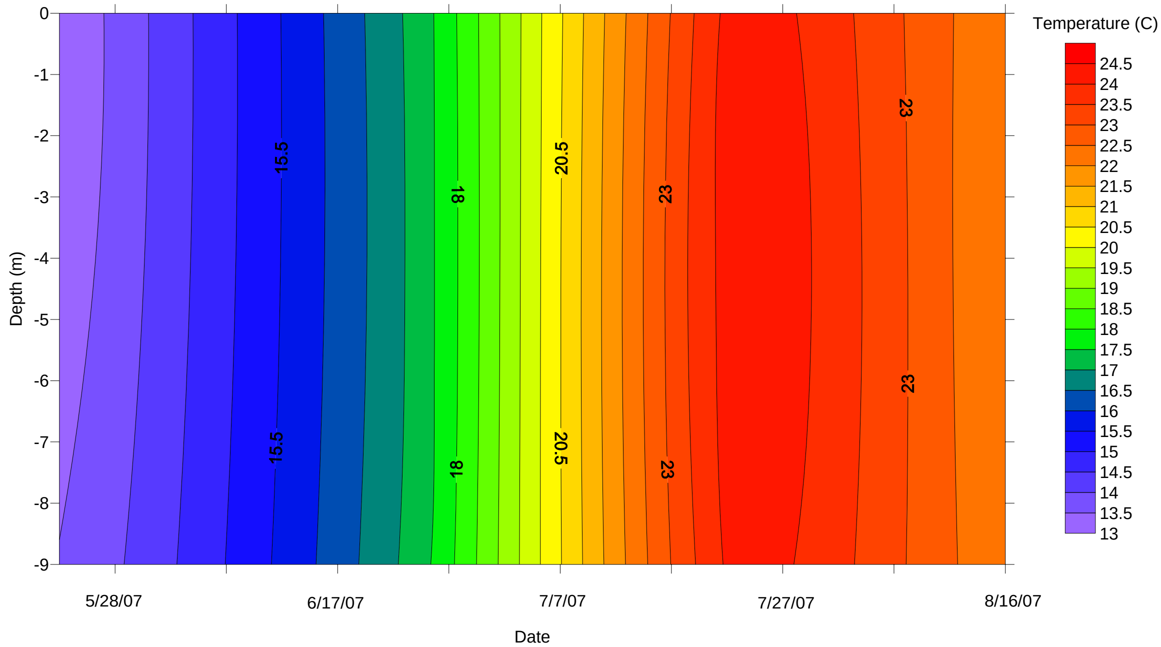

Figure A.3-1. Station V1 temperature profile for May-August 2007.

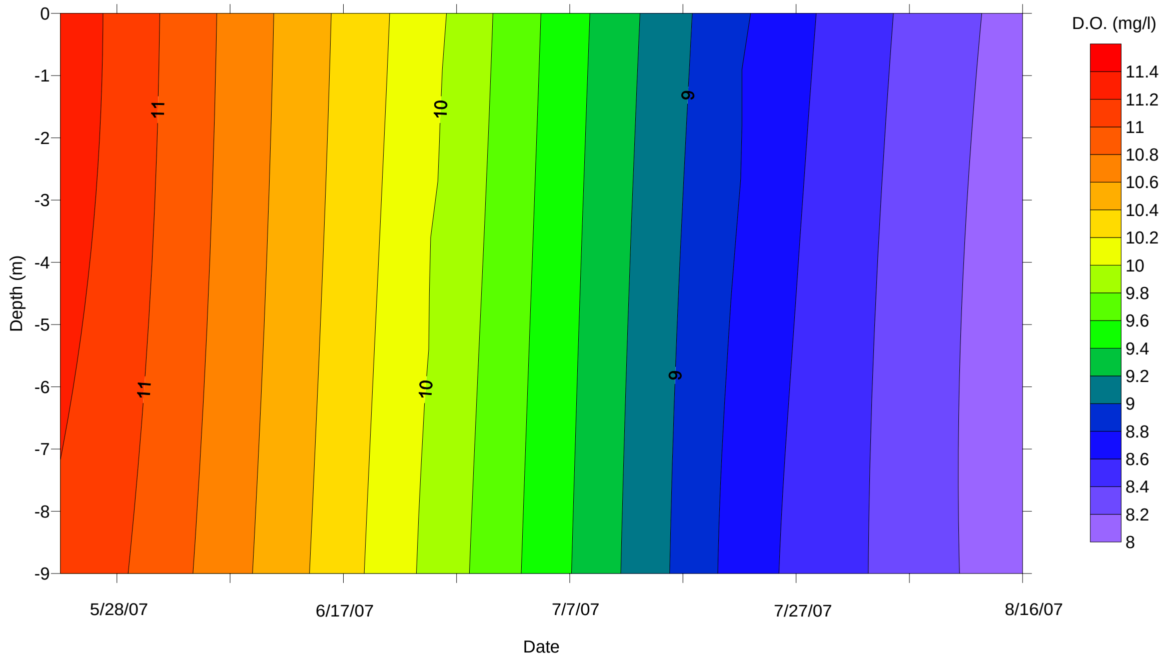

Figure A.3-2. Station V1 dissolved oxygen profile for May-August 2007.

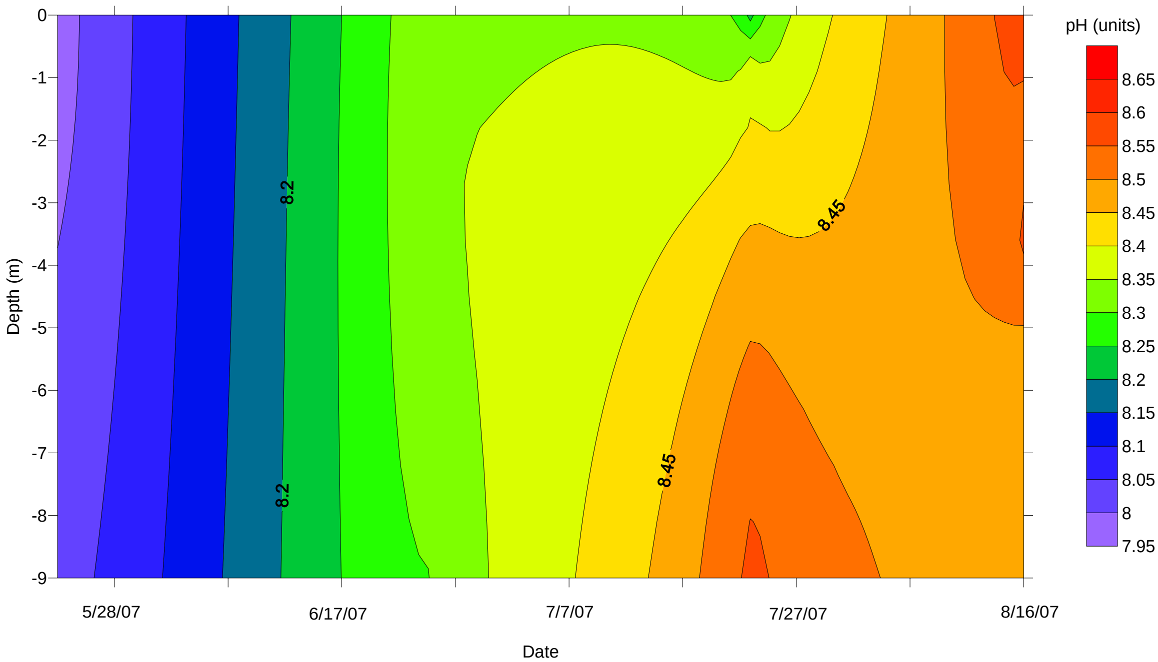

Figure A.3-3. Station V1 pH profile for May-August 2007.

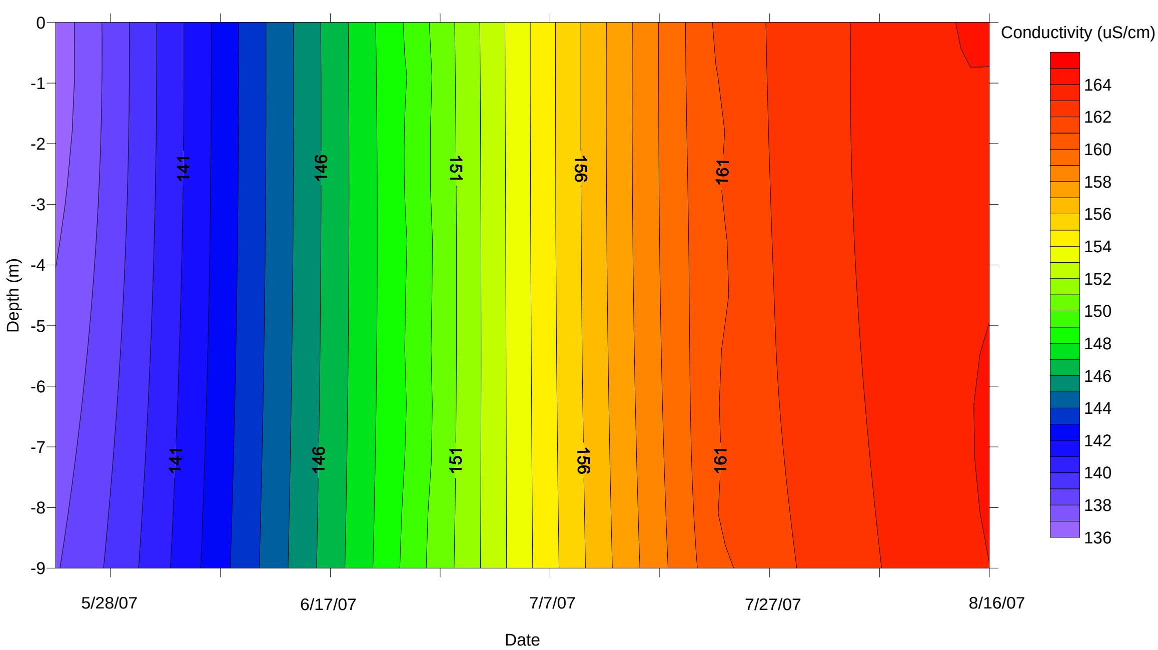

Figure A.3-4. Station V1 conductivity profile for May-August 2007.

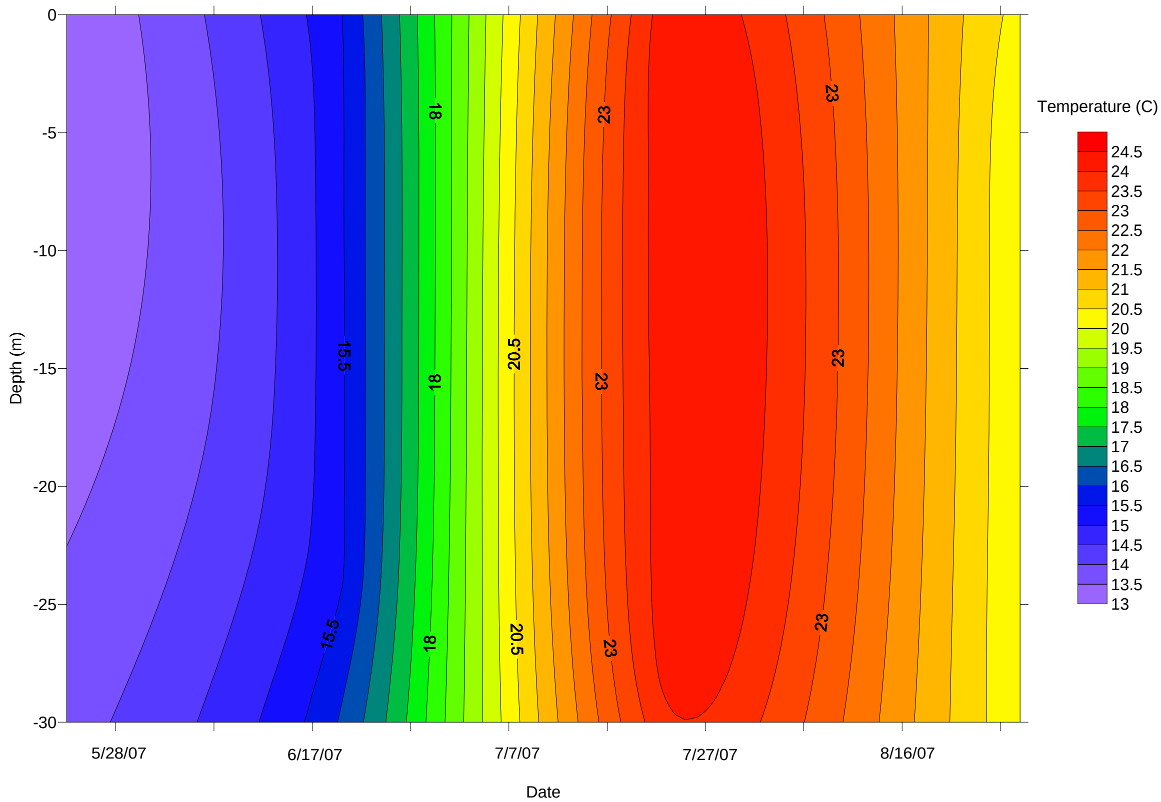

Figure A.3-5. Station V4 temperature profile for May-August 2007.

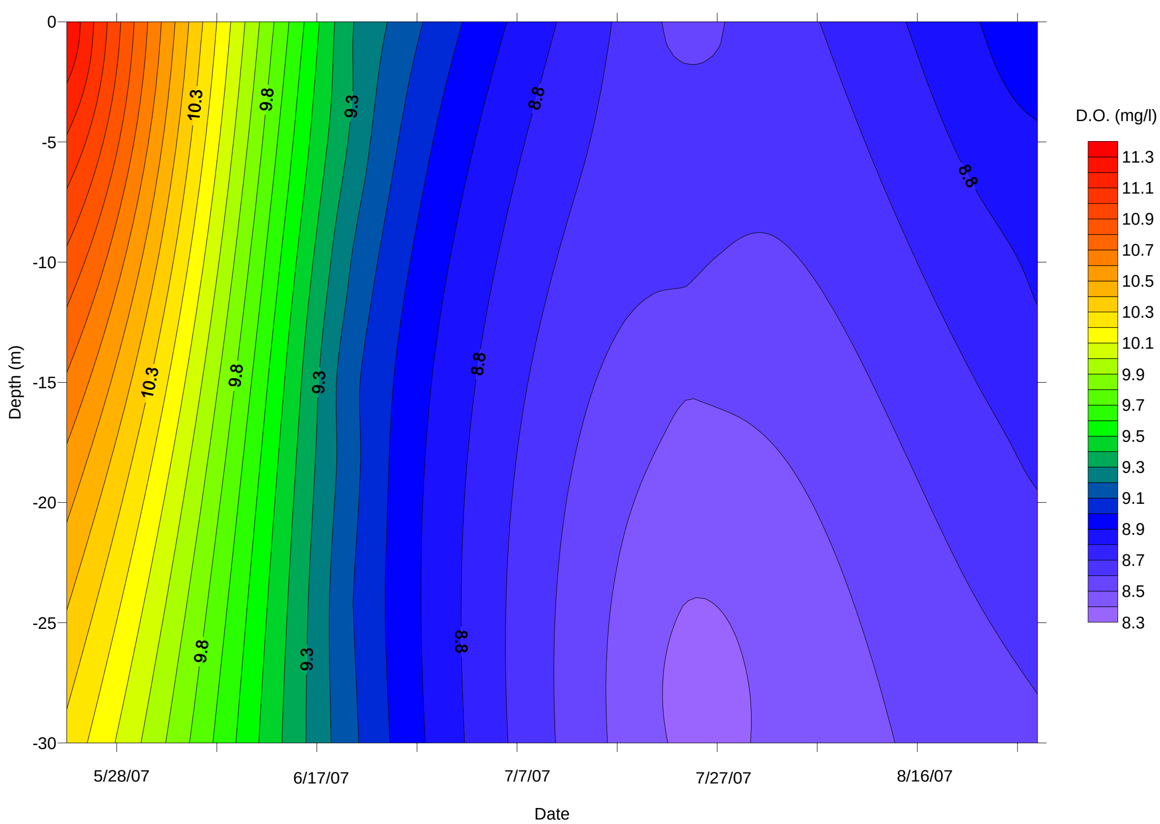

Figure A.3-6. Station V4 dissolved oxygen profile for May-August 2007.

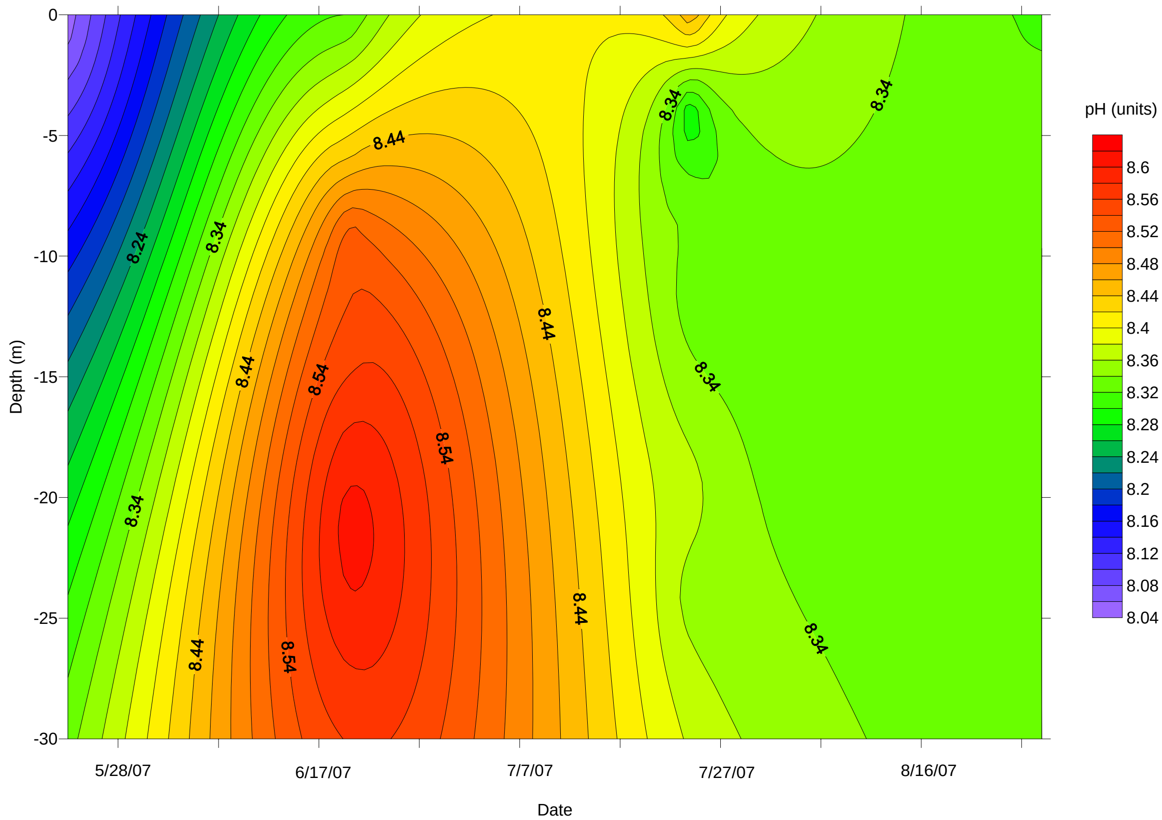

Figure A.3-7. Station V4 pH profile for May-August 2007.

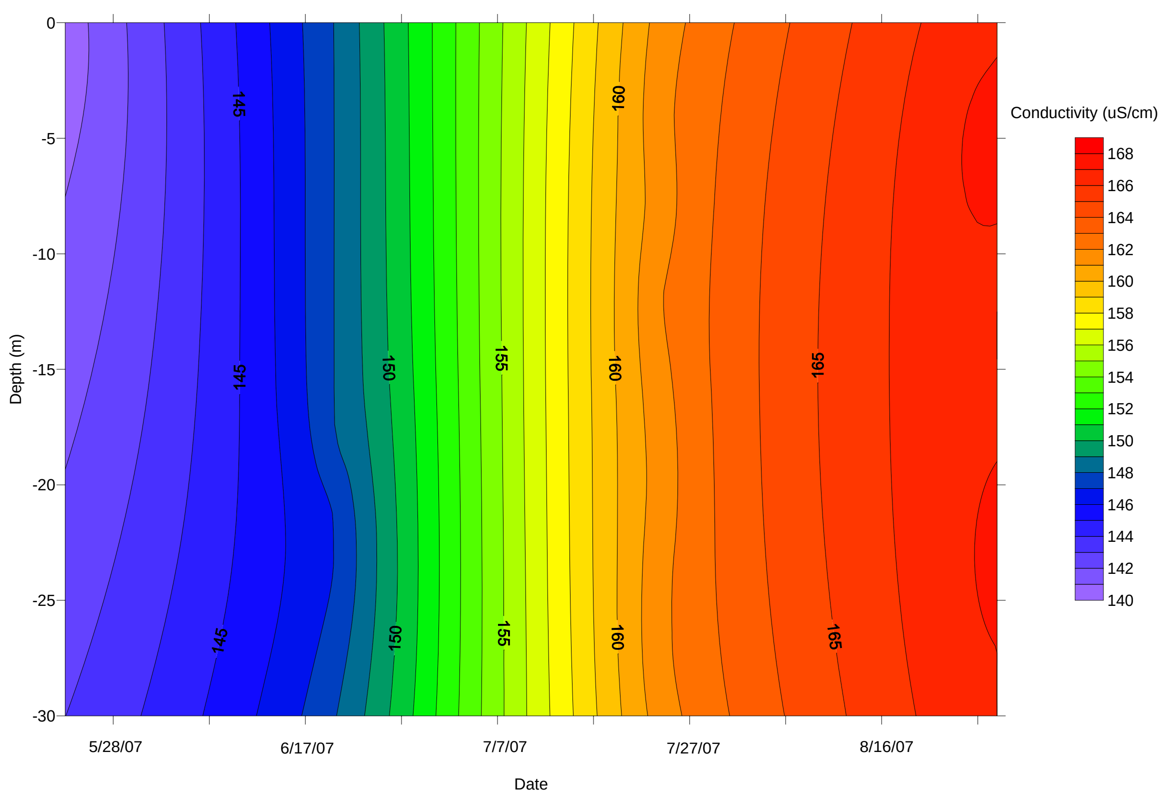

Figure A.3-8. Station V4 conductivity profile for May-August 2007.

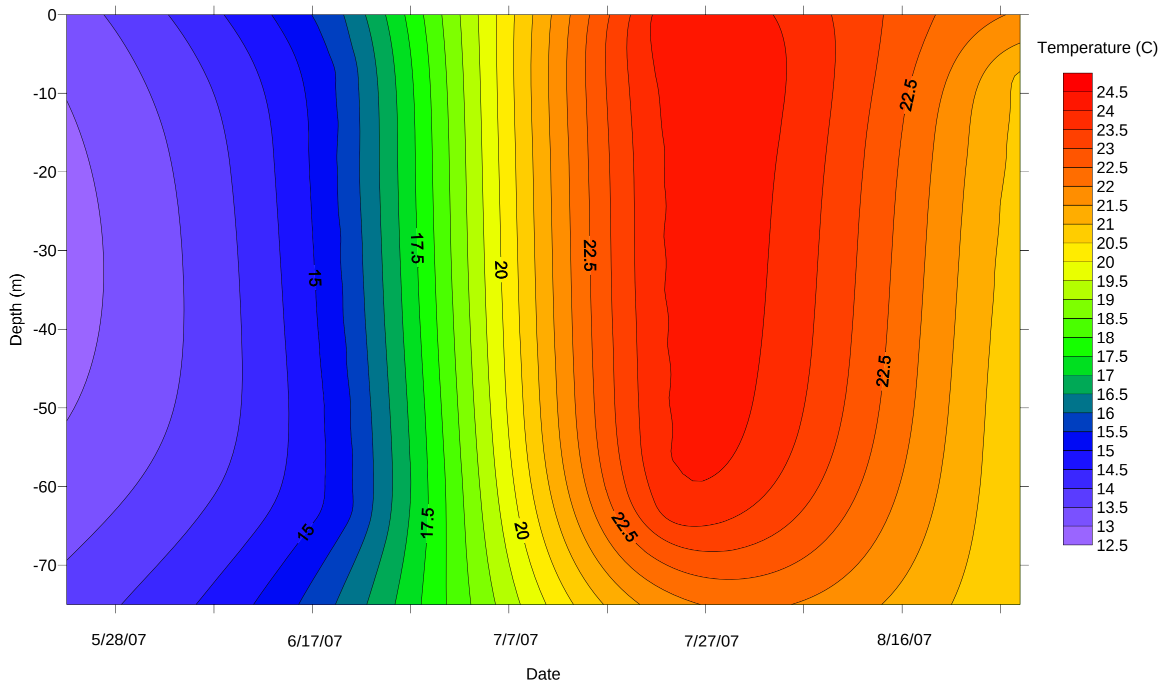

Figure A.3-9. Station V6 temperature profile for May-August 2007.

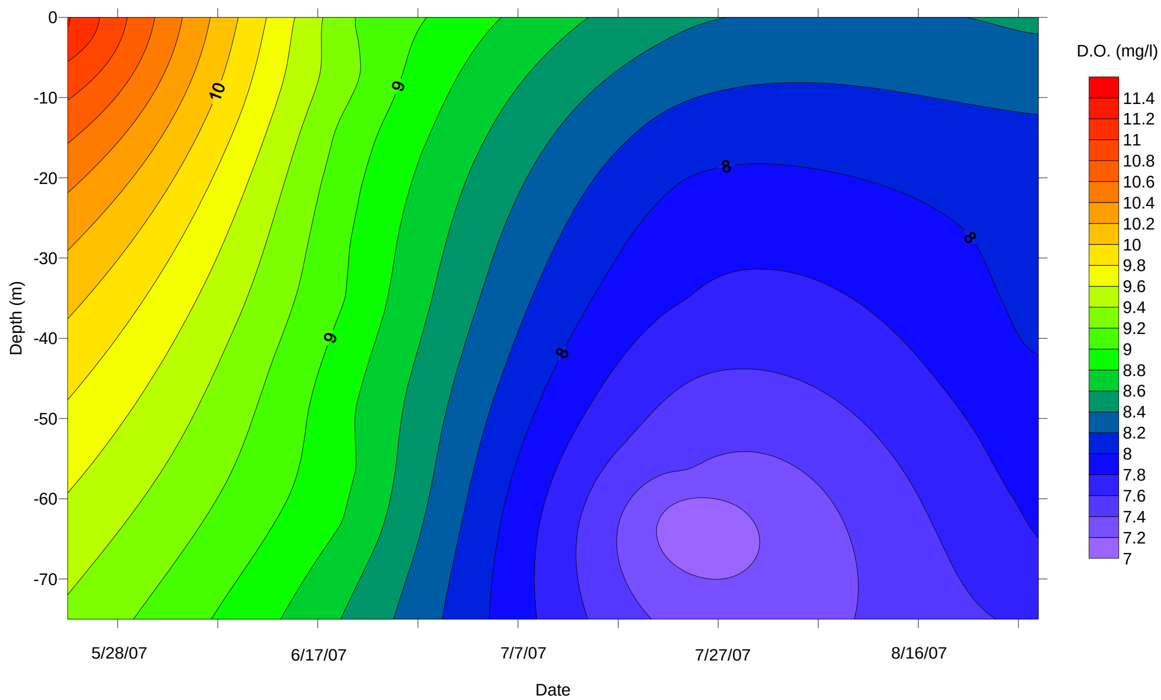

Figure A.3-10. Station V6 dissolved oxygen profile for May-August 2007.

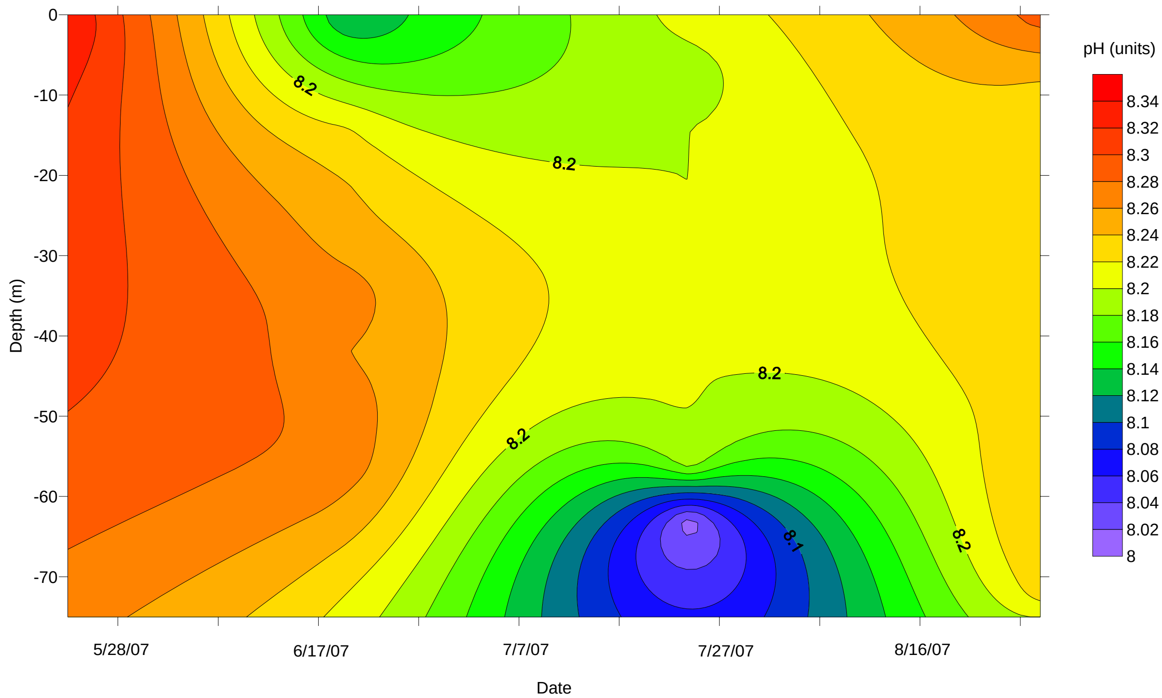

Figure A.3-11. Station V6 pH profile for May-August 2007.

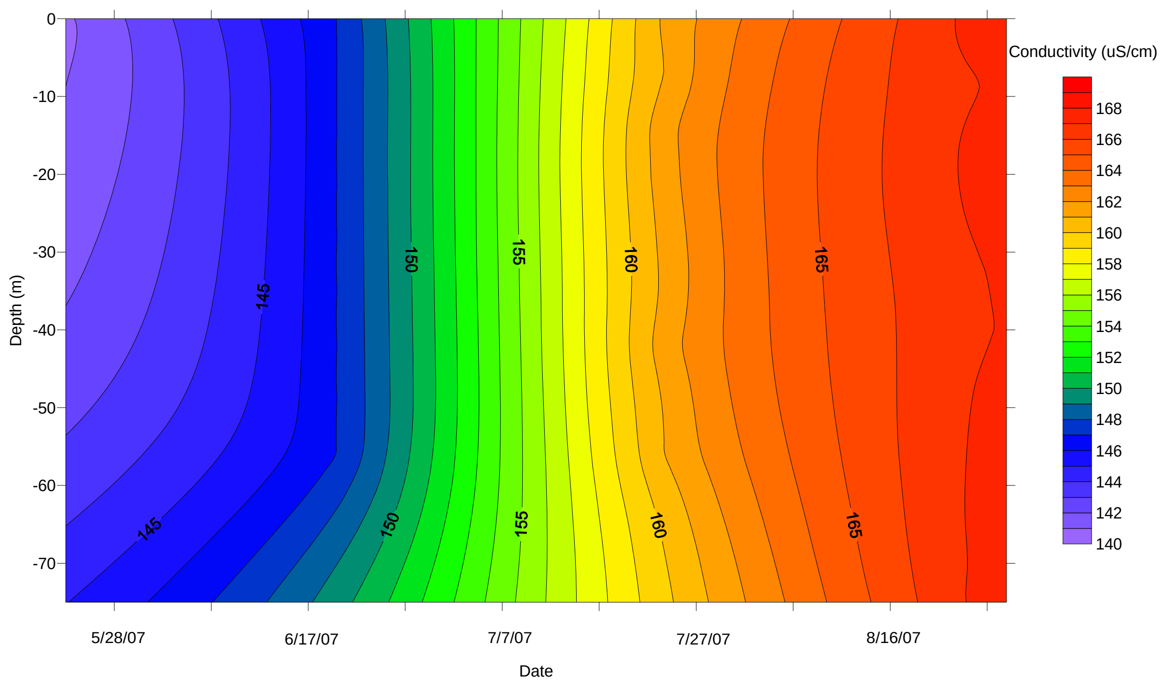

Figure A.3-12. Station V6 conductivity profile for May-August 2007.

Appendix 4. Longitudinal Profile Temperature Data

Continuous temperature measurements for the months of July and August were evaluated along a longitudinal profile of the Project area. Locations of these temperature probes are highlighted in Figure A.4-1. Average daily temperatures and daily diurnal fluctuations (maximum temperature – minimum temperature) were calculated for each station (Figure A.4-2 and Figure A.4-3). The plots did not indicate a longitudinal temperature gradient through the reservoir. Average water column temperatures were warmer in July 2007 than in August 2007 and corresponded with warmer air temperatures recorded during July 2007 sampling (32.2 - 35 ^{o}C) than during August (26.7 ^{o}C). The large temperature fluctuation observed in the tailrace of Boundary Dam and at the Border reflects daily thermal gain potentially arising from the following situations: 1) stagnant, shallow water in the channel at the Boundary Dam tailrace, 2) exposure to high ambient air temperatures during the hottest months of the year (e.g., July and August), 3) potential exposure to air during early morning hours when pool elevations at both sites were at the same elevation as the temperature probes, and 4) the timing of water release between Seven Mile Dam and Boundary Dam were offset so that stagnant, shallow water at the head of the Seven Mile reservoir was mixed with warm, shallow Boundary tailrace water. Water release from Boundary Dam was reduced during the evening hours and corresponded with the period of time continuous temperature records were generated from the lower sites.

Legend

Buoy

Pressure Tranducer Locations

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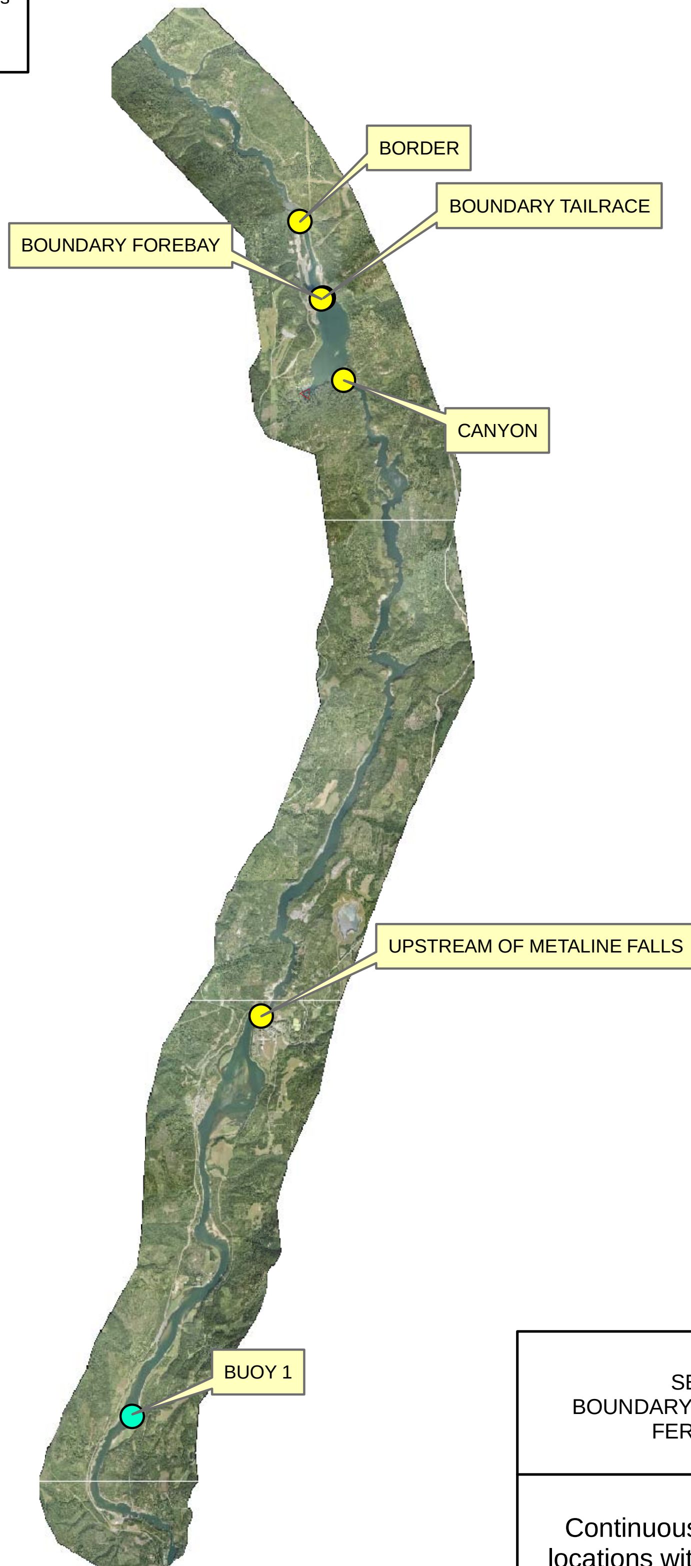

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FERC PROJECT NO. 2144

Figure A.4-1
Continuous temperature data logger locations within the Boundary Reservoir

Project Location

Washington

0 1

Miles

Map Version 10/24/07

N

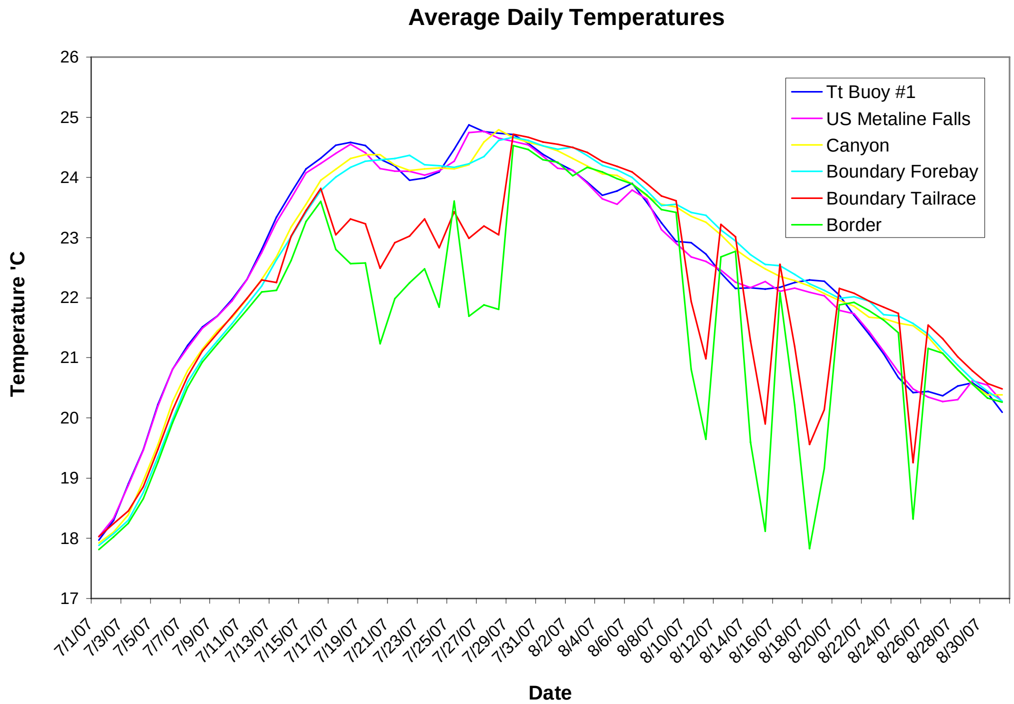

Figure A.4-2. Average daily temperatures for July and August within Boundary Reservoir.

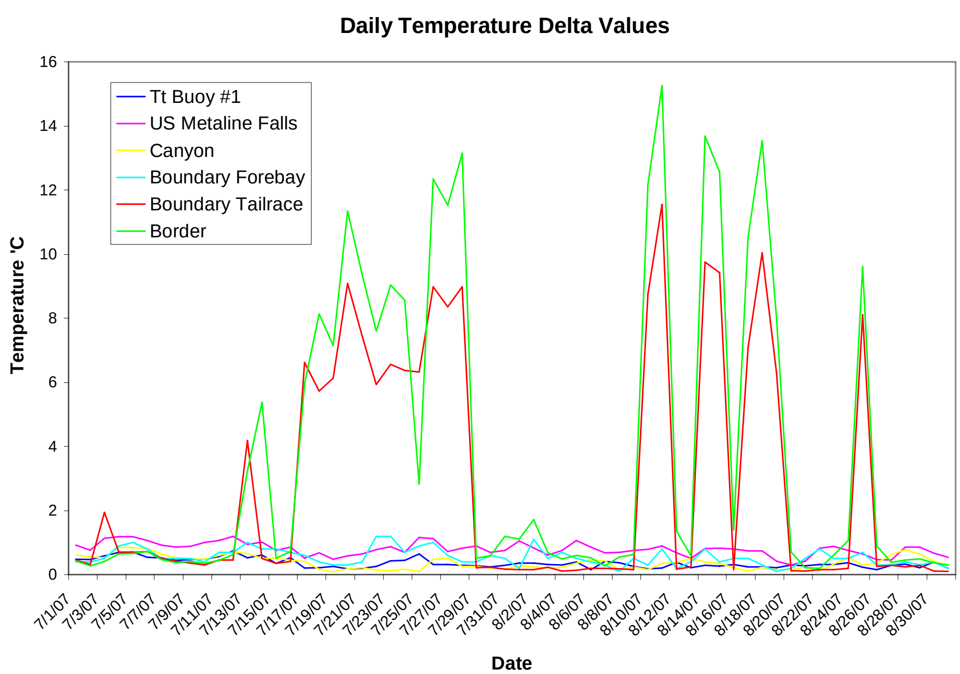

Figure A.4-3. Daily temperature delta values for July and August within Boundary Reservoir.

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Appendix 5. Seasonal Zooplankton Drift Data

Table A.5-1. Seasonal zooplankton drift data from Boundary Reservoir Site V8 June 2007.

BOUNDARY RESERVOIR STUDY 5 ***WATER Environmental Services, Inc.***
ZOOPLANKTON DATA
STATION: V8-1 **NOTE: Zoop net diam 8in**
DATE: 12 JUN 07

Taxon	Ave lngth male(mm)	Ave lngth fem (mm)	#/m3	Estim. Dry wt. ug/male	Estim. Dry wt. ug/fem	ug/m3	Comments
PHYLUM ARTHROPODA							
Subphylum Crustacea							
Subclass Copepoda							
Order Calanoida							
Copepodid		0.6-0.7	1,070	0	2.5	2,675	
Leptodiaptomus ashlandi	1.16	1.47	107	6	10	642	
Epischura nevadensis	2.17	2.40	9	18	28	203	
Order Cyclopoida							
Diacyclops bicuspidatus thomasi	1.00	1.26	642	2.5	5.5	3,531	
Nauplii (cal+cyc)		<.3	9,630	0	0.25	2,408	
Class Branchiopoda(cladocerans)							
Daphnia sp.		1.47	4	8	15	66	tall pt helmet
Leptodora kindtii		3.0-5.0	4	0	50	220	body torn
Class Insecta							
Order Diptera							
PHYLUM ROTIFERA							
Type 1 (mostly loricated malleates)							
Kellicottia longispina		0.21	2,140	0	0.02	43	
Keratella cochlearis		0.16	342,404	0	0.01	3,424	
Keratella earlinae		0.21	51,361	0	0.02	1,027	
Type 2 (mostly illoricate virgates/incudates)							
Gastropus stylifer(small)		0.11	1,070	0	0.02	21	pink color
Polyarthra sp. (small)		0.10	2,140	0	0.02	43	
Synchaeta sp.		0.21	40,661	0	0.08	3,253	body contracted
Synchaeta sp.		0.15	10,700	0	0.025	268	body contracted
Type 3 (mostly malleoramates)							
Others							
Undeter rotifer 2		0.14	1,070	0	0.03	32	long toes
	Total #/m3	**Density #/L**				**Total Dry Wt. Biomass ug/m3**	**ug/L**
	463,012	**463.01**				**17,856**	**17.86**
% Calanoid Copepods	0.26					19.71	
% Cyclopoid Copepods	0.14					19.78	
% Nauplii	2.08					13.48	
% Cladocerans	0.00					1.60	
% Rotifers	97.52					45.42	
% Dipterans	0.00					0.00	
Number of species in sample	**12**						

Table A.5-1 continued…

BOUNDARY RESERVOIR STUDY 5 — ***WATER Environmental Services, Inc.***
ZOOPLANKTON DATA
STATION: V8-2 — **NOTE: Zoop net diam 8in**
DATE: 12 JUN 07

Taxon	Ave lngth male(mm)	Ave lngth fem (mm)	#/m3	Estim. Dry wt. ug/male	Estim. Dry wt. ug/fem	ug/m3	Comments
PHYLUM ARTHROPODA							
Subphylum Crustacea							
Subclass Copepoda							
Order Calanoida							
Copepodid		0.6-0.7	240	0	2.5	599	
Leptodiaptomus ashlandi	1.16	1.47	240	6	10	2,395	
Epischura nevadensis	2.10	2.24	9	18	28	203	
Order Cyclopoida							
Copepodid		0.6-0.7	2,395	0	2	4,791	
Diacyclops bicuspidatus thomasi	1.00	1.26	479	2.5	5.5	1,916	
Nauplii (cal+cyc)		<.3	11,977	0	0.25	2,994	
Class Branchiopoda(cladocerans)							
Bosmina longirostris (juv)		0.28	120	0	0.7	84	
Leptodora kindtii		3.0-5.0	4	0	50	220	body torn
Class Insecta							
Order Diptera							
PHYLUM ROTIFERA							
Type 1 (mostly loricated malleates)							
Kellicottia longispina		0.21	20,361	0	0.02	407	
Keratella cochlearis		0.16	603,646	0	0.01	6,036	
Keratella earlinae		0.21	97,015	0	0.02	1,940	
Type 2 (mostly illoricate virgates/incudates)							
Gastropus stylifer(small)		0.11	2,395	0	0.02	48	pink color
Polyarthra sp. (small)		0.10	4,791	0	0.02	96	
Polyarthra sp.		0.14	3,593	0	0.05	180	appen pr not evid
Synchaeta sp.		0.21	11,977	0	0.08	958	body contracted
Synchaeta sp.		0.15	37,129	0	0.025	928	body contracted
Type 3 (mostly malleoramates)							
Others							
Undeter rotifer 1		0.10	7,186	0	0.03	216	body contracted
Undeter rotifer 2		0.12	1,198	0	0.01	12	long toes
	Total #/m3	**Density #/L**				**Total Dry Wt. Biomass ug/m3**	**ug/L**
	804,755	**804.75**				**24,024**	**24.02**
% Calanoid Copepods	0.06					13.31	
% Cyclopoid Copepods	0.36					27.92	
% Nauplii	1.49					12.46	
% Cladocerans	0.02					1.27	
% Rotifers	98.08					45.04	
% Dipterans	0.00					0.00	
Number of species in sample	**13**						

Table A.5-1 continued…

BOUNDARY RESERVOIR STUDY 5 — ***WATER Environmental Services, Inc.***
ZOOPLANKTON DATA
STATION: V8-3 — **NOTE: Zoop net diam 8in**
DATE: 12 JUN 07

Taxon	Ave lngth male(mm)	Ave lngth fem (mm)	#/m3	Estim. Dry wt. ug/male	Estim. Dry wt. ug/fem	ug/m3	Comments
PHYLUM ARTHROPODA							
Subphylum Crustacea							
Subclass Copepoda							
Order Calanoida							
Copepodid		0.6-0.7	238	0	2.5	594	
Leptodiaptomus ashlandi	1.16	1.47	59	6	10	594	
Epischura nevadensis	2.10	2.31	4	18	28	123	
Order Cyclopoida							
Copepodid		0.6-0.7	1,427	0	2	2,853	
Diacyclops bicuspidatus thomasi	1.00	1.10	713	2.5	5	2,972	
Nauplii (cal+cyc)		<.3	13,078	0	0.25	3,269	
Class Branchiopoda(cladocerans)							
Class Insecta							
Order Diptera							
PHYLUM ROTIFERA							
Type 1 (mostly loricated malleates)							
Kellicottia longispina		0.21	32,100	0	0.02	642	
Keratella cochlearis		0.16	442,272	0	0.01	4,423	
Keratella earlinae		0.21	66,579	0	0.02	1,332	
Keratella quadrata complex(small)		0.13	1,189	0	0.027	32	
Keratella quadrata		0.20	1,189	0	0.13	155	
Monostyla (Lecane) sp.		0.90	1,189	0	0.005	6	1 toe
Notholca foliacea		0.14	1,189	0	0.01	12	
Type 2 (mostly illoricate virgates/incudates)							
Gastropus stylifer		0.14	1,189	0	0.04	48	pink color
Polyarthra sp. (small)		0.10	3,567	0	0.02	71	
Polyarthra sp.		0.13	3,567	0	0.04	143	appen pr not evid
Synchaeta sp.		0.21	13,078	0	0.08	1,046	body contracted
Synchaeta sp.		0.15	60,634	0	0.025	1,516	body contracted
Type 3 (mostly malleoramates)							
Others							
Undeter rotifer 1		0.10	11,889	0	0.03	357	body contracted
	Total #/m3	**Density #/L**				**Total Dry Wt. Biomass ug/m3**	**ug/L**
	655,150	**655.15**				**20,188**	**20.19**
% Calanoid Copepods	0.05					6.50	
% Cyclopoid Copepods	0.33					28.86	
% Nauplii	2.00					16.19	
% Cladocerans	0.00					0.00	
% Rotifers	97.63					48.45	
% Dipterans	0.00					0.00	
Number of species in sample	**14**						

Table A.5-1 continued…

BOUNDARY RESERVOIR STUDY 5 — *WATER Environmental Services, Inc.*
ZOOPLANKTON DATA
STATION: V8-4 — **NOTE: Zoop net diam 8in**
DATE: 12 JUN 07

Taxon	Ave lngth male(mm)	Ave lngth fem (mm)	#/m3	Estim. Dry wt. ug/male	Estim. Dry wt. ug/fem	ug/m3	Comments
PHYLUM ARTHROPODA							
Subphylum Crustacea							
Subclass Copepoda							
Order Calanoida							
Copepodid		0.6-0.7	112	0	2.5	280	
Leptodiaptomus ashlandi	1.16	1.47	40	6	10	396	
Epischura nevadensis	1.75	1.75	9	14	16	134	
Order Cyclopoida							
Copepodid		0.6-0.7	1,342	0	2	2,684	
Diacyclops bicuspidatus thomasi	1.00	1.10	671	2.5	5	2,796	
Nauplii (cal+cyc)		<.3	14,540	0	0.25	3,635	
Class Branchiopoda(cladocerans)							
Daphnia (juv)		1.20	9	0	5	44	high pt helmet
Daphnia sp.		1.54	4	8	16	72	rounded helmet
Bosmina longirostris (juv)		0.28	112	0	0.7	78	
Class Insecta							
Order Diptera							
PHYLUM ROTIFERA							
Type 1 (mostly loricated malleates)							
Kellicottia longispina		0.21	22,369	0	0.02	447	
Keratella cochlearis		0.16	561,462	0	0.01	5,615	
Keratella earlinae		0.21	78,292	0	0.02	1,566	
Keratella quadrata		0.14	1,118	0	0.03	34	
Monostyla (Lecane) sp.		0.90	1,118	0	0.005	6	1 toe
Notholca foliacea		0.17	1,118	0	0.014	16	
Type 2 (mostly illoricate virgates/incudates)							
Asplanchna sp.		0.90	1,118	0	10.4	11,632	
Gastropus stylifer(small)		0.10	2,237	0	0.02	45	pink color
Polyarthra sp. (small)		0.10	5,592	0	0.02	112	
Polyarthra sp.		0.13	2,237	0	0.04	89	appen pr not evid
Synchaeta sp.		0.21	40,264	0	0.08	3,221	body contracted
Synchaeta sp.		0.15	41,383	0	0.025	1,035	body contracted
Type 3 (mostly malleoramates)							
Conochilus sp. (small)		0.10	1,118	0	0.01	11	
Others							
	Total #/m3	**Density #/L**				**Total Dry Wt. Biomass ug/m3**	**ug/L**
	776,266	**776.27**				**33,946**	**33.95**
% Calanoid Copepods	0.02					2.39	
% Cyclopoid Copepods	0.26					16.14	
% Nauplii	1.87					10.71	
% Cladocerans	0.02					0.57	
% Rotifers	97.83					70.19	
% Dipterans	0.00					0.00	
Number of species in sample	**17**						

Table A.5-1 continued…

BOUNDARY RESERVOIR STUDY 5 — ***WATER Environmental Services, Inc.***
ZOOPLANKTON DATA
STATION: V8-5 — **NOTE: Zoop net diam 8in**
DATE: 12 JUN 07

Taxon	Ave lngth male(mm)	fem (mm)	Ave lngth #/m3	Estim. Dry wt. ug/male	Estim. Dry wt. ug/fem	ug/m3	Comments
PHYLUM ARTHROPODA							
Subphylum Crustacea							
Subclass Copepoda							
Order Calanoida							
Copepodid		0.6-0.7	350	0	2.5	875	
Leptodiaptomus ashlandi	1.26	1.47	117	6	10	1,167	
Epischura nevadensis	1.75	2.10	9	14	24	210	
Order Cyclopoida							
Copepodid		0.6-0.7	1,050	0	2	2,100	
Diacyclops bicuspidatus thomasi	1.00	1.26	700	2.5	5.5	3,501	
Nauplii (cal+cyc)		<.3	12,836	0	0.25	3,209	
Class Branchiopoda(cladocerans)							
Daphnia sp.		1.54	117	8	16	1,867	mod helmet w/small pt
Bosmina longirostris (juv)		0.28	117	0	0.7	82	
Alona sp.		0.56	117	0	2	233	
Class Insecta							
Order Diptera							
PHYLUM ROTIFERA							
Type 1 (mostly loricated malleates)							
Kellicottia longispina		0.21	28,005	0	0.02	560	
Keratella cochlearis		0.16	665,125	0	0.01	6,651	
Keratella earlinae		0.21	75,848	0	0.02	1,517	
Type 2 (mostly illoricate virgates/incudates)							
Gastropus stylifer		0.14	2,334	0	0.04	93	pink color
Gastropus stylifer(small)		0.10	2,334	0	0.02	47	pink color
Polyarthra sp. (small)		0.10	3,501	0	0.02	70	
Polyarthra sp.		0.13	1,167	0	0.04	47	appen pr not evid
Synchaeta sp.		0.21	44,342	0	0.08	3,547	body contracted
Synchaeta sp.		0.15	47,842	0	0.025	1,196	body contracted
Type 3 (mostly malleoramates)							
Conochilus sp. (small)		0.12	1,167	0	0.01	12	
Others							
Undeter rotifer 1		0.10	4,668	0	0.03	140	body contracted
	Total #/m3	**Density #/L**				**Total Dry Wt. Biomass ug/m3**	**ug/L**
	891,744	**891.74**				**27,124**	**27.12**
% Calanoid Copepods	0.05					8.30	
% Cyclopoid Copepods	0.20					20.65	
% Nauplii	1.44					11.83	
% Cladocerans	0.04					8.04	
% Rotifers	98.27					51.17	
% Dipterans	0.00					0.00	
Number of species in sample	**14**						

Table A.5-1 continued…

BOUNDARY RESERVOIR STUDY 5			***WATER Environmental Services, Inc.***				
ZOOPLANKTON DATA							
STATION: V8-6			**NOTE: Zoop net diam 8in**				
DATE: 12 JUN 07							
Taxon	**Ave lngth male(mm)**	**fem (mm)**	**Ave lngth #/m3**	**Estim. Dry wt. ug/male**	**Estim. Dry wt. ug/fem**	**ug/m3**	**Comments**
PHYLUM ARTHROPODA							
Subphylum Crustacea							
Subclass Copepoda							
Order Calanoida							
Copepodid		0.6-0.7	114	0	2.5	284	
Leptodiaptomus ashlandi	1.26	1.33	114	6	8	909	
Epischura nevadensis	1.75	2.15	9	14	24	211	
Order Cyclopoida							
Copepodid		0.6-0.7	1,136	0	2	2,272	
Diacyclops bicuspidatus thomasi	1.00	1.26	114	2.5	5.5	625	
Nauplii (cal+cyc)		<.3	12,497	0	0.25	3,124	
Class Branchiopoda(cladocerans)							
Daphnia (juv)		1.00	4	0	5	22	broken carapace
Alona sp.		0.56	114	0	2	227	
Leptodora kindtii		3.0-5.0	4	0	50	222	body torn
Class Insecta							
Order Diptera							
PHYLUM ROTIFERA							
Type 1 (mostly loricated malleates)							
Kellicottia longispina		0.21	13,633	0	0.02	273	
Keratella cochlearis		0.16	255,614	0	0.01	2,556	
Keratella earlinae		0.21	79,524	0	0.02	1,590	
Monostyla (Lecane) sp.		0.90	1,136	0	0.005	6	1 toe
Notholca foliacea		0.15	1,136	0	0.01	11	
Type 2 (mostly illoricate virgates/incudates)							
Gastropus stylifer(small)		0.10	5,680	0	0.02	114	pink color
Polyarthra sp. (small)		0.10	1,136	0	0.02	23	
Synchaeta sp.		0.21	22,721	0	0.08	1,818	body contracted
Synchaeta sp.		0.15	28,402	0	0.025	710	body contracted
Type 3 (mostly malleoramates)							
Others							
Undeter rotifer 2		0.15	1,136	0	0.02	23	long toes
Undeter rotifer 3		0.13	1,136	0	0.02	23	
	Total #/m3	**Density #/L**				**Total Dry Wt. Biomass ug/m3**	**ug/L**
	425,360	**425.36**				**15,042**	**15.04**
% Calanoid Copepods	0.06					9.33	
% Cyclopoid Copepods	0.29					19.26	
% Nauplii	2.94					20.77	
% Cladocerans	0.03					3.13	
% Rotifers	96.68					47.51	
% Dipterans	0.00					0.00	
Number of species in sample	**16**						