FA-01a WATER QUALITY MONITORING STUDY INTERIM REPORT

SKAGIT RIVER HYDROELECTRIC PROJECT FERC NO. 553

Seattle City Light

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Interim Study Report

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List of Acronyms and Abbreviations

°C ....degrees Celsius
°F...............................degrees Fahrenheit
B-IBI ....benthic index of biotic integrity
BMI ....benthic macroinvertebrate
cfs..............................cubic feet per second
CFU...........................colony-forming units
City Light...................Seattle City Light
COC ....chain-of-custody
CoSD..........................City of Seattle datum
CWA ....Clean Water Act
DO.............................dissolved oxygen
E. coli ....*Escherichia coli*
Ecology ....Washington Department of Ecology
FC..............................fecal coliform
fDOM.........................fluorescent dissolved organic matter
FERC..........................Federal Energy Regulatory Commission
IQR............................interquartile range
ISR ....Initial Study Report
LP ....licensing participant
m ....meter
mg/L..........................milligram per liter
mL ....milliliter
mm ....millimeter
mmHg ....millimeter of mercury
MW ....megawatt
NAVD 88...................North American Vertical Datum of 1988
ND.............................non-detectable
NIST...........................National Institute of Standards and Technology
NPS ....National Park Service
NTU ....nephelometric turbidity unit
PAD............................Pre-Application Document

PRM ....Project River Mile
Project ....Skagit River Hydroelectric Project
QA/QC ....quality assurance/quality control
QAPP ....Quality Assurance Program Plan
RSD............................relative standard deviation
RSP ....Revised Study Plan
SC...............................specific conductance
SOP ....Standard Operating Procedure
SPD ....Study Plan Determination
SR...............................State Route
TDG ....total dissolved gas
TSS.............................total suspended solids
USGS .........................U.S. Geological Survey
USR............................Updated Study Report
WAC ....Washington Administrative Code

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1.0 INTRODUCTION

The FA-01a Water Quality Monitoring Study (WQ Monitoring Study) is being conducted in support of the relicensing of the Skagit River Hydroelectric Project (Project), Federal Energy Regulatory Commission (FERC) No. 553, as identified in the Revised Study Plan (RSP) submitted by Seattle City Light (City Light) on April 7, 2021 (City Light 2021). This study is one component of the overall FA-01 study, which also includes the FA-01b Water Quality Model Development Study (WQ Model Development Study), which is addressed in a companion report (City Light 2022a). On June 9, 2021, City Light filed a "Notice of Certain Agreements on Study Plans for the Skagit Relicensing" (June 9, 2021 Notice)[1] that detailed additional modifications to the RSP agreed to between City Light and supporting licensing participants (LP) (which include the Swinomish Indian Tribal Community, Upper Skagit Indian Tribe, National Marine Fisheries Service, National Park Service [NPS], U.S. Fish and Wildlife Service, Washington State Department of Ecology [Ecology], and Washington Department of Fish and Wildlife). The June 9, 2021 Notice included agreed to modifications to the WQ Monitoring Study.

In its July 16, 2021 Study Plan Determination (SPD), FERC approved the WQ Monitoring Study with modifications. Specifically, FERC modified the plan to require City Light to collect one turbidity measurement at tributary deltas within the Ross Lake drawdown zone during spring and fall. FERC did not require City Light to conduct a future nutrient sampling program and develop a nutrient model for the Project reservoirs, major tributaries, and Skagit River from Gorge Dam to the Skagit estuary (which was an agreed to modification in the June 9, 2021 Notice). Notwithstanding, City Light is implementing the WQ Monitoring Study as proposed in the RSP with the agreed to modifications from the June 9, 2021 Notice as described in Section 2 of this study report.

This interim report on the 2021 study efforts is being filed with FERC as part of City Light's Initial Study Report (ISR). City Light will perform additional work for this study in 2022 and include a report in the Updated Study Report (USR) in March 2023.

[1] Referred to by FERC in its July 16, 2021 Study Plan Determination as the "updated RSP."

2.0 STUDY GOALS AND OBJECTIVES

This study has been designed to collect water quality data which, along with previously collected (existing) water quality data, are intended to support Ecology's certification of the Project under Section 401 of the Clean Water Act (CWA) and the data needs of FERC, while also addressing other data needs of City Light, resource agencies, Indian Tribes, and other LPs in the context of FERC relicensing. The goal of this study is to monitor water quality parameters for which existing information is insufficient to characterize conditions within the study area. A summary of existing water quality data, collected prior to the development of this study, is presented in Section 2.3 of the RSP (including Table 2.3-1 of the RSP). City Light is directing resources toward the collection of data needed to characterize parameters that currently are not well understood. The water quality parameters listed below are being monitored over a two-year period in the identified waterbodies during the relicensing study period. Specific objectives of this study are listed below. For all parameters, data collection will take place over a two-year period extending from June 2021 to May 2023.

- Provide a summary and analysis of all relevant existing water quality information identified in Table 2.3-1 of the RSP, other City Light data (e.g., ongoing data collection in tributaries), and data obtained from NPS and other reputable sources.
- Characterize background levels of turbidity and total suspended solids (TSS) in Ross, Diablo, and Gorge lakes.
- Measure temperature, dissolved oxygen (DO), pH, turbidity, and TSS at one location in the Skagit River upstream of Ross Lake.
- Measure turbidity and TSS at the mouths of select tributaries to Ross (Big Beaver and Ruby creeks) and Diablo (Thunder Creek) lakes to characterize conditions during periods of reservoir drawdown.
- Measure turbidity and TSS at transects positioned parallel to the shoreline at three locations in Ross Lake to characterize conditions adjacent to areas of shoreline erosion during reservoir drawdown when erosional faces of the littoral fringe are exposed.
- Measure fecal coliform (FC) levels at targeted locations in Ross and Diablo lakes.
- Measure temperature, DO, and pH in Diablo and Gorge lakes.
- Continuously measure total dissolved gas (TDG) in the Diablo Dam tailrace and Gorge Lake forebay.
- Continuously monitor temperature, DO, TDG, and turbidity at three locations in the Gorge bypass reach.
- Continuously measure temperature, DO, pH, TDG, and turbidity below Gorge Powerhouse. Sample TSS during periods when turbidity levels below Gorge Powerhouse are considered elevated.
- Continuously measure temperature by installing probes at six locations in the Skagit River between Gorge Powerhouse and downstream of the Baker River confluence.
- Sample benthic macroinvertebrates (BMI) in riffle habitat at six locations in the Skagit River between Gorge Powerhouse and downstream of the Baker River confluence.

- Continuously measure temperature at one location in the lower Sauk River.
- Sample BMI in riffle habitat at one location in the lower Sauk River.

The June 9, 2021 Notice commitments with respect to the FA-01a WQ Monitoring Study are identified below. Please see the FA-01b WQ Model Development Study report for commitments pertaining to the development and calibration of the CE-QUAL-W2 model (City Light 2022a), which will be applied to simulate water temperature and water quality parameters in the Project reservoirs and the Skagit River downstream of the Project.

- City Light will provide a Quality Assurance Program Plan (QAPP) that meets Ecology's standards and judge existing data based on the QAPP. If the existing data cannot be confirmed, the data will be reviewed on a case-by-case basis in collaboration with the LPs.
- City Light will execute an expanded benthic macroinvertebrate sampling program to include the Project reservoirs, Skagit River to the estuary (through reference reach sampling mutually agreed to by SCL and the LPs), varying seasons, varying habitat types, and invertebrate drift. The sampling program will be developed in collaboration with the LPs and informed by NPS.
- City Light will convene a workshop with concerned LPs to discuss parameters, frequency, monitoring locations, and temporal overlap with existing data.

3.0 STUDY AREA

The WQ Monitoring Study area extends from the U.S. – Canada Border, through Ross (within the U.S.), Diablo, and Gorge lakes, the Gorge bypass reach, and in the Skagit River downstream to just below the Baker River confluence, and in the lower Sauk River (Figure 3.0-1). Specific locations of the water quality sampling/measurement sites are discussed in Section 4.1 of this study report.

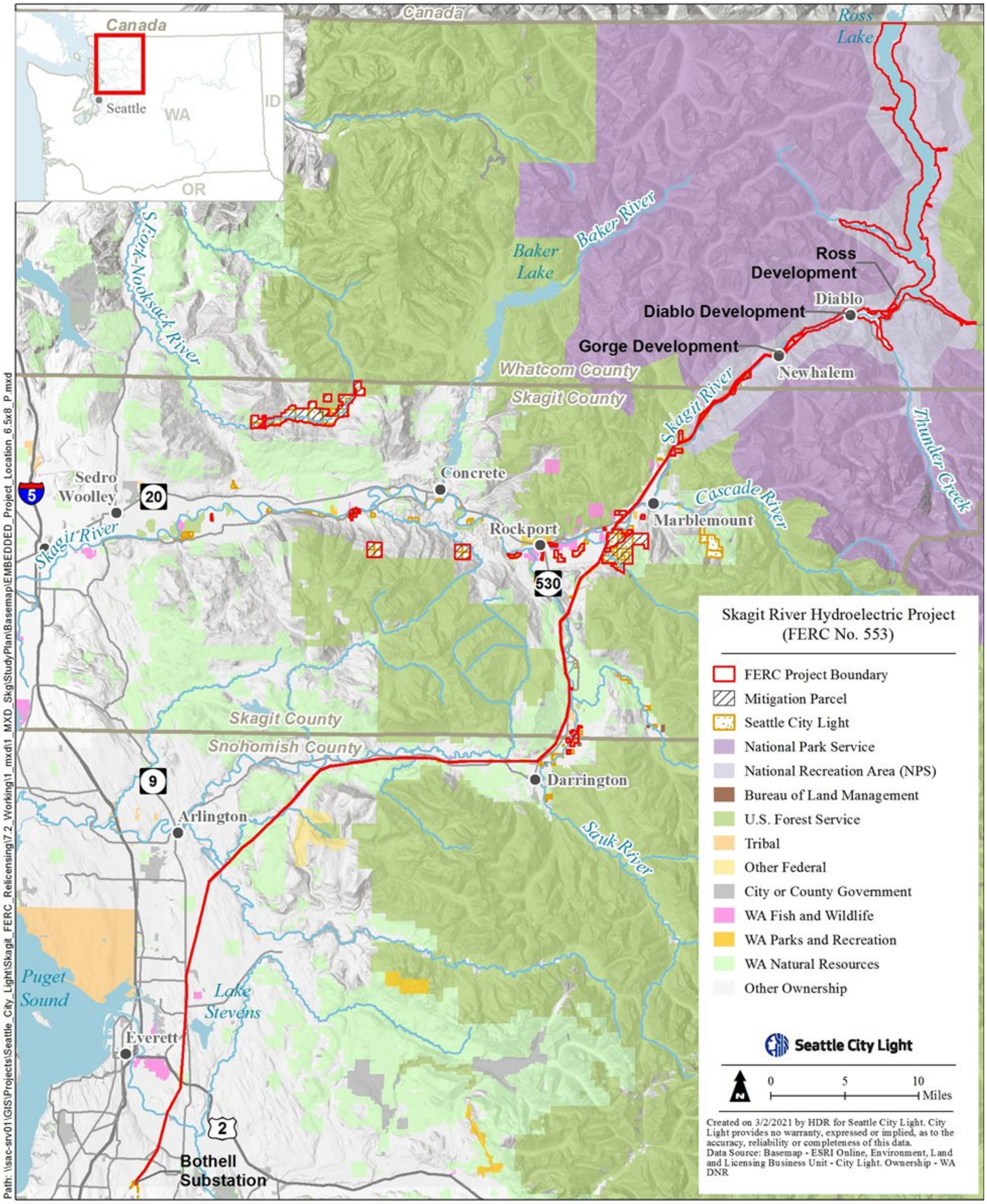


Figure 3.0-1. Location map of the Skagit River Project.

4.0 METHODS

4.1 Field Methods

The WQ Monitoring Study is designed to monitor eight water quality parameters at sites located throughout the Project vicinity over the two-year study period (June 2021 through May 2023). Water quality parameters, sampling type, and sampling frequency vary by location, as summarized in Table 4.1-1. Locations of specific sampling sites are shown in Figures 4.1-1 and 4.1-2. Larger, more detailed maps showing activities conducted at each site are included in Attachment A, and photos of sampling sites are included in Attachment B. Results are grouped into five geographic areas for this report:

- Ross Lake and the Upper Skagit River;
- Diablo Lake;
- Gorge Lake;
- Gorge bypass reach/Powerhouse; and
- Skagit River downstream of Gorge Powerhouse and Sauk River.

Table 4.1-1 provides an overview of parameters to be measured or sampled along with proposed sampling locations, sampling timing and durations, and approach to data collection.

A component of the April 2021 RSP is the Quality Assurance Program Plan (QAPP), provided to Ecology for review in fall 2020. The QAPP details technical elements of field sampling and measurements, laboratory protocols, chain-of-custody (COC) procedures, and data management. The QAPP includes field data collection and laboratory methods, and quality assurance methods to ensure that data collected for this Project are accurate, usable, and repeatable.

Table 4.1-1. Summary of parameters measured or sampled and sampling locations, sampling periods and frequencies, and sampling approach.[1]

Location	Sample Identification	Sample Frequency	Sample Type	Temperature (ºC)	Dissolved Oxygen (mg/L)	pH (units)	Turbidity (NTU)	Total Suspended Solids (mg/L)	Total Dissolved Gas (% Saturation)	Fecal Coliform (CFU)	Benthic Macro-invertebrates
Upper Skagit River											
Upper Skagit River at Swing Bridge	UPSKAGIT1	Monthly (Jun 2021–May 2023)	Grab	1 meter (m)	1 m	1 m	1 m				
Ross Lake											
Pumpkin Mountain	ROSS1	Monthly (Jun 2021–May 2023)	Grab				1 m, 5 m	1 m, 5 m			
Skymo	ROSS2	Monthly (Jun 2021–May 2023)	Grab				1 m, 5 m	1 m, 5 m			
Little Beaver	ROSS3	Monthly (Jun 2021–May 2023)	Grab				1 m, ≤ 5 m	1 m, ≤ 5 m			
Big Beaver Creek Confluence	BBEAVER1[2]	Fall, Winter, Spring 2021–2023	Grab				Surface, 5 m	Surface, 5 m			
Ruby Creek Arm	RUBY1[2]	Fall, Winter, Spring 2021–2023	Grab				Surface, 5 m	Surface, 5 m			
Ross Lake Shoreline Erosional Area North	ROSS4	Fall, Winter, Spring 2021–2023	Grab				400 m transect; 5 surface samples	400 m transect; 5 surface samples			
Ross Lake Shoreline Erosional Area Central	ROSS5	Fall, Winter, Spring 2021–2023	Grab				400 m transect; 5 surface samples	400 m transect; 5 surface samples			
Ross Lake Shoreline Erosional Area South	ROSS6	Fall, Winter, Spring 2021–2023	Grab				400 m transect; 5 surface samples	400 m transect; 5 surface samples			
Hozomeen	ROSS7	Four events (Jun 2021–Sep 2021) Four events (Jun 2022–Sep 2022)	Grab							Surface	
Ross Lake Resort	ROSS8	Four events (Jun 2021–Sep 2021) Four events (Jun 2022–Sep 2022)	Grab							Surface	
Little Beaver Boat Access Camp	ROSS9	Four events (Jun 2021–Sep 2021) Four events (Jun 2022–Sep 2022)	Grab							Surface	
Lightning Creek Boat Access Camp	ROSS10	Four events (Jun 2021–Sep 2021) Four events (Jun 2022–Sep 2022)	Grab							Surface	
Big Beaver Boat Access Camp	ROSS11	Four events (Jun 2021–Sep 2021) Four events (Jun 2022–Sep 2022)	Grab							Surface	
Diablo Lake											
Upper End of Diablo Lake	DIABLO1	Monthly (Jun 2021–May 2023)	Grab	Vertical Profile (2 m)	Vertical Profile (2 m)	Vertical Profile (2 m)	1 m, 5 m	1 m, 5 m			

Location	Sample Identification	Sample Frequency	Sample Type	Temperature (ºC)	Dissolved Oxygen (mg/L)	pH (units)	Turbidity (NTU)	Total Suspended Solids (mg/L)	Total Dissolved Gas (% Saturation)	Fecal Coliform (CFU)	Benthic Macro-invertebrates
Diablo Lake Forebay	DIABLO2	Monthly (Jun 2021–May 2023)	Grab	Vertical Profile (2 m)	Vertical Profile (2 m)	Vertical Profile (2 m)	1 m, 5 m	1 m, 5 m			
Thunder Creek Confluence at Bridge/Colonial Creek Campground	DIABLO3	Fall, Winter, Spring 2021–2023	Grab				100 m transect; 5 surface samples	100 m transect; 5 surface samples			
Thunder Creek Confluence at Bridge/Colonial Creek Campground	DIABLO4	Four events (Jun 2021–Sep 2021) Four events (Jun 2022–Sep 2022)	Grab							Surface	
Environmental Learning Center	DIABLO5	Four events (Jun 2021–Sep 2021) Four events (Jun 2022–Sep 2022)	Grab							Surface	
Gorge Lake											
Upper End of Gorge Lake	GORGE1	Monthly (Jun 2021–May 2023)	Grab	Vertical Profile (2 m)	Vertical Profile (2 m)	Vertical Profile (2 m)	1 m, 5 m	1 m, 5 m			
Gorge Lake Forebay	GORGE2	Monthly (Jun 2021–May 2023)	Grab	Vertical Profile (2 m)	Vertical Profile (2 m)	Vertical Profile (2 m)	1 m, 5 m	1 m, 5 m			
Below Diablo Dam	GORGE3	Jun 2021–May 2023	Continuous						Below Compensation Depth[3]		
Gorge Lake Forebay	GORGE4	Jun 2021–May 2023	Continuous						Below Compensation Depth		
Gorge Bypass Reach											
Below Gorge Dam in plunge pool	BYPASS1	Jun 2021–May 2023	Continuous	1 m	1 m		1 m		Below Compensation Depth		
≈ 1.5 miles above Gorge Powerhouse	BYPASS2	Jun 2021–May 2023	Continuous	1 m	1 m		1 m		Below Compensation Depth		
≈ 0.6 miles above Gorge Powerhouse	BYPASS3	Jun 2021–May 2023	Continuous	1 m	1 m		1 m		Below Compensation Depth		
Skagit River Downstream of Gorge Powerhouse											
Immediately Below Gorge Powerhouse	PHOUSE1	Jun 2021–May 2023	Continuous	2 m	2 m	2 m	2 m		2 m		
Immediately Below Gorge Powerhouse	PHOUSE2	Opportunistically Jun 2021–May 2023	Grab					1 m			
Locations Downstream of Gorge Powerhouse, (6) (PRMs 91.6, 85.9, 75.6, 69.3, 60.8, and 54.5)	SKAGIT2–7	Jun 2021–May 2023	Continuous	1 m							
Locations Downstream of Gorge Powerhouse, (6) (PRMs 91.6, 85.9, 75.6, 69.3, 60.8, and 54.5)	SKAGIT2X–7X	Jul and Sep 2021; Jul and Sep 2022	Grab								Streambed
Sauk River											
RM 2.8	SAUK1	Jun 2021–May 2023	Continuous	1 m							
RM 2.8	SAUK1X	Jul and Sep 2021; Jul and Sep 2022	Grab								Streambed

Notes: ºC = degrees Celsius; mg/L = milligram per liter; NTU = nephelometric turbidity unit; CFU = colony-forming units; PRM = Project River Mile.

1 Source: Table 4, Quality Assurance Project Plan, attached to RSP (City Light 2021). Additional monitoring beyond what is identified in the RSP is described in Section 4.4 of this study report.

2 Turbidity and TSS samples are being collected during drawdown at the mouths of 11 tributaries to Ross Lake two times between fall and spring of 2021-2022 and 2022-2023, for a total of four events. Sampling is described in Section 4.4.1 of this study report. Big Beaver and Ruby creeks are now included as part of this sampling effort, and are now identified as TRIB8 and TRIB11, respectively.

3 The depth at which the sum of hydrostatic and atmospheric pressure exceeds the gas pressure of TDG-supersaturated water.

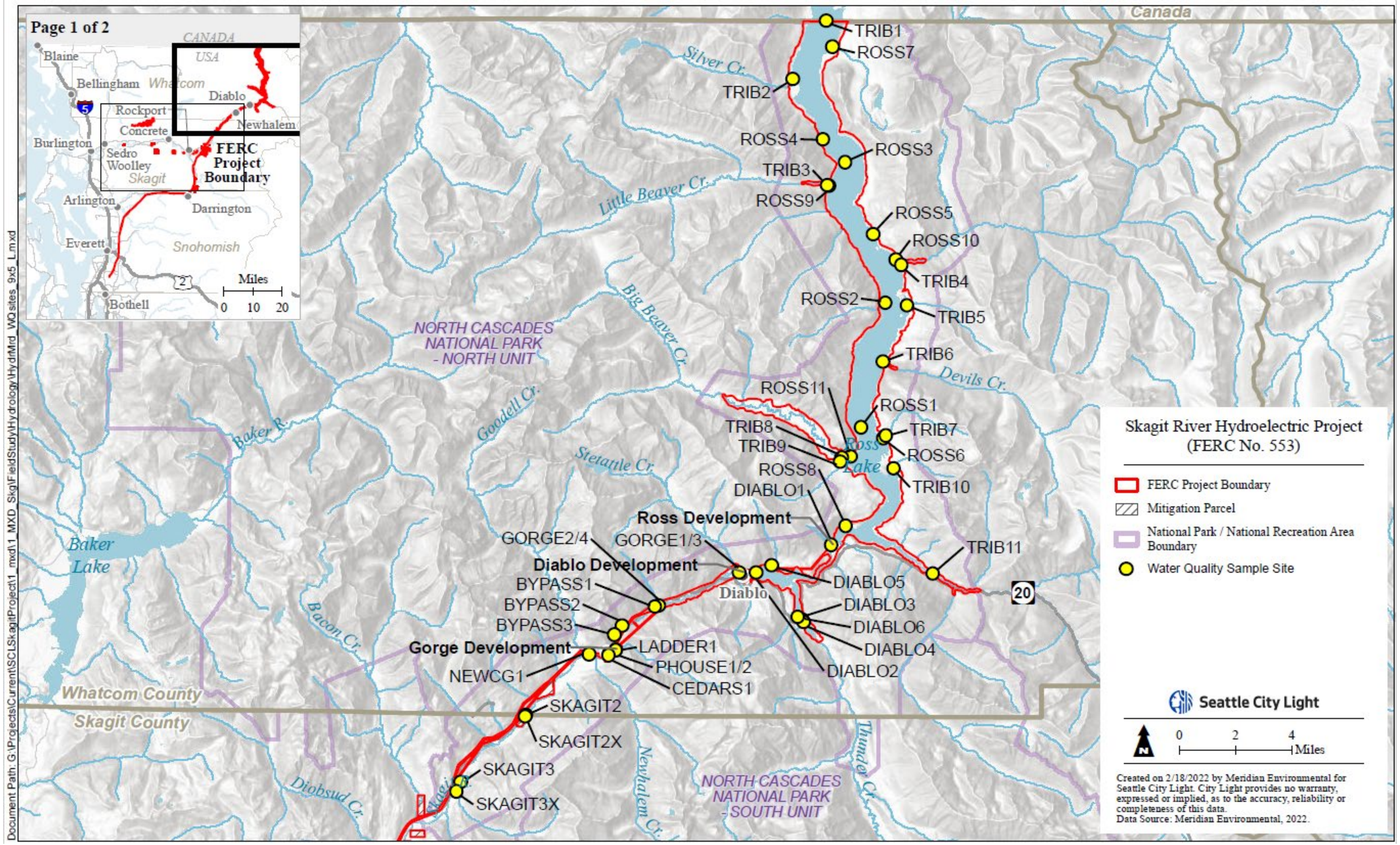


Figure 4.1-1. Map of water quality monitoring locations in Ross, Diablo, and Gorge lakes, the Gorge bypass reach, Gorge Powerhouse, and mainstem Skagit River.

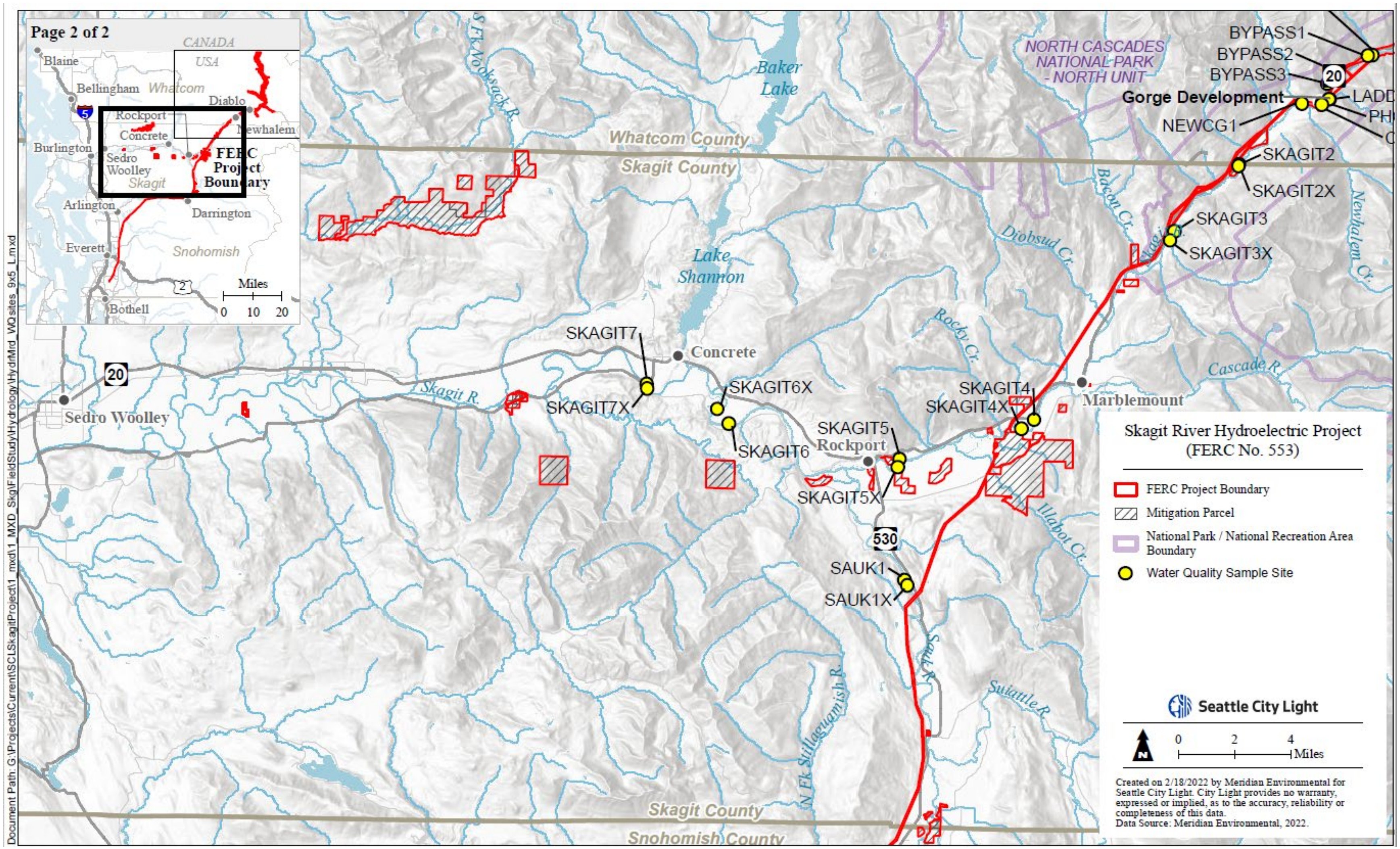


Figure 4.1-2. Map of water quality monitoring locations in the Gorge bypass reach, Gorge Powerhouse, Sauk River, and mainstem Skagit River.

As discussed in the sections below, water quality data are collected at each site using either *in situ* monitoring or grab sampling for analysis at an accredited laboratory. BMI are collected using a D-frame kicknet.

Field methods for the various components of the monitoring program adhere to relevant Ecology Standard Operating Procedures (SOP; Ecology 2006; 2017; 2018a,b; 2019a,b,c,d). Per the RSP, samples will be collected from June 2021 to May 2023, and for purposes of this interim report, results are presented for the period June through October 2021. An overview of field methods and sampling frequency for each sample type is presented below.

***In situ* Monitoring.** *In situ* measurements of water temperature, DO, TDG, turbidity, and pH are being collected using a multi-parameter Hydrolab Series 5 DataSonde (MS5 or DS5). For continuous monitoring of water temperature, DO, TDG, turbidity, and pH, the datasondes are deployed at a depth of approximately 1-m (depending on water level) and log data at 30-minute intervals. Sondes are serviced every three to four weeks to download data, clean the sensors, conduct a quality assurance check, and maintain a continuous power supply.

For vertical profiles at sites in the Project reservoirs, measurements of water temperature, DO, and pH are collected with a Hydrolab DataSonde at 2-m intervals extending from the water surface to the bottom of the reservoir.

Continuous *in situ* measurement of water temperature in the Skagit River downstream of Gorge Powerhouse (i.e., SKAGIT2-7 and SAUK1) is conducted using Onset HOBO TidbiT Temperature Loggers (MS2203), deployed at a depth of approximately 1 m (depending on water level), and data are logged at 30-minute intervals. Temperature loggers are serviced every three months to clean the sensor and download data.

Grab Samples. Water sampling protocols for laboratory analysis were adapted from Ecology's SOP EAP034 (Ecology 2017). Grab samples for laboratory analysis of turbidity, TSS, and FC are taken at a single sampling point with a Van Dorn horizontal water sampler. Prior to sample collection, the water sampler is rinsed with either local water (for turbidity and TSS sampling) or isopropyl alcohol (for FC sampling) to avoid cross-contamination. Samples are collected by lowering the Van Dorn sampler to the appropriate depth and dropping a shuttle to close the sampler. During each monthly event, a field duplicate and field blank are also collected using the same sampling device. Upon retrieval, samples are immediately transferred into pre-cleaned containers provided by the laboratory, placed on ice, and transported to Edge Analytical Laboratory (Burlington, WA), a Washington Department of Ecology accredited laboratory, within acceptable holding times.

Benthic Macroinvertebrate Samples. BMI samples are collected using the procedures described in Ecology SOP EAP073 (Ecology 2019a), using a D-frame kicknet with a mesh size of 500 µm and an area of 1-ft^2 over a site length of approximately two bankfull widths. After positioning the net, samples are taken by first scrubbing large substrate particles to remove any organisms that cling to the substrate, followed by disturbing the sediment for 30-120 seconds at each location. Eight 1-ft^2 kicknet samples are taken at each site to obtain a single 8-ft^2 composite sample. Samples are preserved with ethanol at the time of collection and shipped to EcoAnalysts for identification. Sample processing methods are detailed in Attachment C.

4.1.1 Ross Lake

As described in the RSP, Section 2.6.2 (City Light 2021), monthly grab samples of TSS, turbidity, and FC were collected at Ross Lake between June and October 2021 at the sites summarized in Table 4.1-1. Sampling locations are depicted in Figure 4.1-1. Field methods for Ross Lake sampling are described below.

TSS and turbidity are sampled for laboratory analysis at three locations (Pumpkin Mountain (ROSS1), Skymo (ROSS2), and Little Beaver (ROSS3), at depths of 1- and 5-m. As noted in the RSP, samples will be collected from June 2021 to May 2023, but for purposes of this interim report, only June through October results are summarized (Table 4.1-1). Turbidity was intended to be measured *in situ* using a digital water quality meter. However, starting with the July event, samples were sent for laboratory turbidity analysis, in addition to *in situ* measurements, to serve as a check and backup. Both grab samples for laboratory analysis and *in situ* measurements were collected for June (the grab sample for June was only analyzed for TSS), July, and September events.

In addition to the three locations described above, TSS and turbidity are measured along three 400-m transects in Ross Lake to characterize conditions adjacent to areas of shoreline erosion during reservoir drawdown, when erosional faces of the littoral fringe are exposed. Locations (North, Central, and South, i.e., ROSS4 through 6) are shown in Attachment A, Figures 2, 3, and 5, respectively.

In situ field measurement protocols were adapted from Ecology's SOP EAP011 and EAP129 (Ecology 2019b, c). *In situ* turbidity is measured using digital water quality meters. Depending on availability, the first few events used different water quality meters (AquaRead AP2000D, YSI EXO1, and YSI ProDSS for June, July, and September, respectively). Each meter met the accuracy and precision requirements in the QAPP (City Light 2021). Probes are lowered to the desired depth, and values are recorded after 1 minute of stabilization. Prior to each event, the water quality meters are recalibrated using deionized water and turbidity standards. After each event, a post-calibration check is performed to assess instrument drift.

FC sampling protocols were adapted from Ecology's SOP EAP030 (Ecology 2018a). Samples were collected monthly from June through September at five sites in Ross Lake: (Hozomeen (ROSS7); Ross Lake Resort (ROSS8); and three boat access camps—Little Beaver (ROSS9), Lightning Creek (ROSS10), and Big Beaver (ROSS11) (Figure 4.1-1). In addition, *Escherichia coli* (*E. coli)* samples were collected at Ross Lake Resort (ROSS8) during the August event and at all FC sites during the September event. *E. coli* samples were added for the latter two events because of a change in Washington State water quality standards to the use of *E. coli* rather than FC for water contact recreation bacterial criteria (the change came into effect on January 1, 2021 [WAC 173-201A-200(2)(b)]). City Light communicated the addition of *E.coli* samples to Ecology on September 2, 2021 (Fisher 2021).

Bacteria samples are collected approximately 15 centimeters below the water surface using a Van Dorn horizontal water sampler. To avoid contamination, clean gloves are used to handle all equipment, and the depth sampler is rinsed with isopropyl alcohol or ethanol and then rinsed with nearby site water prior to each sample. Samples are poured directly into sterile bottles with sodium thiosulfate to neutralize residual chlorine. Samples are immediately packed into coolers with ice and transported to Edge Analytical Laboratory (Burlington, WA) for processing within 8 hours of collection.

Locations of the monitoring sites are shown in Figure 4.1-1 and Attachment A. Photos of each water quality monitoring location are included in Attachment B.

4.1.2 Diablo Lake

Beginning in June 2021, water quality data have been collected at four locations in Diablo Lake. DIABLO1 is located at the upper end of Diablo Lake, just downstream of the Ross Dam Powerhouse at the northwest corner of the boathouse near the base of Ross Lake Dam. DIABLO2 is located near the Diablo Dam intake, along the northern side of the forebay log boom. *In situ* vertical profile measurements of temperature, DO, and pH are taken at 2-m intervals at both locations from surface to bottom using a Hydrolab DS5 multiparameter sonde or equivalent.[2] Water samples are collected at depths of 1- and 5-m at each location using a Van Dorn sampler for laboratory measurement of turbidity and TSS. Samples are placed on ice until delivered to Edge Analytical Laboratory (Burlington, WA). Profiles and water samples are collected on a monthly basis at both sites and will continue through May 2023.

During fall, winter, and spring, turbidity and TSS are measured along two 100-m transects in the Thunder Arm to characterize conditions when the reservoir is drawn down. The two transects (DIABLO3 and DIABLO6) are located on either the side of the State Route (SR) 20 bridge at Colonial Creek Campground, near Rhode and Colonial Creeks, respectively (see Figure 7 in Attachment A).

Per the RSP, samples for FC analysis are collected at two sites in Diablo Lake; DIABLO4 is located at the Thunder Creek confluence with Diablo Lake at the bridge at Colonial Creek Campground, and DIABLO5 at the dock at the Environmental Learning Center. Bacterial samples are collected monthly from June through September at these locations; sampling at DIABLO4 and DIABLO5 will occur again from June through September of 2022.

Locations of the monitoring sites are shown in Figure 4.1-1 and Attachment A. Photos of each water quality monitoring location are included in Attachment B.

4.1.3 Gorge Lake

Beginning in June 2021, water quality data have been collected at two locations on Gorge Lake. GORGE1 is located at the upstream end of Gorge Lake at Reflector Bar, across from the Diablo Powerhouse. GORGE2 is located near the Gorge Dam intake, along the southern side of the forebay log boom. Similar to Diablo Lake, vertical profiles at 2-m intervals recording temperature, DO, and pH, and grab samples from depths of 1- and 5-m for laboratory analysis of turbidity and TSS are collected on a monthly basis at both sites. Sampling for these parameters will continue through May 2023.

In addition to profiles and water sample collection, continuous monitoring of TDG began at GORGE1 and GORGE2 in September 2021. Hydrolab MS5s are placed within perforated PVC

[2] Due to instrument availability, a YSI EXO1 was used to collect vertical profile measurements for the June 2021 sampling event.

pipe and deployed at a depth of approximately 3-m. The sonde at GORGE1 is attached to a fixed location and logging depth varies with water surface elevation. The sonde at GORGE2 is attached to the floating log boom and maintains a depth of approximately 3-m regardless of water surface elevation. Both sondes record TDG at 30-minute intervals. Scheduled to begin in June, per the RSP, TDG data collection at the two Gorge Lake locations was delayed due to supply chain issues at the manufacturer.

Locations of the two monitoring sites are shown in Figure 4.1-1 and Attachment A. Photos of water quality monitoring location are included in Attachment B.

4.1.4 Gorge Bypass Reach/Gorge Powerhouse

Water quality monitoring within the Gorge bypass reach began in January 2021. BYPASS1 is located in the plunge pool immediately downstream of Gorge Dam. BYPASS2 is located in a pool approximately 1.5 miles upstream of the Gorge Powerhouse, and BYPASS3 is located in a pool approximately 0.6 miles upstream of the Gorge Powerhouse.

In addition to the three Gorge bypass reach sites, monitoring is being conducted immediately downstream of the Gorge Powerhouse on the south bank (PHOUSE1). Locations of the four monitoring sites are shown in Figures 4.1-1 and 4.1-2 and Attachment A. Photos of each water quality monitoring location are included in Attachment B.

Water quality data are collected in the Gorge bypass reach using Hydrolab MS5s programmed to record water temperature, DO, TDG, and turbidity at 30-minute intervals. These same parameters, along with pH, are recorded using a Hydrolab DS5 at the PHOUSE1 site.

The Hydrolab MS5 datasondes used in the Gorge bypass reach are deployed within perforated PVC pipes, anchored to boulders, and cabled to a second anchor point located approximately 10-20-m above the streambank. The Hydrolab DS5 deployed at PHOUSE1 is deployed within a perforated PVC pipe, attached to a fence post placed in the river, and cabled to a tree approximately 10-20-m from the normal high-water mark. External 12 volt/10-amp lithium-ion batteries are connected to each of the datasondes to augment their internal battery supply. Data logging at these locations will continue through May 2023.

To facilitate calculation of percent saturation of TDG, local barometric pressure is recorded using an Onset Model S-BPB sensor and data logger installed at an upland location near BYPASS1, approximately 0.25 miles downstream of Gorge Dam. This unit collects barometric pressure data (mmHg [millimeters of mercury]) at 30-minute intervals. Logging of barometric pressure will continue as long as TDG is monitored, currently through May 2023.

Per the RSP, samples for laboratory measurements of TSS are collected at the Gorge Powerhouse as needed if turbidity is visually elevated above background. Sampling is conducted using a Van Dorn sampler at a depth of approximately 0.5-m at the PHOUSE2 location.

4.1.5 Skagit River below Gorge Powerhouse and Sauk River

Water temperature and BMI are monitored/sampled at six sites in the Skagit River downstream of Gorge Powerhouse and at one site in the lower Sauk River. Site locations and deployment/sampling dates are described below (Table 4.1-2) and shown in Figure 4.1-2.

Table 4.1-2. Skagit River downstream of Gorge Powerhouse and Sauk River sampling locations.

Sample ID[1]	Location	Description	Date of Thermograph Deployment	Date of BMI Sampling
SKAGIT2	PRM 91.6	Within North Cascades National Park at the U.S. Geological Survey (USGS) gage[2]	9/23/2020	8/24/21
SKAGIT3	PRM 85.9	Within North Cascades National Park at USGS gage[2]	9/23/2020	8/24/21
SKAGIT4	PRM 75.6	Private property in Marblemount, at USGS gage[2]	9/23/2020	8/23/21
SKAGIT5	PRM 69.3	City Light property in Rockport	6/23/2021	8/23/21
SKAGIT6	PRM 60.8	City Light property in Van Horn	6/17/2021	8/23/21
SKAGIT7	PRM 54.5	City Light property at the Concrete-Sauk Valley Road bridge, at USGS gage 12194000	6/23/2021	8/23/21
SAUK1	Sauk River	RM 5.4, at USGS gage 12189500	6/23/2021	8/22/21

1 BMI sampling locations are denoted with an “X” after the Sample ID.
2 New USGS gage installed in 2020; no official gage number has been assigned.

Per the RSP, SAUK1 was to be deployed at River Mile 2.8. River conditions at this location are braided with variable shorelines. Therefore, the SAUK1 thermograph was deployed at RM 5.4 where conditions are stable and consistently wetted.

Onset temperature loggers were placed within protective PVC pipes and cabled to anchor points on the streambank at each of the seven locations. All seven units are programmed to log water temperature at 30-minute intervals. Temperature logging at these sites will continue until May 2023.

BMI were sampled in August 2021. Individual sample locations were selected based on presence of wadeable riffle habitat as close as possible to the thermograph locations listed in Table 4.1-1. BMI sampling locations are identified with an “X” following the Sample ID. Samples are preserved in ethanol at the time of collection, which is decanted prior to shipping to EcoAnalysts for processing. Samples are rehydrated with ethanol upon receipt at the laboratory.

4.2 Quality Assurance / Quality Control

The QAPP, included as an appendix to the RSP, was developed to provide guidance for quality assurance/quality control (QA/QC) for water quality sampling and analyses in support of the Project’s FERC relicensing and Section 401 certification. The QAPP and associated Ecology SOPs outline QA/QC procedures for collection of data in the field, laboratory analysis, and processing of water quality data.

4.2.1 Field QA/QC

Data obtained in the field are collected in accordance with Ecology’s SOPs (Ecology 2006; 2017; 2018a, b; 2019a, b, c). Specific methods for *in situ* and grab sampling are detailed below.

4.2.1.1 *In situ* Sampling

Hydrolab Multiparameter Sondes

Hydrolab MS5s and DS5s are being used for continuous water quality monitoring at the GORGE1, GORGE2, BYPASS1, BYPASS2, BYPASS3, AND PHOUSE1 sites. Sondes deployed at each location were tested and calibrated by the manufacturer prior to deployment. Consistent with Ecology SOPs, subsequent calibration for all parameters is conducted as specified by the datasonde manufacturer, following published procedures and using approved calibration standards.

As recommended in Ecology SOP EAP029 (Ecology 2019c), mid-deployment field data quality checks are completed during datasonde servicing, approximately once every four weeks. These checks include running paired tests with a newly calibrated sonde at each deployment site. Both the newly calibrated and deployed datasondes are set to record data for approximately 10 minutes (at 30-second intervals). These data are then compared, and the average is taken of the absolute value of the difference between the recorded values from each sonde. If the average difference is within the quality objective for accuracy (Table 4.2-1), the sonde is redeployed. If the calculated average difference is found to be outside of the quality objective, the sonde is recalibrated prior to deployment. For TDG, if a mid-deployment check is unable to be run during instrument servicing due to time limitations, the TDG sensor is recalibrated using current barometric pressure to ensure accuracy of collected data.

Table 4.2-1. Field measurement data quality objectives.

Parameter	Unit	Accuracy
Temperature	Degrees Celsius (°C)	0.2 °C
pH	Units	0.5 units
Dissolved Oxygen (DO)	Milligrams per liter (mg/L)	0.5 mg/L
Turbidity	Nephelometric turbidity units (NTU)	5%
TDG	Percent saturation	1% / 5 mmHg[1]

1 TDG field accuracy based on Ecology SOP EAP002 of 10 mmHg.

Ecology SOP EAP002 (Ecology 2006) for TDG requires no greater than a 10 mmHg difference at mid-deployment checks between field and recently calibrated sondes. This differs slightly from the QAPP-based criteria shown above in Table 4.2-1 (1 percent or 5-mm). The EAP002 criteria of 10 mmHg is applied in the field; however, given observed barometric pressure and based on field checks conducted to date, the more stringent 1 percent QAPP criterion was effectively met (see Section 5.2.7).

TDG membranes are fragile and prone to failure, and suspect TDG membranes are either tested and or replaced with a new membrane. Membrane failure may be indicated by paired test results with a difference of greater than 10 mmHg, or a lack of an increase in TDG when tested in the field using club soda, consistent with Ecology SOP EAP002 (Ecology 2006).

Hydrolab multiparameter sondes are also used to measure instantaneous vertical profiles in Diablo and Gorge lakes. Prior to each use, the sonde is calibrated using manufacturer's recommended methods. The sonde also undergoes a calibration check after vertical profile measurements are taken to ensure sonde accuracy during profile measurements.

Onset HOBO TidbiT Water Temperature Loggers

Onset water temperature loggers are being used for continuous measurement of water temperature at six locations in the Skagit River downstream of Gorge Powerhouse and at one location in the Sauk River. Prior to deployment, all water temperature loggers underwent a pre-deployment calibration check to confirm accuracy, consistent with Ecology SOP EAP080 (Ecology 2018b). A two-point calibration check was completed using an ice bath, room temperature water, and a National Institute of Standards and Technology (NIST) traceable thermometer. Temperature loggers were placed in an ice bath and recorded temperature until 10 relatively constant and consecutive measurements were taken with an NIST thermometer. The process was repeated in a room temperature water bath. The mean absolute value of the difference between the temperature logger measurements and the NIST thermometer for each water bath was calculated. Temperature loggers that had a mean difference greater than 0.2°C in one or both water baths are not used to monitor water temperatures for this WQ Monitoring Study.

A post-deployment accuracy check following the above procedures will be conducted upon retrieving the temperature loggers from the field in May 2023. Per Ecology SOP EAP080 (Ecology 2018b), all data will be assigned a measurement accuracy value based on the pre-and post-deployment calibration check results.

4.2.1.2 Grab Sampling

Water Samples

Surface water samples are collected in the field for subsequent TSS, turbidity, and FC analysis by a qualified laboratory (Edge Analytical). A COC record is maintained with the laboratory samples at all times. The COC forms identify the sample bottles, date and time of sample collection, and analyses requested and are initiated at the time of sample collection and signed prior to sample release. The samples are transported to the lab in insulated containers within the appropriate holding time and are accompanied by the COC form. The laboratory performs all analyses within the constituent- or method-specific holding times (6-24 hours for FC, 7 days for TSS and turbidity). After analyses are conducted, all samples are disposed of in accordance with federal, state, and local requirements.

Multiple steps are taken to avoid sampling and laboratory bias. To avoid contamination, all sample bottles are filled by field personnel wearing clean nitrile gloves. One field duplicate sample is taken each sampling day to evaluate quality assurance at the analytical laboratory. The field duplicate sample is taken during normal sample collection where processing procedures are repeated to collect a second grab sample at a randomly selected field station. The sample is labeled with the site location and "Duplicate."

A blank sample is also taken each sampling day to assess possible field and/or laboratory contamination sources. Blank sample bottles are held with the sampling bottles throughout the day and filled with deionized water while on site. The sample is labeled with "Blank" and the time the bottle is filled. Duplicate and blank samples are processed in the field and in the laboratory following the same procedures as routine samples. The duplicate sample provides a measure of variability potentially due to local field conditions, sample collection and processing, and laboratory analysis. The blank sample captures potential contamination from sample collection, processing and laboratory analysis.

BMI Samples

BMI sampling at each of six sites in the Skagit River and one site in the Sauk River are composited from eight stations within the sample site. Sampling from multiple locations, or stations, provides a representative sample of the site. Each site is sampled via targeted riffle sampling to reduce habitat or substrate related variation in the data. Taxonomic analyses and calculation of index values are conducted by EcoAnalysts in Moscow, ID.

4.2.2 Laboratory QA/QC

Edge Analytical Laboratory's QA/QC program includes calibration checks, method blanks (laboratory equivalent of field blanks), and use of quality control samples. The latter are samples with known TSS or turbidity and analyses are reported as percent recovery. Lab QA/QC samples are included in each analytical batch containing City Light samples.

Field quality assurance for BMI samples is estimated by collecting a side-by-side duplicate composite sample at one site each sampling season (SKAGIT3 at PRM 85.9 in 2021) during the same sampling event. QA/QC procedures for sample processing by EcoAnalysts are included in Attachment C.

4.2.3 Data Processing

Consistent with Ecology SOP EAP130 (Ecology 2019d), the first step in reviewing a Hydrolab raw data file is to remove all measurements where the sonde was out of water or had not yet equilibrated. Field notes and deployment and retrieval times are used to remove data points where the sonde or thermograph was out of water. Any removal of data is made on a processed data file; raw data files for each site retain all field data collected.

Once data are reviewed to identify outliers due to exposure or equilibration, processing then involves plotting the data and a reasonableness review based on professional judgement and comparison to prior data for the site. Finally, as discussed above, results of mid-deployment checks are reviewed and the data qualified, if necessary, based on criteria shown in Table 4.2-1. Per Ecology SOP EAP130 (Ecology 2019d), data that are qualified based on performance checks are considered estimates and are not removed from processed data, nor are any data adjusted based on observed differences.

As noted in Section 4.1 of this study report, DO concentration, not percent saturation, is measured in the field. However, for reference, percent saturation is calculated for values that appear low or otherwise questionable using an Oregon Department of Environmental Quality formula available online.[3]

As noted in the QAPP, completeness of the data is an important quality objective. While not a regulatory requirement, an assumption of the RSP is that measurement techniques selected for use in this study are capable of generating data that is of 90 percent or greater completeness for field and laboratory analyses. Per the QAPP, data completeness is expressed as a percentage, and is

[3] https://www.oregon.gov/deq/FilterPermitsDocs/RPADOSaturationEquation.xls.

calculated by subtracting the number of unreported results from the total planned results and dividing by the total number of planned results.

For continuous monitoring data, each half-hourly observation during the study period reported in this study report (January 28 through October 5, 2021) was assigned one of the three designations (accepted, qualified, or rejected) shown in Table 4.2-2. Estimated results from failed performance checks are considered qualified and do not count against data completeness because they are considered usable, as long as any limitations are identified. Data completeness calculations excluded half-hour intervals during which no data were collected due to factors beyond the control of the investigators such as site access issues (e.g., spill or high flows), supply chain issues, or deployment prior to the start date of the RSP.

Table 4.2-2. Processed data classifications.

Designation	Description
Accepted	Data valid; included in processed data
Qualified	Data qualified due to failed performance check, detectable blank values, or high RSD[1]; qualified data included in processed data
Rejected	Data invalid (outliers, equilibration, exposure); removed from processed data

1 RSD = relative standard deviation.

Data completeness was calculated for each site and parameter as follows:

$$\frac{Obs_{Planned} - Obs_{Rejected}}{Obs_{Planned}}$$

where $Obs_{Planned} = Obs_{Accepted} + Obs_{Qualified} + Obs_{Rejected}$

Gantt charts provide a visual overview as to whether data collected during a given week are accepted, qualified, or rejected, or the reason data were not collected during a given week (e.g., due to access issues, supply chain issues, or deployment prior to the start date of the RSP). If any data are classified as accepted during a given week, that week in the Gantt chart is coded as accepted. If no data were accepted but some data were qualified, all data in that week are coded as qualified. If no data were accepted or qualified, but some were rejected, all data in that week are coded as rejected. Similarly, if no data were collected during a given week, it is coded as due to access if any access issues occurred during that week. If access was not an issue, but supply was, the week is coded as supply. Pre-RSP periods are defined for each site independent of the other designations.

4.3 Existing Data

An objective of the WQ Monitoring study is to provide a summary and analysis of available, relevant existing water quality data collected by City Light, NPS, USGS, Ecology, and other entities, as appropriate. As part of its June 9, 2021 Notice, City Light committed to providing LPs with a provisional water quality data summary to identify potential data gaps and ensure those gaps are addressed through data collection during the relicensing timeframe. City Light developed a catalog of existing water quality data to identify and improve access to the extensive data that have been and continue to be collected throughout the Project vicinity. The catalog is an Excel spreadsheet tabbed with four primary groups of data: Tributary, including those to the Skagit River and Project reservoirs, and data pertaining to Ross, Diablo, and Gorge lakes. For tributaries and the Skagit River mainstem there are currently more than 50 sites represented, covering primarily water temperature (continuous monitoring) but also discrete measurements of DO, pH, specific conductance (SC), turbidity and BMI at several locations. Reservoir data included continuous water temperature measurements at multiple stations and depths, as well as discrete measurements of DO, pH, SC, chlorophyll *a*¸ turbidity, dissolved solids, zooplankton, and water chemistry (nutrients and ions). This cataloging of water quality data covers the period 2000 to 2020.

Per the June 9, 2021 Notice, City Light provided the data catalog along with provisional graphic and tabular presentations of many of the data acquired to date in a Memorandum to LPs on September 3, 2021. The June 9, 2021 Notice also states that a more comprehensive analysis will be prepared and included in this study report (Attachment D). Integration of existing and new data collected during relicensing will be an important component of the USR, to be submitted in March 2023.

4.4 Additional Monitoring

As discussed in Sections 4.1.1 through 4.1.5 of this study report, monitoring previously described will continue through as late as May 2023, depending on the activities and schedule outlined in the RSP. Details on sample frequency are included in Table 4.1-1. Additional monitoring beyond what is identified in the RSP is described below.

4.4.1 Sampling at Tributary Mouths in Ross Lake

As required by FERC's SPD, turbidity and TSS samples are being collected during drawdown at the mouths of 11 tributaries to Ross Lake two times between fall and spring of 2021-2022 and 2022-2023, for a total of four events. Sampling locations are included in Table 4.4-1, Figure 4.1-1, and on maps in Attachment A. FERC's SPD specified sampling at 1-m and 5-m depths off tributary mouths. However, given depths observed in the field, samples are collected at the mouth at a depth of approximately 1-m, and, due to shallow depths at the tributary mouths, a sample is taken within the tributary above the normal maximum surface elevation, if accessible.

FERC's SPD modifies sampling identified in the RSP at Big Beaver and Ruby Creeks. The RSP prescribed sampling at BBEAVER1 and RUBY1 in fall, winter, and spring of 2021-2022 and 2022-2023; the SPD instead identifies sampling at TRIB8 (Big Beaver Creek) and TRIB11 (Ruby Creek) sampled twice between fall and spring of 2021-2022 and 2022-2023.

Table 4.4-1. Ross Lake tributary locations for turbidity and TSS sampling.

Location	Site ID	Latitude, Longitude	Depths	Frequency
Skagit River at International Boundary	TRIB1	49.00022, -121.074	1-m and above the normal maximum surface elevation	2 events between fall and spring each year
Silver Creek	TRIB2	48.97023, -121.104		
Little Beaver Creek	TRIB3	48.91536 -121.077		
Lightning Creek	TRIB4	48.87443 -121.018		
Dry Creek	TRIB5	48.85340 -121.014		
Devil's Creek	TRIB6	48.82411 -121.033		
May Creek	TRIB7	48.78624 -121.030		
Big Beaver Creek	TRIB8	48.77471 -121.065		
Pierce Creek	TRIB9	48.77242 -121.066		
Roland Creek	TRIB10	48.76913 -121.024		
Ruby Creek	TRIB11	48.71477 -120.993		

4.4.2 Additional Transect in Diablo Lake

An additional transect was added for turbidity and TSS sampling in Diablo Lake downstream of the SR 20 bridge over Thunder Arm near the Colonial Creek confluence with Diablo Lake (DIABLO6). The transect location identified in the RSP (DIABLO3) is at the confluence of Rhode Creek and Diablo Lake, upstream of the bridge. DIABLO6 was identified as a possible erosional area during a field visit and was added to the list of transect sampling locations. Transect sampling is completed using the same methodology and sampling interval as for DIABLO3.

4.4.3 Total Dissolved Gas Downstream of Gorge Powerhouse

Preliminary results of monitoring indicate elevated TDG during a spill event in late June 2021 (see Section 5.2.5 of this study report). To evaluate the downstream extent of elevated levels of TDG, the existing monitoring at the Bypass and Powerhouse locations is being augmented with measurement of TDG during spill events at locations downstream of Gorge Powerhouse. These measurements are opportunistic; not all spill events are monitored. Measurements are being made via discrete, instantaneous samples or short-term programmed measurements with a Hydrolab datasonde. Measurements of TDG are being made from bridges in the vicinity of the Powerhouse and may include Ladder Creek falls bridge, the suspension bridge to Trail of the Cedars, or the bridge at Newhalem Campground. Data collected during each spill event will be included in the USR in 2023. Preliminary data from a spill event monitored in October 2021 are presented in Section 5 of this study report.

5.0 PRELIMINARY RESULTS

This section presents results of City Light's water quality monitoring program through October 2021. Data collection is ongoing and will extend as late as May 2023, depending on the activity (see Table 4.4-1). Results are preliminary in that roughly 20 percent of the planned monitoring program has been completed to date (through October 2021). Ecology's water quality standards are shown for reference in some of the data summary figures.

5.1 Project Reservoirs

This section of the study report presents results of field and laboratory-based water quality monitoring in Ross, Diablo, and Gorge lakes.[4] As noted in Section 4 of this study report, the information included in this study report extends from June through October 2021 and does not include results of turbidity/TSS sampling at Ross Lake tributary mouths (discussed in Section 4.4.1). Water samples were collected from all three Project reservoirs on a monthly basis, and the data collection effort will continue through May 2023, depending on the activity (see Table 4.4-1).

5.1.1 Ross Lake

5.1.1.1 Ross Lake Turbidity and TSS

TSS and turbidity levels in Ross Lake over the period covered in this study report (June – October 2021) were generally low, with most measurements either below or close to the quantification limits (Table 5.1-1). TSS was above the detection limit in June at ROSS1 (Pumpkin Mountain) at 1-m depth,[5] and in August at ROSS3 (Little Beaver) at 5-m depth—in both cases the measured concentration was 3 mg/L. Turbidity samples were above the quantification limit of 0.1 NTU from July through September but largely below 1 NTU. September had the highest turbidity, with values above 0.73 NTU, and reaching 1.10 NTU at ROSS1 and ROSS3, at 5-m depths. Most TSS measurements were non-detect, suggesting that, at these low levels, TSS-turbidity correlations may not be reliable.

As noted earlier, field personnel used three different instruments to monitor turbidity in Ross Lake: an AquaRead AP2000D, a YSI EXO1, and a YSI ProDSS (depending on availability). The YSI EXO1 used during the July monitoring event registered low or negative turbidity values, likely due to instrument drift or the use of deionized water for calibration. The corresponding laboratory turbidity values for this event were at or near zero NTU, like the June event.

In contrast to laboratory results for September, which ranged from 0.73 to 1.1 NTU, *in situ* measurements in September were lower. A YSI ProDSS used for the September event registered readings of 0 ± 0.03 NTU at all sites. *In situ* turbidity measurements were not conducted during the August and October events due to time constraints.

In general, the *in situ* measurements of turbidity and the laboratory measurements of TSS and turbidity all indicate that Ross Lake is clear during the summer. Given that the *in situ* turbidity

4 Results of data collected in Ross Lake near the U.S.-Canada border by the USGS, Washington Water Science Center are provided in Attachment D to this interim report.

5 June values were based on *in situ* measurements, all other turbidity values were determined in the laboratory.

measurements were all very low, the laboratory measurements are reported in Table 5.1-1 (except for June) because they are all slightly higher, and therefore, more conservative.

Table 5.1-1. Ross Lake monthly turbidity and total suspended solids sampling results at 1- and 5-m depths, June through November 2021.

Date	Reservoir Elevation (NAVD 88)	ROSS1				ROSS2				ROSS3			
		Turbidity (NTU)		TSS (mg/L)		Turbidity (NTU)		TSS (mg/L)		Turbidity (NTU)		TSS (mg/L)	
		1-m	5-m	1-m	5-m	1-m	5-m	1-m	5-m	1-m	5-m	1-m	5-m
Jun 29	1.606.2	0 (0)	0	ND (ND)	ND	0	0	ND	ND	0	0	ND	ND
Jul 26	1,607.6	0.4	0.48	ND	ND	0.59 (0.42)	0.66	ND (ND)	ND	0.31	0.17	ND	ND
Aug 17	1,607.8	0.39	0.41	ND	ND	0.32	0.43	ND	2	0.25 (0.30)	0.22	ND (ND)	3
Sep 14	1,602.3	0.94 (0.78)	1.1	ND (ND)	ND	0.94	0.86	ND	ND	0.73	1.1	ND	ND
Oct 28	1,593.4	0.46	0.35	ND	ND	0.35 (0.46)	0.48	ND (ND)	ND	0.5	0.33	ND	ND
Nov 30	1,591.1	13	13	4	4	10	10	3	3	6.7	6.5	2	2

Notes:
NAVD 88 = North American Vertical Datum of 1988.
ROSS1 = Pumpkin Mountain; ROSS2 = Skymo; ROSS3 = Little Beaver.
Samples measured below the quantification limit (0.1 NTU and 2 mg/L) are reported as non-detectable (ND).
Field duplicate results are shown in parenthesis.
June turbidity data are from in situ measurements, while other months are from laboratory measurements.

5.1.1.2 Drawdown Total Suspended Solids and Turbidity

As described in Section 4.1.1 of this study report, turbidity and TSS samples are collected under drawdown conditions at three transect locations (ROSS4 through 6; see Attachment A, Figures 2, 3, and 5) three times between fall and spring of each year for a total of six transect events. Additionally, sampling at the mouths of 11 tributaries into Ross Lake is conducted twice between fall and spring of each year for a total of four events. The tributary locations target the tributary mouth at normal maximum water surface elevation and either slightly upstream or downstream of the mouth into the reservoir/lake. These stations are described in Table 4.4-1 and can be viewed on the maps in Attachment A.

The first event was conducted on November 30 and December 1. Transect results were largely consistent within each transect (Table 5.1-2). Values ranged from 7.2 to 16 NTU and from non-detect to 6 mg/L for turbidity and TSS, respectively. These values were also comparable to the samples collected at the monthly turbidity/TSS stations (ROSS1-3) on the same day (Table 5.1-1). The ROSS5 transect had slightly lower turbidity (7.5-9.3 NTU) and largely non-detect values for TSS compared to transects ROSS4 and ROSS6.

Table 5.1-2. Ross Lake turbidity and total suspended solids transect results, December 2021.

Date	Distance along Transect (m)	ROSS4		ROSS5		ROSS6	
		Turbidity (NTU)	TSS (mg/L)	Turbidity (NTU)	TSS (mg/L)	Turbidity (NTU)	TSS (mg/L)
Dec 1	0	14	6	7.2	3	16	4
	100	12	ND	8.3	ND	15	6
	200	12	4	8.9	ND	15	ND
	300	12	3	8.9	ND	16	4
	400	11	3	9.3	ND	16	2

Notes:
ROSS4 = Ross Lake Erosional Area North; ROSS5 = Ross Lake Erosional Area Central; ROSS6 = Ross Lake Erosional Area South.
Reservoir elevation at the time of transects was 1,591.1 feet NAVD 88.
Samples measured below the quantitation limit are reported as ND.
TSS quantitation limit was 2 mg/l. Turbidity quantitation limit was 0.1 NTU.

5.1.1.3 Tributary Samples

Results from turbidity and TSS sampling in Ross Lake tributaries are shown below (Table 5.1-3). Turbidity and TSS samples from Ross Lake tributaries exhibit a broader range than samples collected in Ross Lake, with the highest values measured at the Skagit River at the international boundary (TRIB1) and Ruby Arm (TRIB11), with turbidity measured at 100 and 40 NTU and TSS at 88 and 39 mg/L for TRIB1 and TRIB11, respectively. Stations TRIB2-8 had intermediary results ranging from 4 to 17 NTU, and non-detect to 31 mg/L for turbidity and TSS, respectively. Stations TRIB9 and 10 had the lowest results with turbidity values less than 2 NTU and non-detect for TSS.

TRIB6 and 7 were not sampled during the fall 2021 event. The reservoir elevation at the time of sampling (1,591-1,592 feet NAVD 88) did not expose any appreciable varial zone or erosive substrates at TRIB6 (Devil’s Creek). For TRIB7 (May Creek), the ROSS6 transect captures conditions at the mouth of the creek. Neither creek appeared to be passable to fish at the time of sampling.

Table 5.1-3. Results from turbidity and total suspended solids sampling in Ross Lake tributaries, fall 2021.

Site ID	Site Name	Depth (m)	Turbidity (NTU)	TSS (mg/L)
TRIB1	Skagit River at International Boundary	<1	100 (100)	88 (86)
TRIB2-A	Silver Creek - Mouth	Surface	1.1	ND
TRIB2-B	Silver Creek - Lake	<1	17	24
TRIB3-A	Little Beaver Creek - Inlet	<1	17	31
TRIB3-B	Little Beaver Creek - Lake	<1	17	27
TRIB4-A	Lighting Creek - Inlet	<1	15	12
TRIB4-B	Lightning Creek - Lake	<1	12	8
TRIB5-A	Dry Creek - Upstream	Surface	4.1	3
TRIB5-B	Dry Creek - Mouth	Surface	6.1	8
TRIB6	Devil’s Creek	N/A	N/A	N/A
TRIB7	May Creek	N/A	N/A	N/A
TRIB8-A	Big Beaver Creek - Upstream	Surface	7	18
TRIB8-B	Big Beaver Creek - Mouth	Surface	8	19
TRIB9-A	Pierce Creek - Upstream	Surface	1.2	ND
TRIB9-B	Pierce Creek - Mouth	Surface	1.2	ND
TRIB10-A	Roland Creek - Upstream	Surface	1.4	ND
TRIB10-B	Roland Creek - Mouth	Surface	1.4	ND
TRIB11	Ruby Arm	<1	18	8
		5	40	39

Notes:
Most sampling was conducted on November 30 except the Ruby Arm site which was collected on December 1.
Samples measured below the quantitation limit are reported as ND.
TSS quantitation limit was 2 mg/L. Turbidity quantitation limit was 0.1 NTU.
Field duplicate results are shown in parenthesis.
No samples collected at Devil’s Creek (TRIB6) or May Creek (TRIB7).

5.1.1.4 Fecal Coliform/*E. Coli*

FC concentrations in the reservoirs were largely below quantification limits during the June to September season, although several samples did contain detectable CFU (Table 5.1-4). The highest FC concentrations were recorded in June (600 CFU/100 milliliter [mL] at ROSS8 and 3 CFU/100 mL at ROSS7, 10, and 11), respectively. Only the ROSS7 and 8 samples had detectable FC concentrations in August and September.

E. coli concentrations at ROSS8 closely mirrored the FC results (Table 5.1-4). August and September results were at or below the quantification limit.

Table 5.1-4. Ross Lake monthly fecal coliform and *E.coli* sampling results, June through October 2021.

Date	Reservoir Elevation (NAVD 88)	ROSS7		ROSS8		ROSS9		ROSS10		ROSS11	
		FC	*E. coli*	FC	*E. coli*	FC	*E. coli*	FC	*E. coli*	FC	*E. coli*
Jun 30	1,606.2	3 (5)	-	600	-	ND	-	3	-	3	-
Jul 26	1,607.6	ND	-	ND (ND)	-	ND	-	ND	-	ND	-
Aug 17	1,607.8	2	-	2	2	ND (ND)	-	ND	-	ND (ND)	-
Sep 14	1,602.3	2	ND	11	2	ND	ND	ND (ND)	ND (ND)	ND	ND

Notes:
ROSS7 = Hozomeen; ROSS8 = Ross Lake Resort; ROSS9 = Little Beaver Boat Access Camp.
ROSS10 = Lightning Creek Boat Access Camp; ROSS11 = Big Beaver Boat Access Camp.
Results are in CFU/100 mL.
Samples measured below the quantification limit (2 CFU/100 mL) are reported as ND.
Field duplicate results are shown in parenthesis.
E. coli was measured at ROSS8 in August and all sites in September.

5.1.1.5 QA/QC

Overall, the FC and *E. coli* data are considered reliable. However, it should be noted that the warm summer air temperatures and large sample volumes made it difficult for field personnel to meet the laboratory's recommended 4°C holding temperature, despite the fact that the samples were placed in coolers packed with ice. As a result, Edge Analytical flagged all August FC samples as estimated (assigned a J qualifier) for exceedance of the holding temperature. In general, the times at which the samples were delivered to the laboratory were within a few hours of sampling, and the laboratory preserves the samples immediately upon receipt. Thus, despite the "J" flag, these samples are still useable and provide reliable data. During future events larger and/or more coolers will be used to enable more ice to be packed into the coolers to meet the holding temperature requirements.

Three field duplicate pairs, one FC (values of 3 and 5 CFU/100 mL) and two turbidity measurements (both less than 1 NTU), exceeded the 10 percent RSD criteria. At low concentration, small differences between replicates results in large RSDs. These samples were qualified as estimated (J qualifier).

The negative values for *in situ* turbidity measurements during the July and August events may have resulted from the use of deionized water for instrument calibration. YSI guidance documents indicate that negative results can occur at very low turbidity when deionized or distilled water is used for calibration (Xylem 2019). Negative results were reported as 0 and flagged as estimated (J qualifier).

Three field blanks, two for turbidity and one for TSS, between the August and September events had detected results. Discussion with the head of laboratories at Edge Analytical indicates that it is not uncommon for low levels of turbidity to be measured in distilled water. These samples are flagged for blank violation (B qualifier).

5.1.2 Diablo Lake

Each of the vertical profiles in Diablo Lake, June through October, were conducted at elevations of approximately 1,206-1,208 feet NAVD 88 (per USGS Gage 12176500, Diablo Reservoir near Newhalem, WA). Per the Pre-Application Document (PAD), average elevation over a 28-year period, 1991-2018, for each of these five months is approximately 1,208 feet NAVD 88 (1,202 feet City of Seattle datum [CoSD]) (City Light 2020).

5.1.2.1 Diablo Lake Vertical Profiles

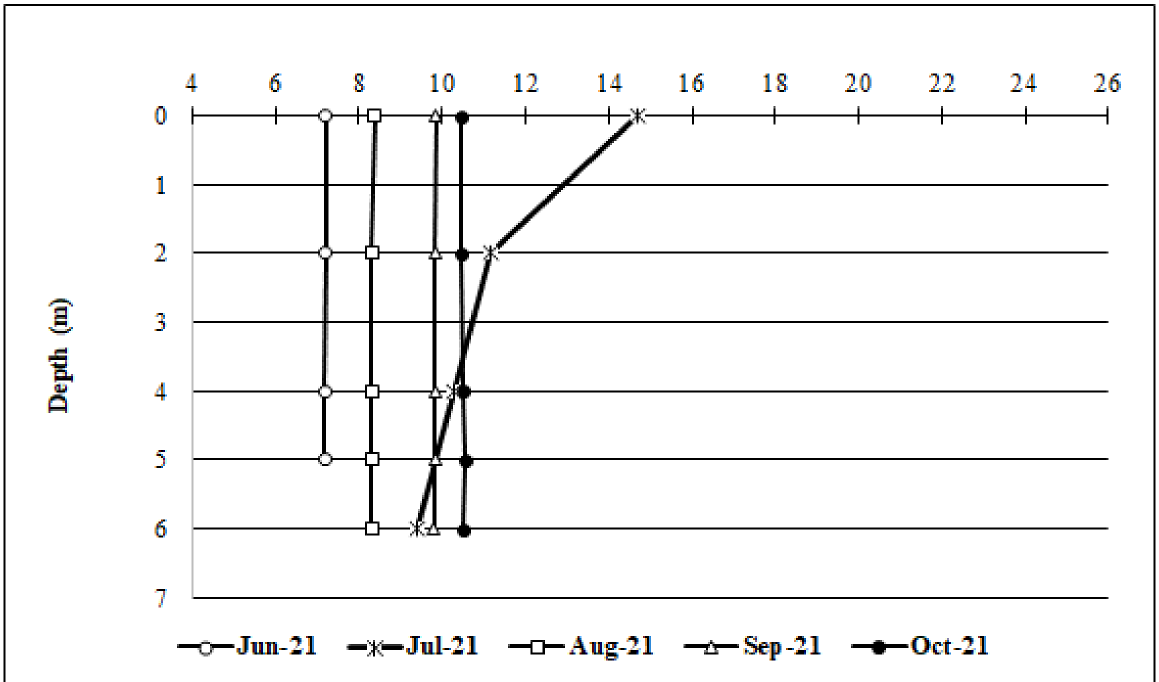
Surface water temperatures at DIABLO1, the station at the Ross Powerhouse boathouse, increased from approximately 7°C in June to approximately 14°C in October (Figure 5.1-1). However, with the exception of July, water temperatures were generally isothermal throughout the water column. A thermal gradient is seen in the July profile from the surface, at approximately 14°C, to approximately 10°C at a depth of 4-m (Figure 5.1-1).

Despite the short detention time (9.4 days) in Diablo Lake (City Light 2020), thermal stratification is evident at the deeper, downstream site at the Diablo forebay (DIABLO2), particularly in July when water temperatures in the upper 2-m were 24.5°C on July 21 (Figure 5.1-1). In contrast to DIABLO1, stratification at DIABLO2 is apparent from June through September, but not October.

DO profiles at DIABLO1 and DIABLO2 are shown in Figure 5.1-2. At DIABLO1, values were lowest during July and highest in June. Surface DO was 9.5 mg/L in July, increasing to 11.5 mg/L at 4 m. In June, surface DO was 13.6 mg/L, with values remaining constant to the bottom depth of 5-m. These minimum and maximum DO concentrations correspond to 98 percent and 118 percent saturation, respectively, based on temperatures shown above and assuming a reservoir elevation of 1,211.36 feet NAVD 88 (1,205 feet CoSD), as reported in the PAD (City Light 2020).

At DIABLO2, minimum DO was 7.8 mg/L at the surface in July, corresponding to a calculated saturation of 98 percent at the surface water temperature noted above (24.5°C). Remaining profile measurements were generally 10-12 mg/L; from July through September DO profiles increase slightly through the mid-water column with decreasing temperatures.

pH profiles collected at the two Diablo sites are shown in Figure 5.1-3. Slightly larger differences were seen in pH among months at DIABLO1 than at DIABLO2, likely due to a more stable water column near the log-boom.



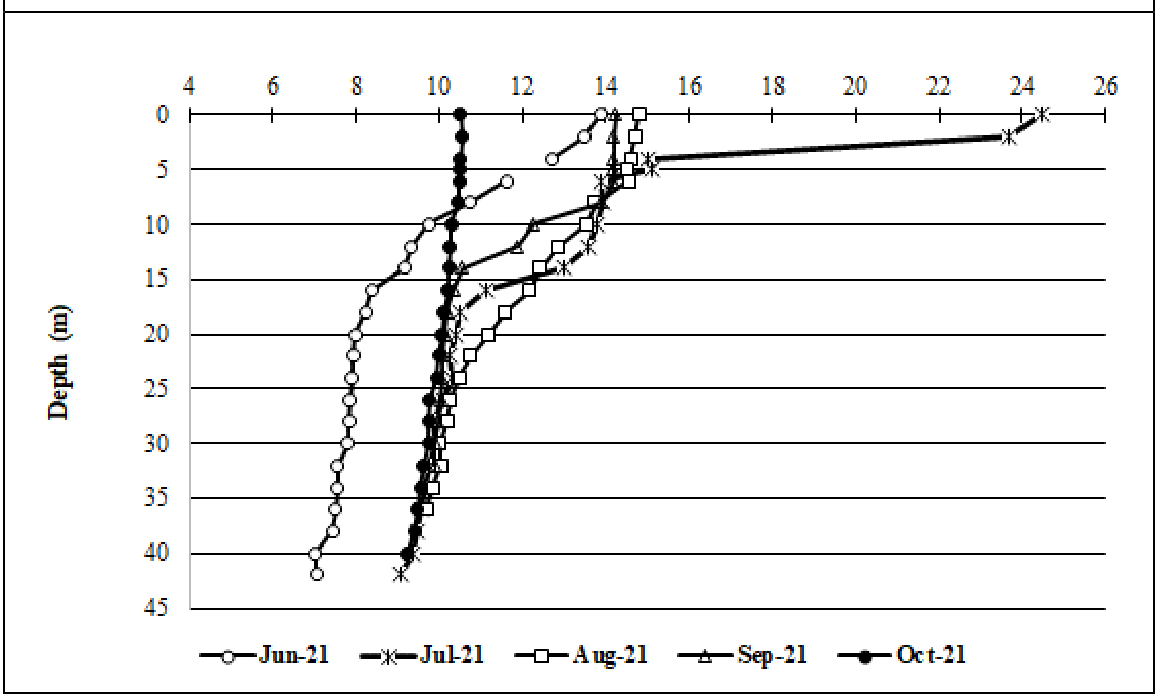


Figure 5.1-1. Temperature profile at DIABLO1 (top) and DIABLO2 (bottom), June through October 2021.

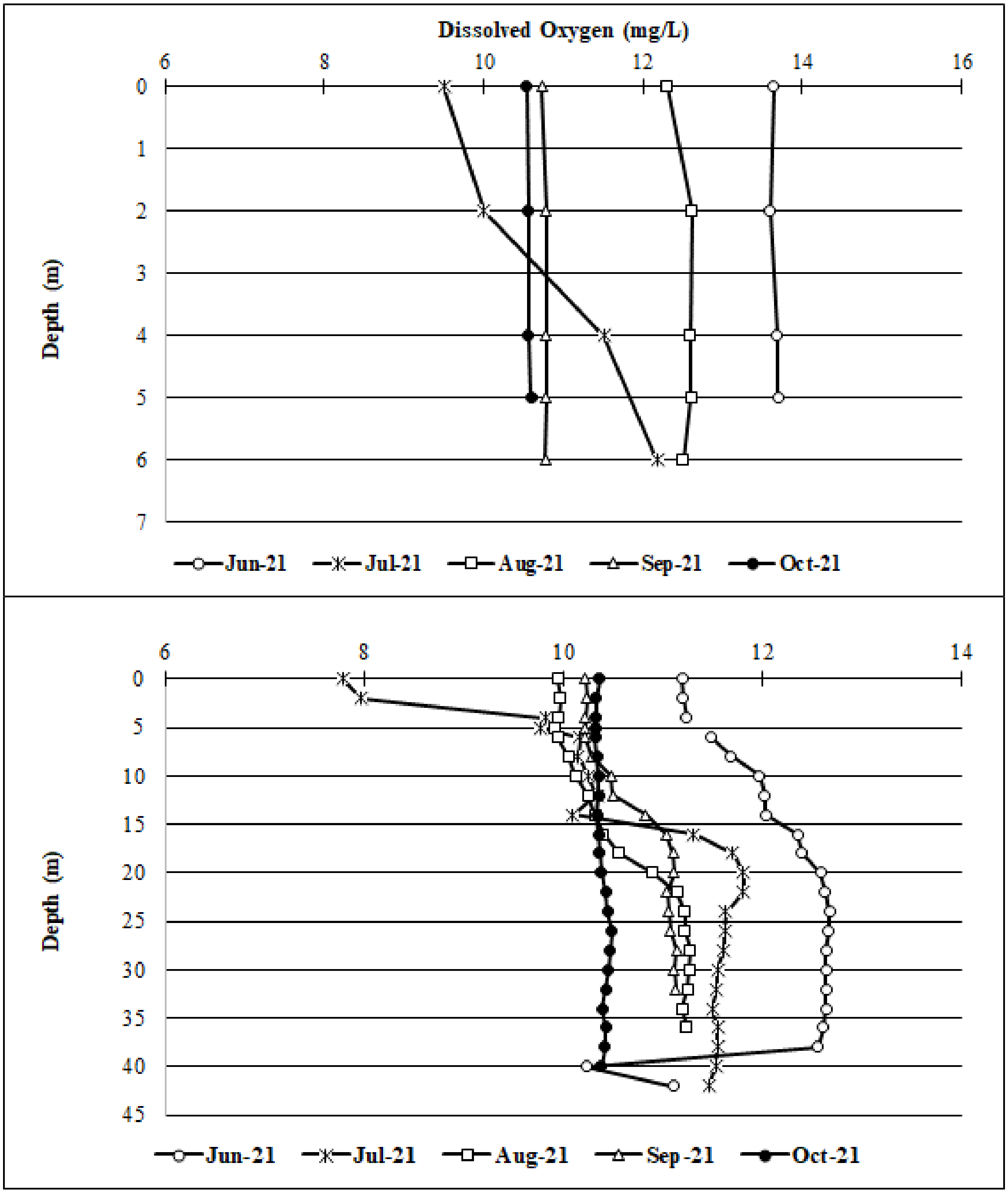
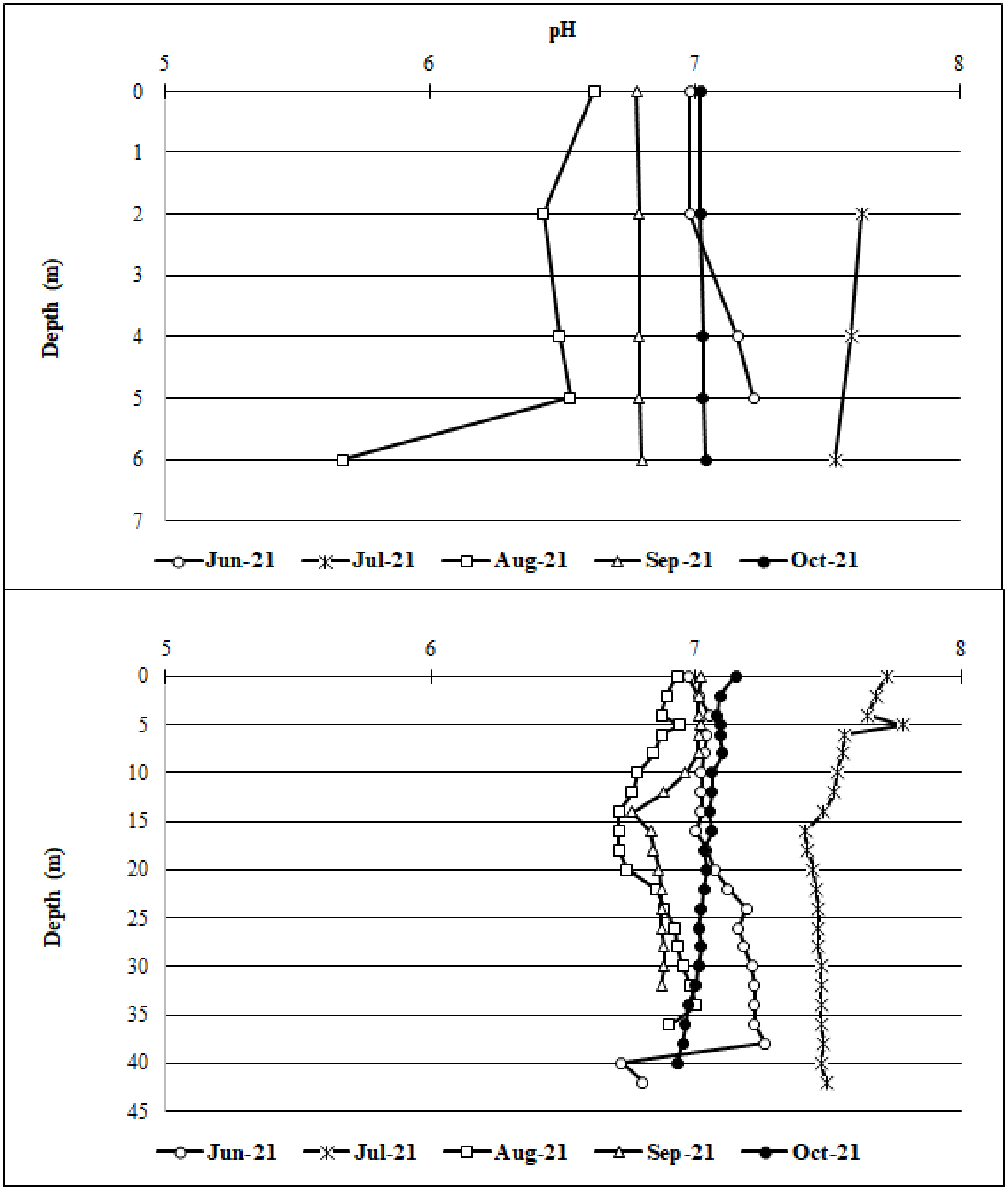


Figure 5.1-2. **Diablo Lake dissolved oxygen profile at DIABLO1 (top) and DIABLO2 (bottom), June through October 2021.**



Note: The pH measurement at the surface at DIABLO1 during the July profile was removed during QA/QC.

Figure 5.1-3. pH profile at DIABLO1 (top) and DIABLO2 (bottom), June through October 2021.

5.1.2.2 Turbidity and TSS

Results of turbidity and TSS sampling at both DIABLO1 and DIABLO2 are shown in Table 5.1-5. While the turbidity values were lower at DIABLO1, values at both sites were less than 5 NTU, with little difference between the 1- and 5-m samples. TSS values were generally less than the quantification limit at both sites (maximum of 3 mg/L at DIABLO2 in August and DIABLO1 in June).

Table 5.1-5. Turbidity and total suspended solids at DIABLO1 and DIABLO2 at 1- and 5-m depths, June through October 2021.

Date	Reservoir Elevation (NAVD 88)	DIABLO1				DIABLO2			
		Turbidity (NTU)		TSS (mg/L)		Turbidity (NTU)		TSS (mg/L)	
		1-m	5-m	1-m	5-m	1-m	5-m	1-m	5-m
Jun 24	1,206.8	3	2.5	1	3	2	1.7	2	2
Jul 22	1,207.2	1.1	0.71	ND	ND	2.9	3.1	ND	2
Aug 18	1,208.5	0.68	1.1	ND	ND	4.6	4.4	3	3
Sep 9	1,207.2	0.54	0.3	ND	ND	1.4	1.2	ND	ND
Oct 6	1,206.8	2.9	2.2	2	ND	2.9	3.1	ND	ND

Notes:
DIABLO1 = Upper end of Diablo Lake; DIABLO2 = Diablo Lake Forebay.
Samples measured below the quantification limit are reported as ND.

Results of turbidity and TSS measurements along transects in Diablo Lake are shown below (Table 5.1-6). Samples for both parameters were collected at 25-m intervals along the two 100-m transects. As shown in Figure 7 of Attachment A, both transects are in the Thunder Arm of Diablo Lake. DIABLO3 is approximately center channel on the south side of the bridge, and DIABLO6 is parallel to and roughly 40 meters from the mouth of Colonial Creek.

Table 5.1-6. Turbidity and total suspended solids at DIABLO3 and DIABLO6 transects, December 2021.

Date	Distance along Transect (m)	DIABLO3		DIABLO6	
		Turbidity (NTU)	TSS (mg/L)	Turbidity (NTU)	TSS (mg/L)
Dec 17	0	0.47	ND	0.66	ND
	25	0.54	ND	0.51	ND
	50	0.65	ND	0.56	ND
	75	0.56	ND	0.62	ND
	100	0.63	ND	1.7	ND

Notes:
DIABLO3 = Thunder Creek Confluence at Bridge/Colonial Creek Campground at Rhode Creek.
DIABLO6 = Thunder Creek Confluence at Bridge/Colonial Creek Confluence.
Reservoir elevation at the time of transects was 1,207.1 feet NAVD 88.

TSS measurements along both transects were all less than the laboratory quantification limit. Turbidity was less than 1 NTU at all sites with the exception of 1.7 NTU at the 100-m sampling station on DIABLO6. Average turbidity along DIABLO3 was 0.57 NTU, and 0.81 NTU along DIABLO6.

5.1.2.3 Fecal coliform/*E. Coli*

Results of bacterial analyses at Diablo Lake are shown in Table 5.1-7. Maximum coliform concentrations were reported in June at DIABLO4 (104 CFU/100 mL); measurements of both FC and *E. coli* were also detectable in August at DIABLO4.

Table 5.1-7. Diablo Lake monthly fecal coliform and *E. coli* sampling results, June through September 2021.

Date	Reservoir Elevation (NAVD 88)	DIABLO4		DIABLO5	
		FC	*E. coli*	FC	*E. coli*
Jun 30	1,209.2	104	-	52	-
Jul 26	1,207.4	ND	-	ND	-
Aug 17	1,208.6	-	-	ND	-
Aug 20	1,207.4	13 (15)	11	-	-
Sep 14	1,209.1	ND	ND	2	2

Notes:
DIABLO4 = Thunder Creek Confluence at Bridge/Colonial Creek Campground.
DIABLO5 = Environmental Learning Center.
Results are in units of CFU/100 mL.
Samples measured below the quantification limit (2 CFU/100 mL) are reported as ND.
Field duplicate results are shown in parenthesis.
E. coli was only measured at DIABLO4 in August, and at both sites in September.

5.1.2.4 QA/QC

As noted in Section 4.2 of this study report, duplicate samples were collected during each visit at one of the four reservoir sites (two each on Diablo and Gorge) and at one of eight possible sample depths (four on each reservoir) immediately following routine sample collection. Duplicates were measured for turbidity and TSS, and their RSD calculated to assess sample variability in the field. Results for duplicate samples collected are shown below for Diablo (Table 5.1-8), and for Gorge in Table 5.1-10. For TSS and turbidity, the QAPP duplicate precision criteria require no more than 10 percent and 5 percent RSD, respectively, between replicate or duplicate pairs.

Table 5.1-8. Results of field duplicate measurements of turbidity and total suspended solids at Diablo Lake, June through September 2021.

Date	Site ID	Turbidity (NTU)			TSS (mg/L)		
		R	D	RSD	R	D	RSD
Jun 24	DIABLO1 / 5-m	2.5	2.8	8.0	3	2	28.3
Jul 22	DIABLO2 / 1-m	2.9	2.8	2.5	ND	3	N/A
Sep 9	DIABLO2 / 5-m	1.2	1.2	0.0	ND	ND	N/A

Notes: R = routine; D = Duplicate; RSD = (S*100)/mean

For turbidity, RSD values exceeded 5 percent in June (8.0 percent). TSS results were more variable; RSD values of 28.3 percent were measured in June in Diablo Lake, with no TSS detected in the other two duplicate samples.

Results of blank sample analyses were non-detectable for all TSS samples. Detectable turbidity in blanks was reported for three of the five samples, ranging from 0.1 to 0.6 NTU.

Data completeness was 100 percent for turbidity and TSS sample collection. Only one data point was rejected from the vertical profiles, i.e., for pH at DIABLO1 for 94 percent data completeness. All other parameters at both DIABLO1 and DIABLO2 were 100 percent complete. All visits were conducted per the schedule outlined in the RSP.

5.1.3 Gorge Lake

Vertical profiles in Gorge Lake, June through September, were conducted at elevations of approximately 877-879 feet NAVD 88 (per USGS Gage 12177700, Gorge Reservoir near Newhalem, WA). Per the PAD, average elevation in Gorge Lake over a 28-year period, 1991-2018, for each of these five months ranges from approximately 874 to 878 feet NAVD 88 (868 to 872 feet CoSD) (City Light 2020).

5.1.3.1 Gorge Lake Vertical Profiles

Surface temperatures were highest in July at GORGE1 (13.6°C) and in August at GORGE2 (12.8°C). Weak stratification is seen in June at GORGE1 and in June and July at GORGE2 (Figure 5.1-4), although there was also a thermal gradient evident at GORGE2 in August.

DO profiles at GORGE1 and GORGE2 are shown in Figure 5.1-5. Values were between 10 and 11 mg/L at GORGE1, with the exception of slightly higher values in June of 12.5 mg/L, corresponding to a DO saturation of 111 percent, based on temperatures shown above and assuming a reservoir elevation of 881.51 feet NAVD 88 (875 feet (CoSD), as reported in the PAD [City Light 2020]).

At GORGE2, minimum DO was 10.37 mg/L at the surface in July, corresponding to a calculated saturation of 100 percent. Remaining profile measurements were generally 10 to 11 mg/L throughout the water column.

Profiles of pH at the two Gorge sites are shown in Figure 5.1-6. Profiles for pH were very similar from surface to bottom. There were no observations of algae in the water column that could influence pH during any of the monitoring events.

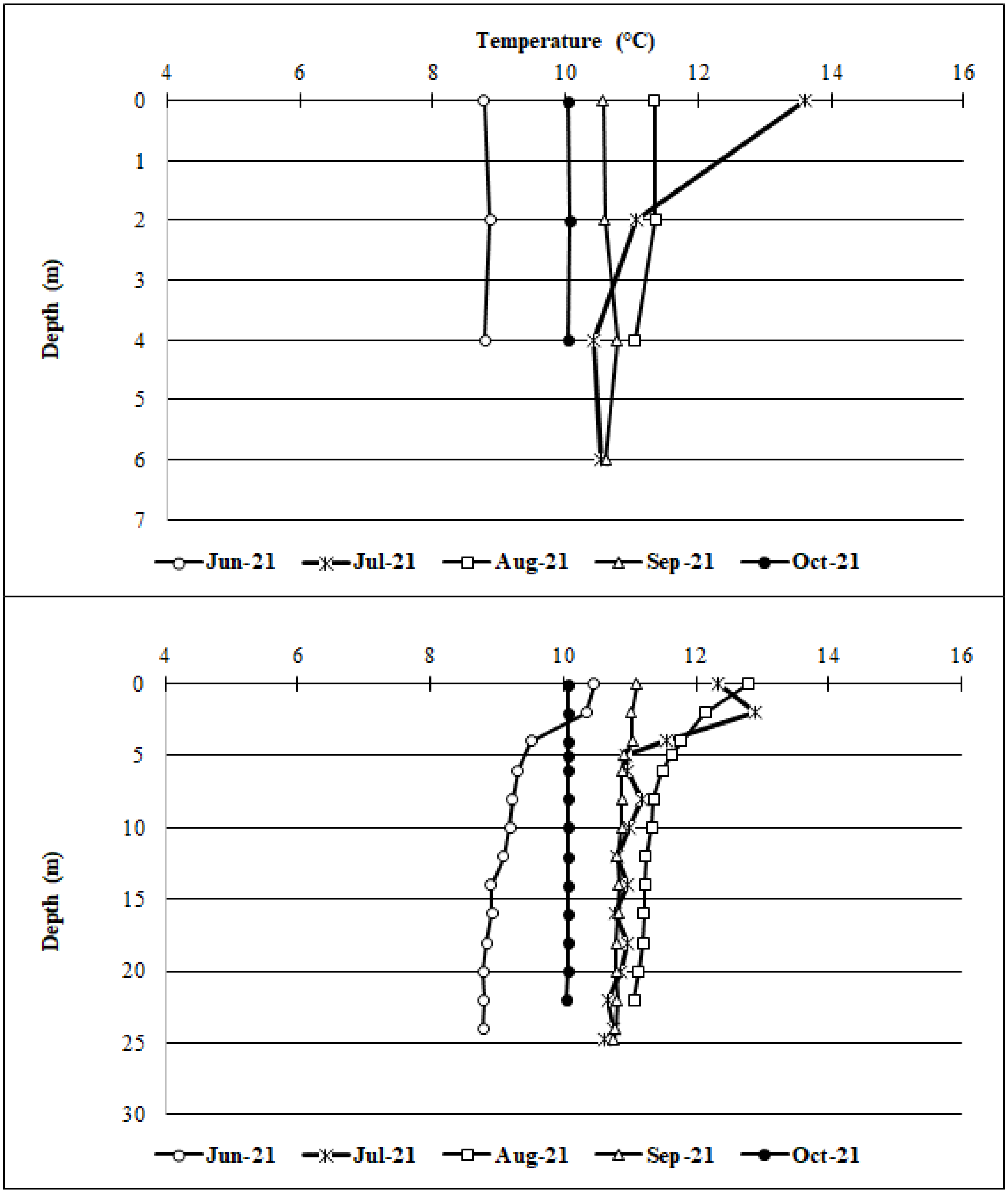


Figure 5.1-4. Temperature profile at GORGE1 (top) and GORGE2 (bottom), June through October 2021.

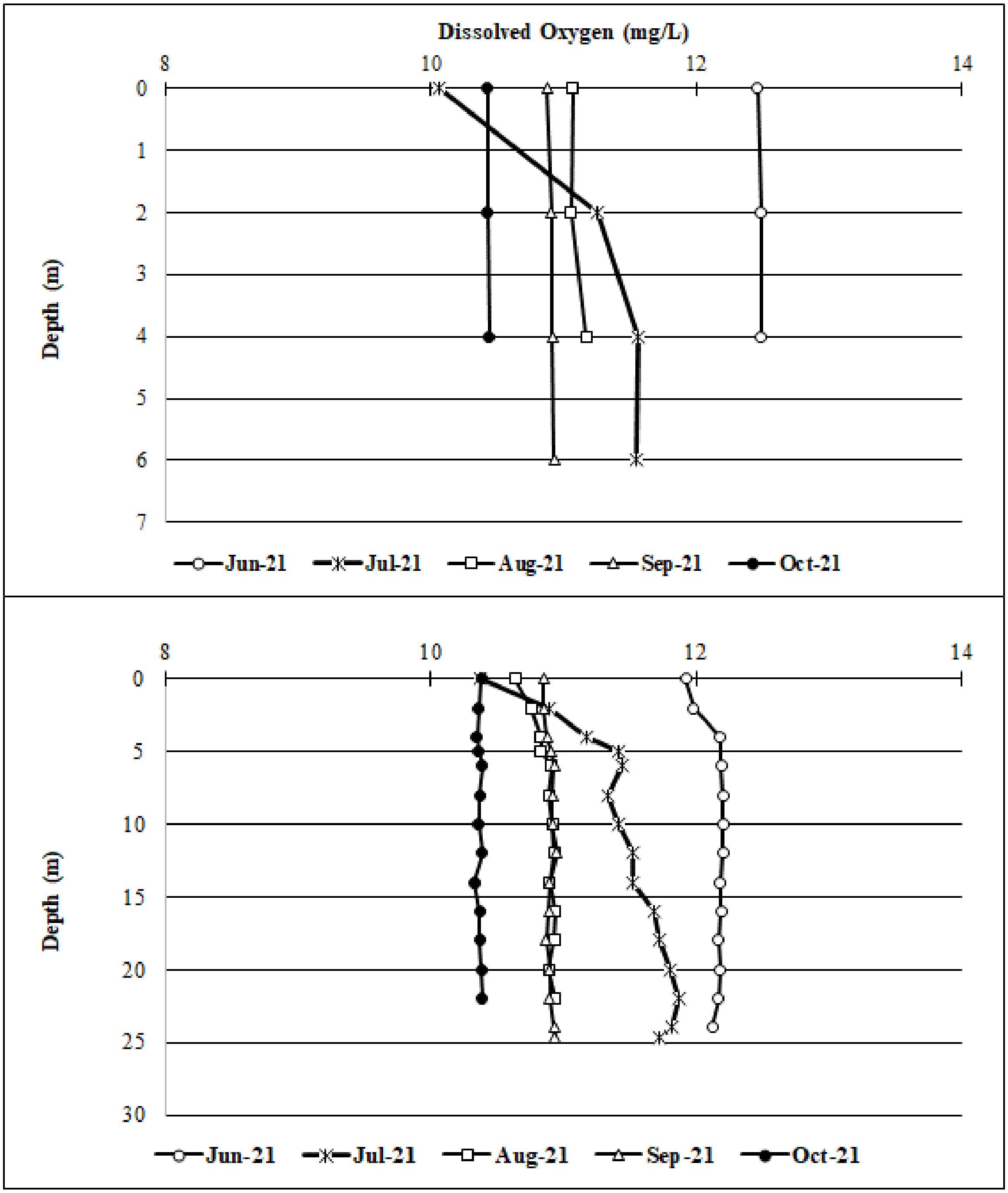
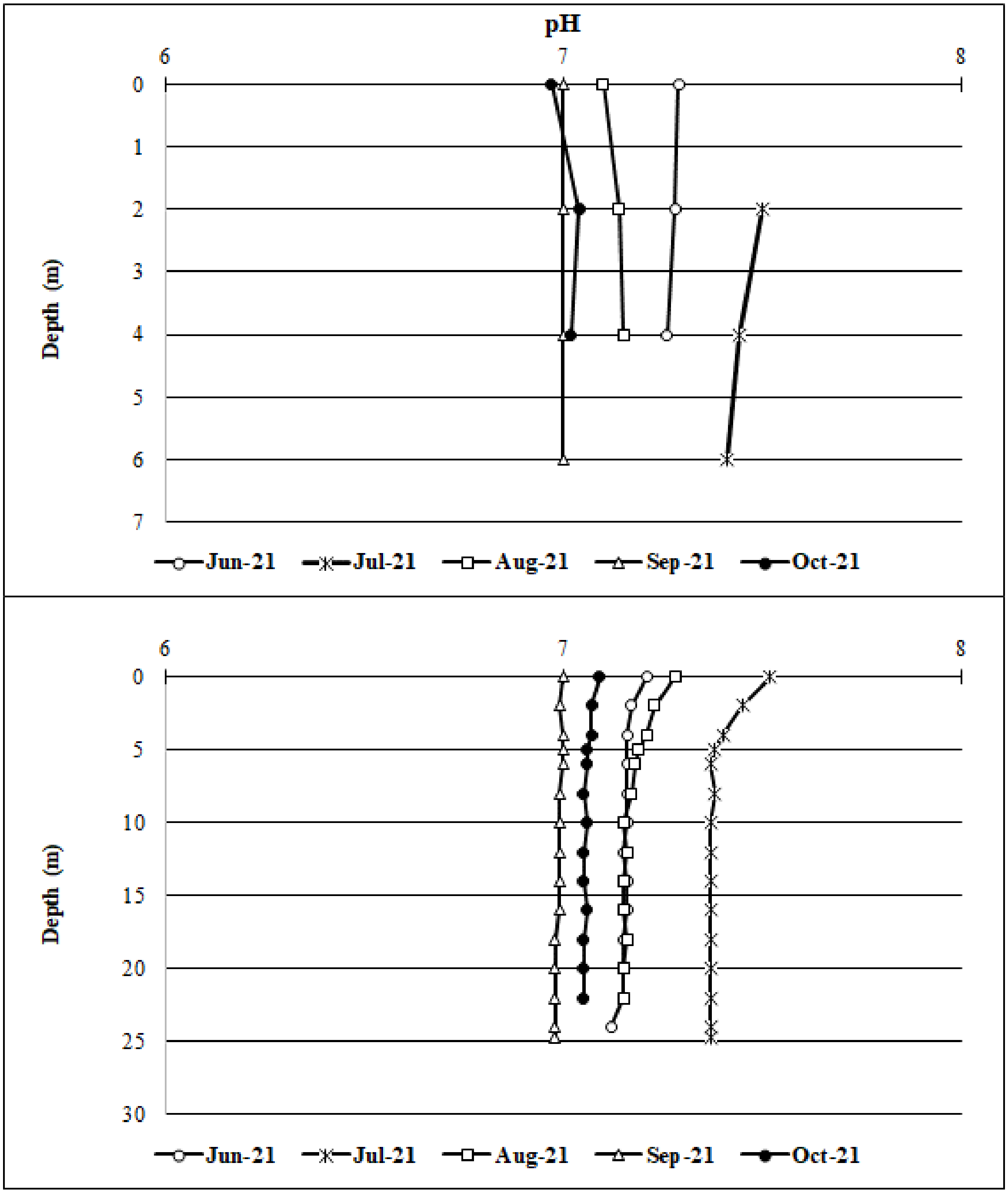


Figure 5.1-5. Dissolved oxygen profile at GORGE1 (top) and GORGE2 (bottom), June through October 2021.



Notes: The pH measurement at the surface at GORGE1 during the July profile was removed during QA/QC.

Figure 5.1-6. pH profile at GORGE1 (top) and GORGE2 (bottom)s, June through October 2021.

5.1.3.2 Turbidity and TSS

Measurements of turbidity and TSS at both GORGE1 and GORGE2 are shown in Table 5.1-9. Turbidity was generally 1-3 NTU from June through September, increasing to between 6-7 NTU at GORGE1 and GORGE2 in October. October was also the month in which maximum turbidity was seen at Diablo Lake (2-3 NTUs at both sites), likely a result of greater runoff and the onset of fall rains throughout the basin.

Comparing turbidity at Gorge and Diablo lakes, differences during October were the most notable, and may reflect higher suspended sediment (reduced settling) given the lower detention time in Gorge Lake (0.8 days), or greater sediment contribution from tributaries, e.g., Stetattle Creek. TSS values at the Gorge sampling sites were low (2-3 mg/L) but more often detectable than at the Diablo sites.

Table 5.1-9. Turbidity and total suspended solids at GORGE1 and GORGE2 at 1- and 5-m depths, June through October 2021.

	GORGE1				GORGE2			
	Turbidity		TSS		Turbidity		TSS	
Date	1-m	5-m	1-m	5-m	1-m	5-m	1-m	5-m
Jun 24	3.1	2.3	2	3	1.7	2.3	1	3
Jul 22	1.8	2	2	ND	1.9	1.9	2	2
Aug 18	2.6	2.8	3	3	2.7	3.1	2	2
Sep 9	0.88	1.4	ND	ND	0.87	1.3	ND	ND
Oct 6	6	5.8	3	ND	6.4	6.8	3	3

Notes:
GORGE1 = Upper end of Gorge Lake; GORGE2 = Gorge Lake Forebay.
Samples measured below the quantification limit are reported as ND.

5.1.3.3 Total Dissolved Gas

Available TDG data collected in Gorge Lake from September 9 through October 5, 2021 and the corresponding flow data from Diablo Powerhouse during this same period are presented in Figure 5.1-7. TDG greater than 110 percent saturation was observed at GORGE3 on September 18 (112 percent) and again on September 30 (114 percent). Values at GORGE4 remained near 105 percent throughout this period. Closer examination of the September 18 and September 30 data at GORGE3 suggests that periods of higher TDG correspond to reduced flows at Diablo Powerhouse (> 1,000 cubic feet per second [cfs]). Substituting generation (megawatt [MW]) for flow, peak TDG corresponded to generation of less than 20 MW during each of these two periods (Figures 5.1-8 and 5.1-9).

As noted above, TDG at the Gorge Lake Forebay site appeared unaffected by reduced generation at Diablo Powerhouse. Robert Gordon, a Senior Mechanical Engineer at City Light, indicated that these elevated TDG levels are likely associated with the operation of an air admission system on the two turbines at the Diablo Powerhouse (U31 and U32). Both units have systems in place that admit air from about 30 MW to 90 MW, allowing the units to run smoother and improve operational efficiency at low generation (Gordon 2021). City Light will further evaluate relationships between Diablo Powerhouse generation and TDG during the 2022 field season.

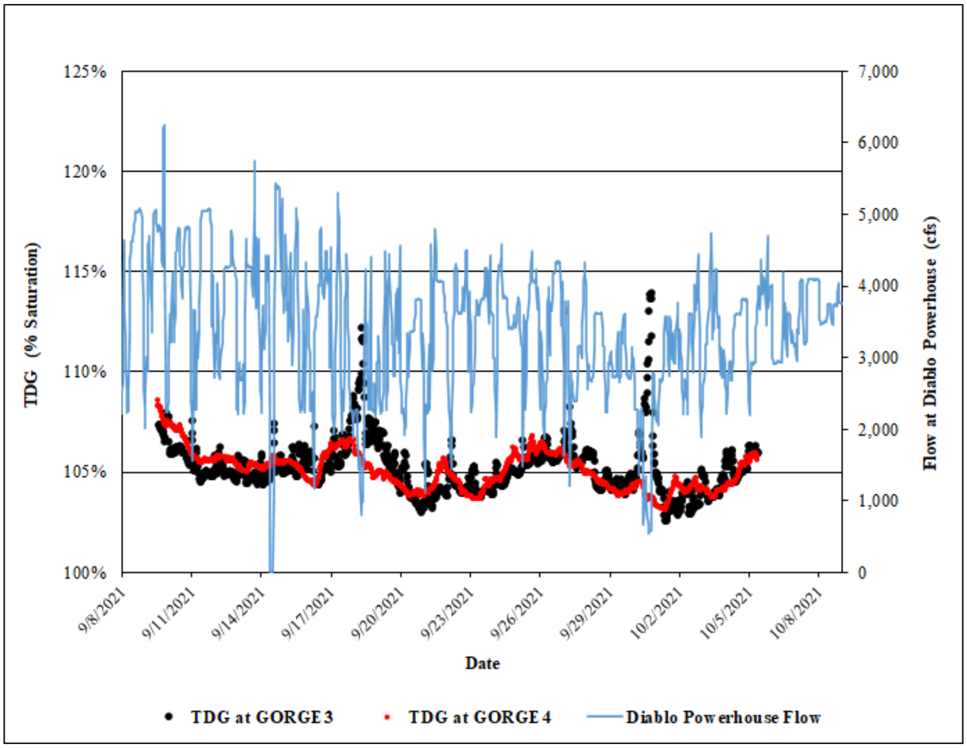


Figure 5.1-7. Total dissolved gas at Gorge Lake sites, September 9 through October 8, 2021, and flow at Diablo Powerhouse (cfs).

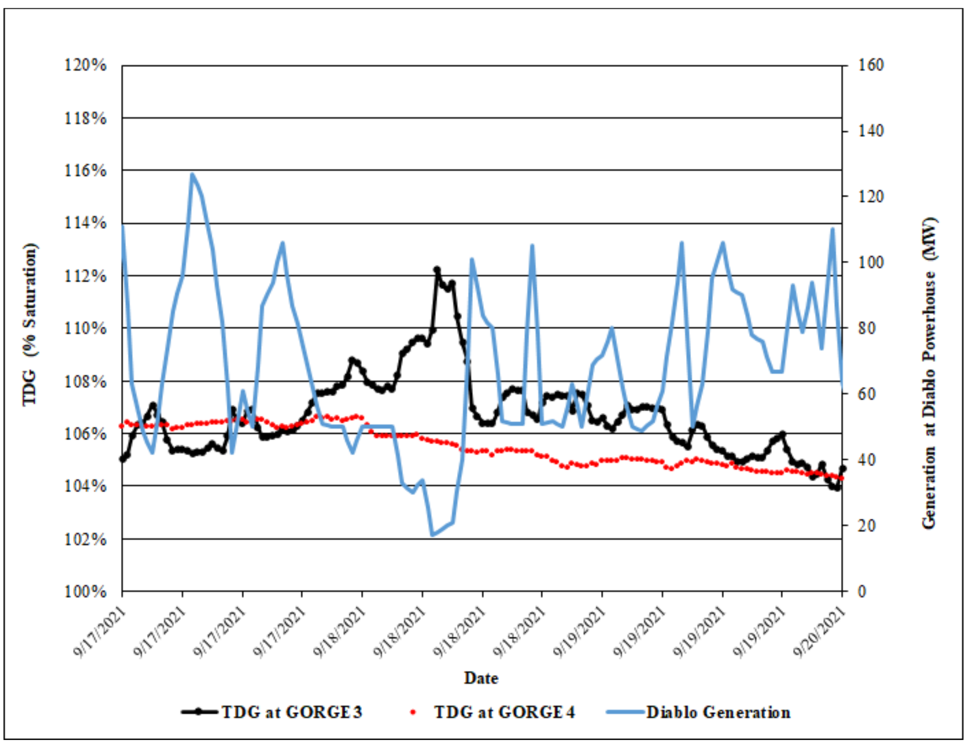


Figure 5.1-8. Total dissolved gas at Gorge Lake sites, September 17 through September 20, 2021, and generation at Diablo Powerhouse (mW).

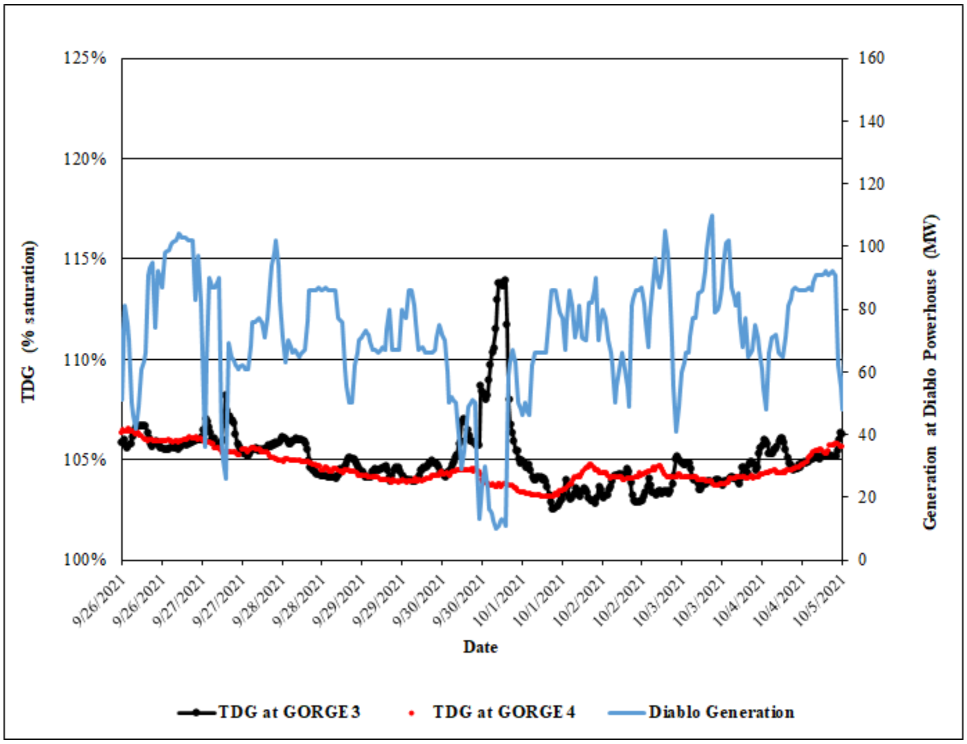


Figure 5.1-9. Total dissolved gas at Gorge Lake sites, September 26 through October 5, 2021, and generation at Diablo Powerhouse (mW).

5.1.3.4 QA/QC

As noted in Sections 4.2 and 5.1.2.4 of this study report, duplicate samples were collected during each visit at one of the four reservoir sites (two each on Diablo and Gorge) and at one of eight possible sample depths (four on each reservoir) immediately following routine sample collection. As discussed in Section 5.1.2.4 for Diablo Lake, duplicates from Gorge Lake were measured for turbidity and TSS, and their RSD was calculated to assess sample variability in the field (Table 5.1-10). For TSS and turbidity, the QAPP duplicate precision criteria require no more than 10 percent and 5 percent RSD, respectively, between replicate or duplicate pairs.

Table 5.1-10. Results of field duplicate measurements of turbidity and total suspended solids at Gorge Lake, June through September 2021.

		Turbidity (NTU)			TSS (mg/L)		
Date	**Site**	**R**	**D**	**RSD**	**R**	**D**	**RSD**
Aug 18	GORGE2 – 1 m	2.7	2.5	5.4	2	2	0.0
Oct 6	GORGE2 – 5 m	6.8	4.8	24.4	3	2	28.3

Notes: R = routine; D = Duplicate; RSD = (S*100)/mean.

For turbidity, RSD values exceeded 5 percent in August (5.4 percent) and October (24.4 percent RSD for a difference of 2 NTU). TSS results were more variable; RSD values of 28.3 percent were measured in October in Gorge Lake. The latter reflect low TSS and a difference of only 1 mg/L between field and duplicate on both samples.

Results of blank sample analyses were non-detectable for all TSS samples. Detectable turbidity in blanks was reported for three of the five samples, ranging from 0.1 to 0.6 NTU.

With respect to TDG at Gorge Lake, the performance check on October 6 (covering data from September 9 through October 6) met QA/QC requirements.

Data completeness was 100 percent for turbidity and TSS sample collection. Only one pH data point was rejected from the vertical profile at GORGE1, resulting in 93 percent completeness for this parameter. Other vertical profile parameters at both GORGE1 and GORGE2 were 100 percent complete. One data point was rejected from continuous monitoring of TDG at both GORGE3 and GORGE4 for 99.9 percent data completeness at both sites (Table 5.1-11). With the exception of TDG, all visits were conducted per the schedule outlined in the RSP. Continuous monitoring of TDG in Gorge Lake began on September 9, later than the June start date specified in the RSP, due to supply chain limitations at the manufacturer.

Table 5.1-11. Percent completion results for continuous total dissolved gas monitoring at Gorge Lake sites from September 9 to October 5, 2021.

Parameter	Site ID	Accepted	Qualified	Rejected	Total Planned Results	Percent Complete
TDG	GORGE3	1,249	0	1	1,250	99.9%
TDG	GORGE4	1,250	0	1	1,251	99.9%

5.2 Gorge Bypass Reach and Powerhouse

This section presents results of continuous water temperature and water quality monitoring at three locations in the Gorge bypass reach and at one location situated just downstream of Gorge Powerhouse (Figure 5.2-1). The data collected at these sites include water temperature (°C), DO (mg/L), turbidity (NTU), pH, and TDG (percent saturation). Time series and box and whisker plots for each parameter are presented below.

Box-and-whisker plots show six statistics for each data set: the minimum, first quartile (lower edge of box), median (horizontal line inside the box), average (*x* inside the box), third quartile (upper edge of box) and maximum. Whiskers above and below the box indicate the smallest and largest observations that fall within the 1.5 interquartile range (IQR; the difference between the first and third quartiles, or the height of the box). The elevations of these sites range from approximately 725 feet NAVD 88 at BYPASS1 to approximately 490 feet NAVD 88 at PHOUSE1.

Monitoring at BYPASS1 and BYPASS3 sites began on January 28, 2021, and PHOUSE1 on February 11, 2021. Each site is accessed every 3 to 4 weeks for datasonde maintenance, data transfer, and repositioning if a datasonde became dewatered or dislodged during the prior period. Monitoring at BYPASS2 began on August 2, 2021, and the data presented below extend through the October 5, 2021 site visit.

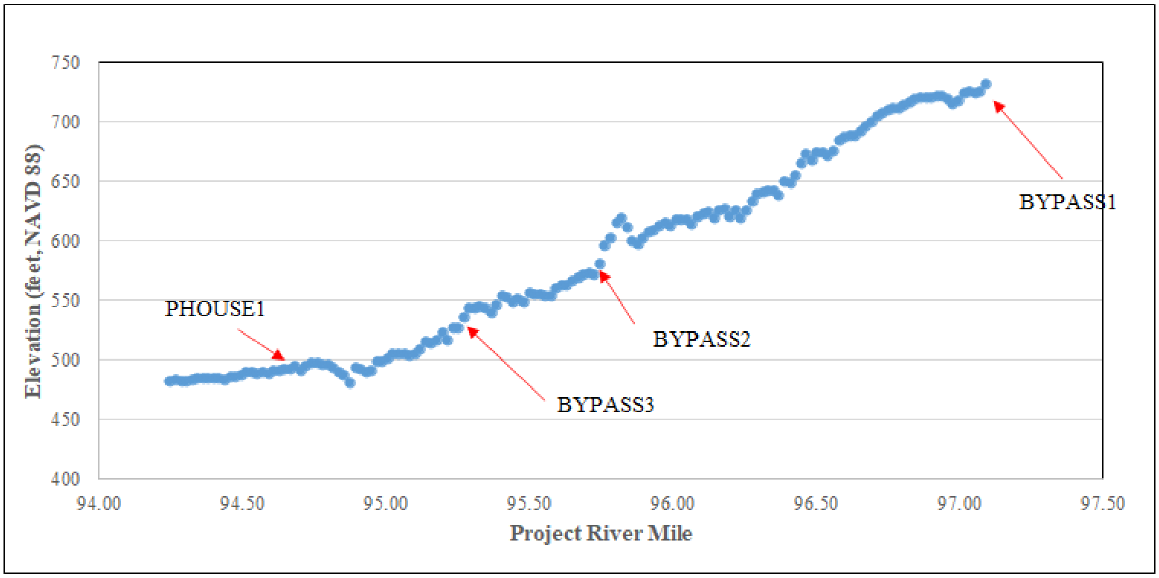


Figure 5.2-1. Gorge bypass reach and Powerhouse monitoring locations by Project River Mile and their elevations (NAVD 88).

As described in Section 4.2 of this study report, field personnel conducted mid-deployment performance checks of each datasonde, as defined in Ecology SOP EAP129 (Ecology 2019c), at each monitoring site during the majority of the field visits. These on-site checks compared the data generated by each field instrument to the data generated by a recently calibrated sonde. Any differences in the readings were then used to calculate deviation thresholds. As discussed in Section 4.2 of this study report, any datasondes that failed these comparisons were recalibrated following the manufactures recommended calibration protocols.

Subsequent data processing then removed any obvious outliers resulting from instrument maintenance, low battery voltages, and low-flow related sensor dewatering. A series of unplanned spill events and pandemic-related equipment supply chain issues contributed to varying levels of data completeness for each of the monitoring sites (see Section 5.2.7 of this study report). Water quality data reported on in this study report have complied with QAQC procedures. These data will be made available upon request.

5.2.1 Water Temperature

Time-series and box-and-whisker plots showing the water temperatures recorded at each of the Gorge bypass reach sites are shown in Figures 5.2-2 and 5.2-3, respectively. Maximum water temperatures at these sites ranged from 12.2°C at PHOUSE1 to 24.6 °C at BYPASS1. Water temperatures at PHOUSE1 were less variable and usually cooler than the temperatures recorded at the three BYPASS sites.

It should be noted that air temperatures during the monitoring period were, at times, substantially above normal based on data from the National Weather Service (normal data are averages over the period 1991-2020). For example, the maximum air temperature recorded at Newhalem on June 29, 2021 was 45°C (113ºF), 22°C (40 ºF) above the normal maximum of 23°C (73ºF) for this day. Associated glacial melting during this heat wave also resulted in a spill event at Gorge Dam (see

Section 5.2.5 of this study report). Normal and 2021 air temperatures (average, minimum, and maximum) at Newhalem for June, July and August are shown in Figure 5.2-4.

Some observed differences in the summary metrics for water temperature and other parameters among the Gorge bypass reach sites reflect the timing and duration of instrument deployment. The datasondes located at the BYPASS1, BYPASS3, and PHOUSE1 sites were deployed early in the year, whereas the BYPASS2 datasonde was not deployed until August, thus minimum and average temperatures are higher and the range of temperatures lower than seen at the other three sites.

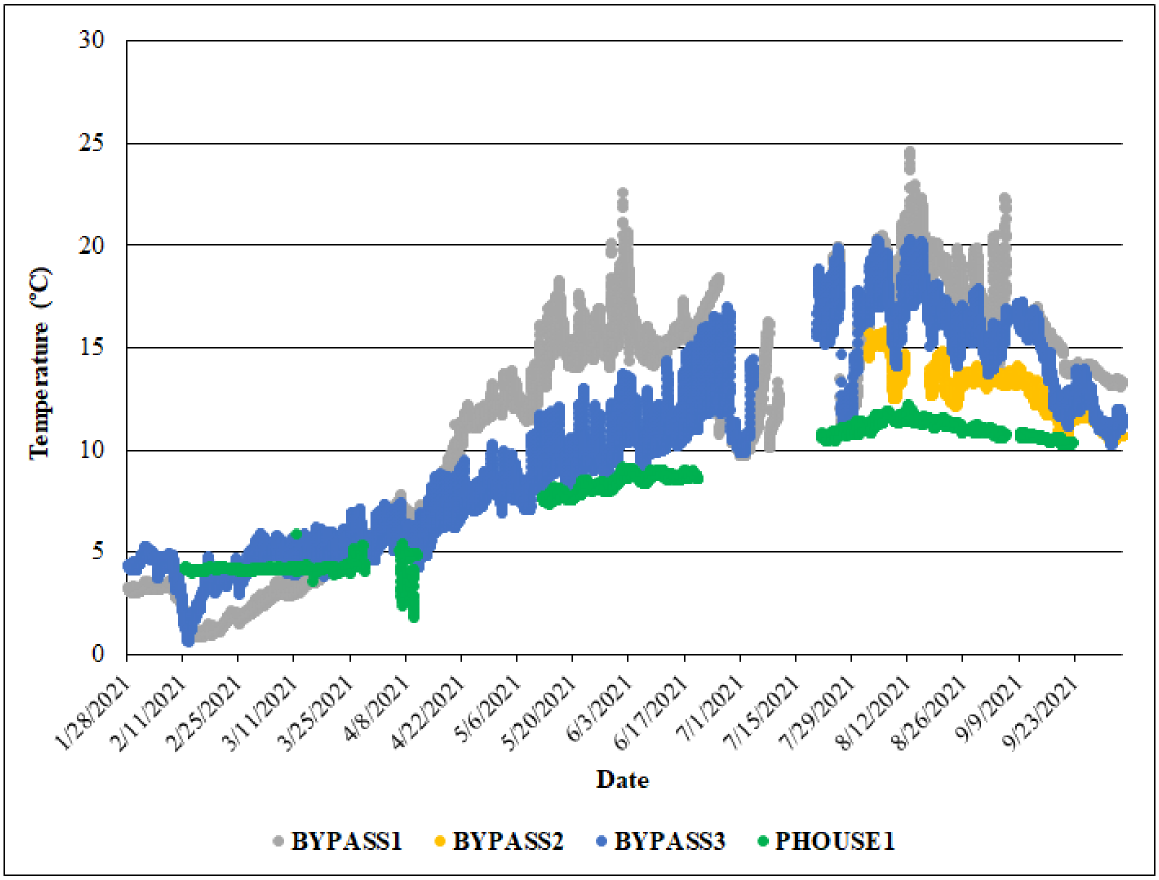


Figure 5.2-2. Time series of temperatures at Gorge bypass reach and Powerhouse sites, January 28 through October 5, 2021.

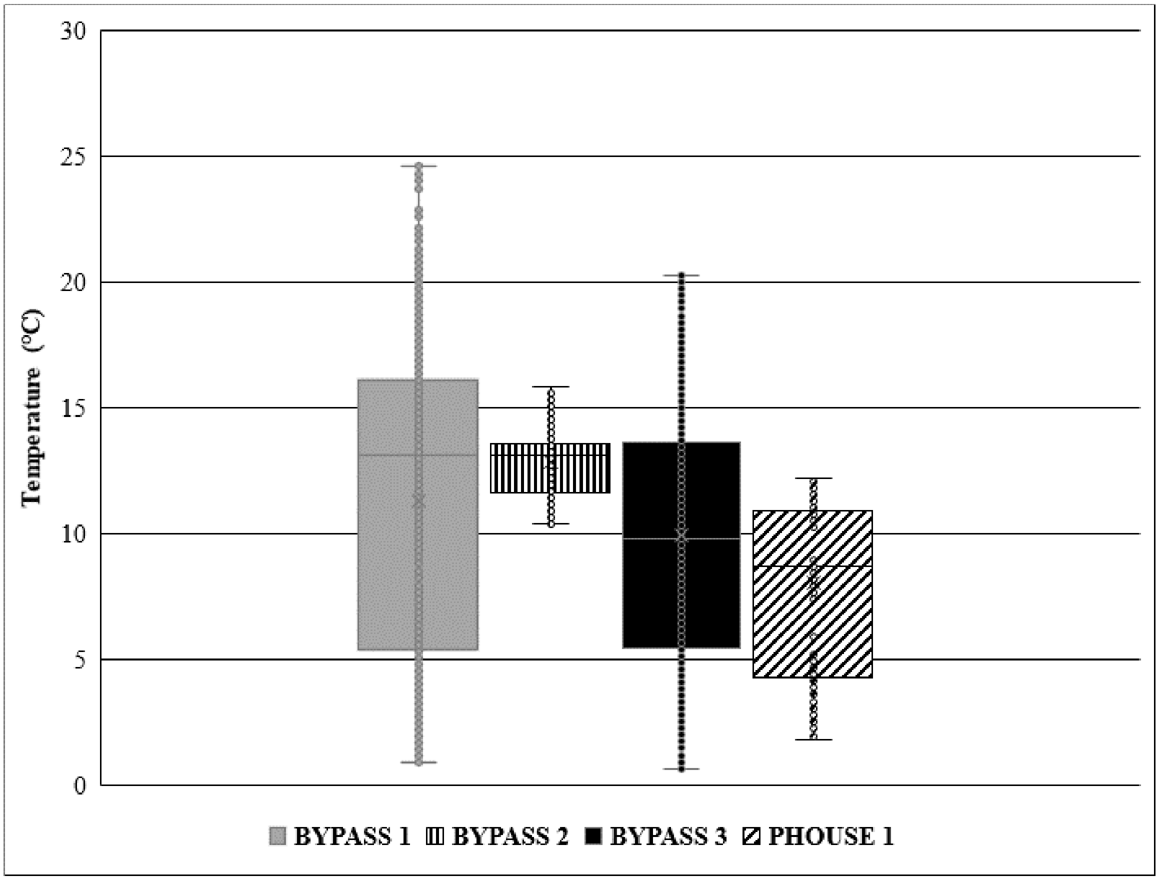


Figure 5.2-3. Box-and-whisker plot showing temperature at the Gorge bypass reach and Powerhouse sites, January 28 through October 5, 2021.

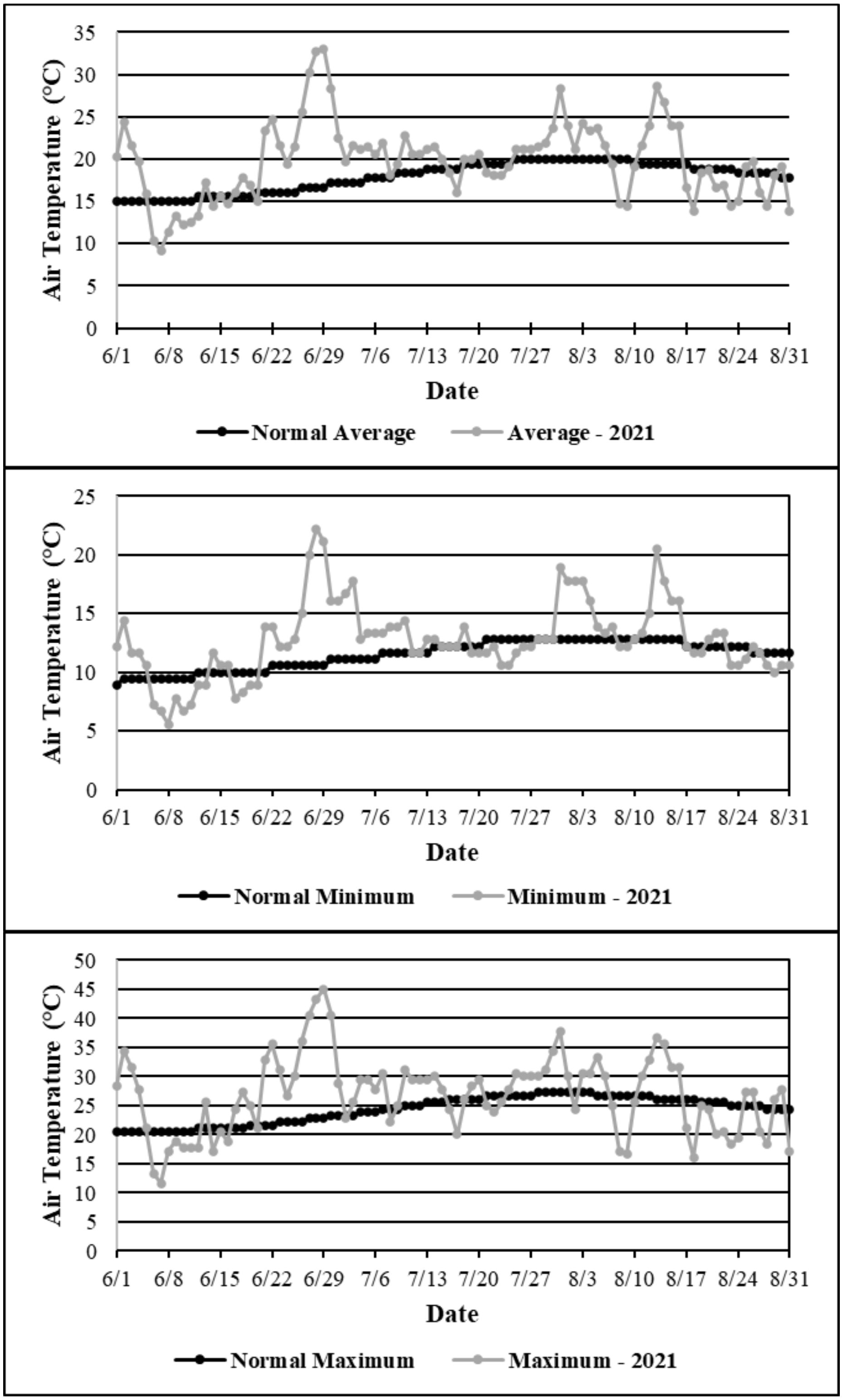


Figure 5.2-4 **Normal and 2021 air temperatures (daily average, minimum, and maximum) at Newhalem, Washington, for June, July and August. Source: National Weather Service.**

5.2.2 Dissolved Oxygen

Time-series and box-and-whisker plots of DO are shown below in Figures 5.2-5 and 5.2-6. DO concentrations at BYPASS1 and BYPASS2 sites gradually decreased throughout the monitoring period as temperatures increased. DO at PHOUSE1 is generally higher (and water temperatures were lower), and concentrations demonstrated comparatively little diel variability; in contrast to BYPASS2 data are more variable. Average DO ranged from 9.7 mg/L at BYPASS2 (3,071 observations) to 11.6 mg/L at PHOUSE1 (9,011 observations). Minimum DO was 7.3 mg/L at both BYPASS1 and BYPASS2, 8.4 mg/L at BYPASS3, and 10.6 mg/L at PHOUSE1.

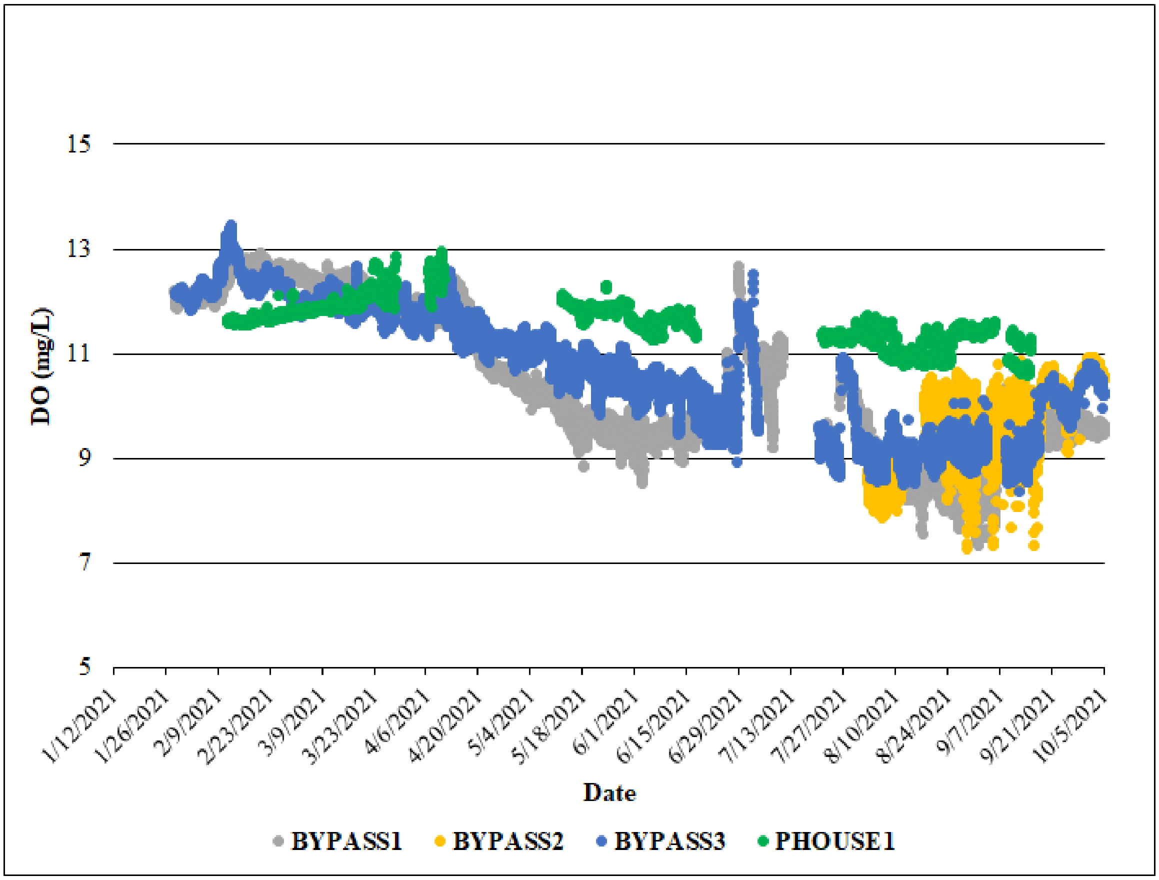


Figure 5.2-5. Time-series of dissolved oxygen at the Gorge bypass reach and Gorge Powerhouse sites, January 28 through October 5, 2021.

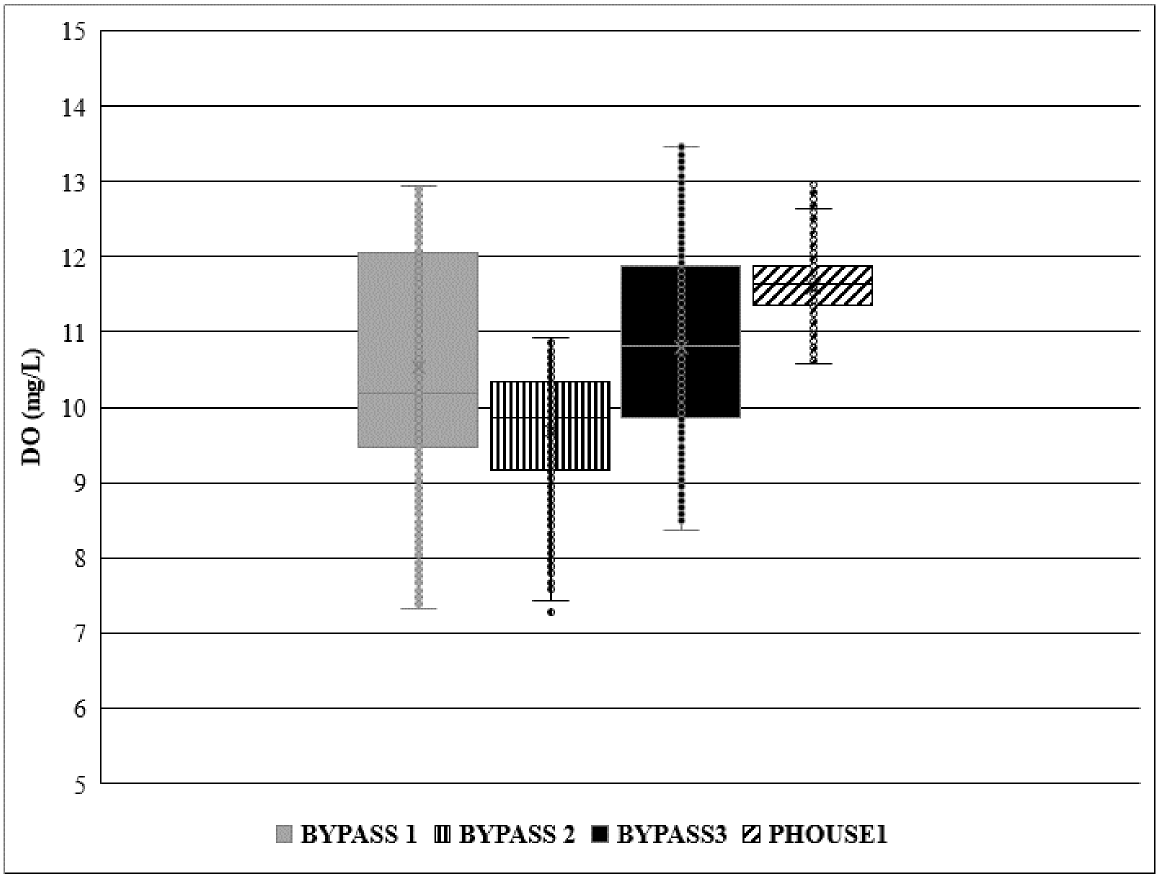


Figure 5.2-6. Box-and-whisker plot of dissolved oxygen at the Gorge bypass reach and Powerhouse sites, January 28 through October 5, 2021.

5.2.3 Turbidity

Turbidity was generally very low at all monitoring sites in the Gorge bypass reach and below Gorge Powerhouse, averaging near or less than 1 NTU (Figure 5.2-7). Turbidity at BYPASS3 during late June increased to nearly 120 NTU, likely in response to the late June spill event at Gorge Dam. Values were also higher at PHOUSE1 on several occasions in August and early September (103 NTUs August 10, 129 NTUs on August 29, and 93 NTUs on September 2). However, these were isolated “spike” values among otherwise low turbidity (near 1 NTU), and there was no spill at Gorge Dam during at this time. Review of USGS data at the Newhalem gage (USGS Gage 12178000) indicates flows were relatively stable during this period, suggesting that debris was interfering with the datasonde’s optical sensor. Similarly, with respect to BYPASS3, flows at Newhalem were level at approximately 2,200 cfs during the first week of September, and review of NWS climate data indicates that there was no precipitation at this time that could have led to elevated turbidity, e.g., hillslope runoff. Increased turbidity at BYPASS3 values may also be a result of debris or possibly algal growth on the turbidity sensor.

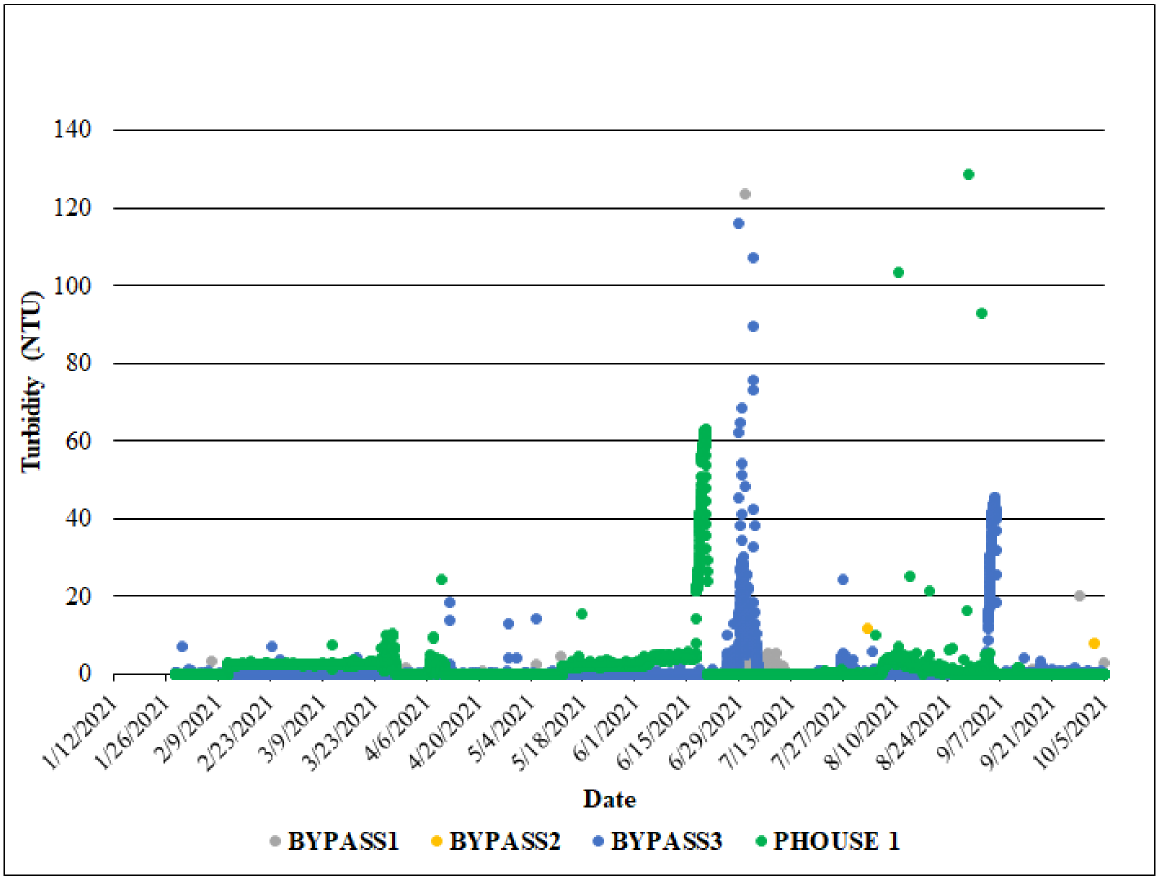


Figure 5.2-7. Turbidity at the Gorge bypass reach and Powerhouse sites, January 28 through October 5, 2021.

5.2.4 pH

Per the RSP, pH is monitored at PHOUSE1 only. As noted in Section 4.1 of this study report, data was collected at this site prior to the RSP study period. When data collection began in January 2021, a datasonde capable of monitoring pH was not available. A Hydrolab DS5, capable of monitoring all parameters required in the RSP (temperature, DO, TDG, turbidity, and pH), was deployed on July 21, 2021 when it was received from the manufacturer.

pH values averaged 7.5 with a range of 7.2 to 7.7 (Figure 5.2-8). The data appeared reasonable; however, all pH data were qualified based on exceedance of performance check thresholds over three successive visits (August, September, and October). Discussion with the manufacturer (Hach) suggests that performance of the pH probe and decreasing values may have been due to leakage of the potassium chloride reference solution in the pH probe.

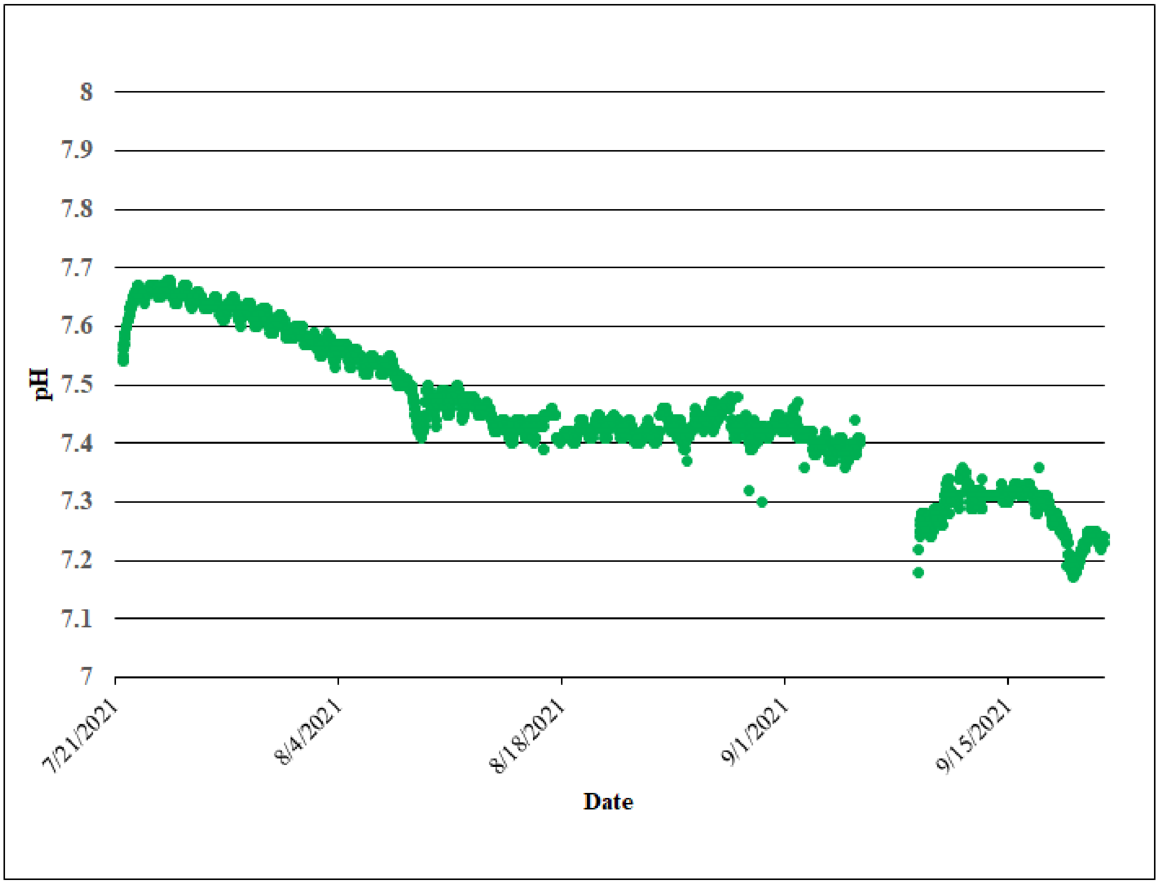


Figure 5.2-8. pH at the Gorge Powerhouse site, July 22 through October 5, 2021.

5.2.5 Total Dissolved Gas

Time series and box plots of TDG data collected continuously at the three Gorge bypass reach sites and the Gorge Powerhouse are shown in Figures 5.2-9 and 5.2-10. Median values for all sites are between 101 percent and 105 percent saturation.

Maximum percent saturation was 124 percent at BYPASS1 in the Gorge Plunge Pool during a spill event in late June. Values were also elevated during this same event at BYPASS3, although as discussed below (Section 5.2.7 of this study report), data at BYPASS3 are qualified over this period based on the mid-deployment check conducted on July 20 (see Section 5.2.7 of this study report). Relationships between TDG and spill observed during this event, and the frequency/magnitude of historical spill events that have occurred at Gorge Dam are discussed below. TDG was also elevated at PHOUSE1 in August, and briefly at GORGE3 in the first half of September. Evaluation of TDG at PHOUSE1 will be conducted following collection of additional data at GORGE4 (the Gorge Lake Forebay site) and presented in the USR.

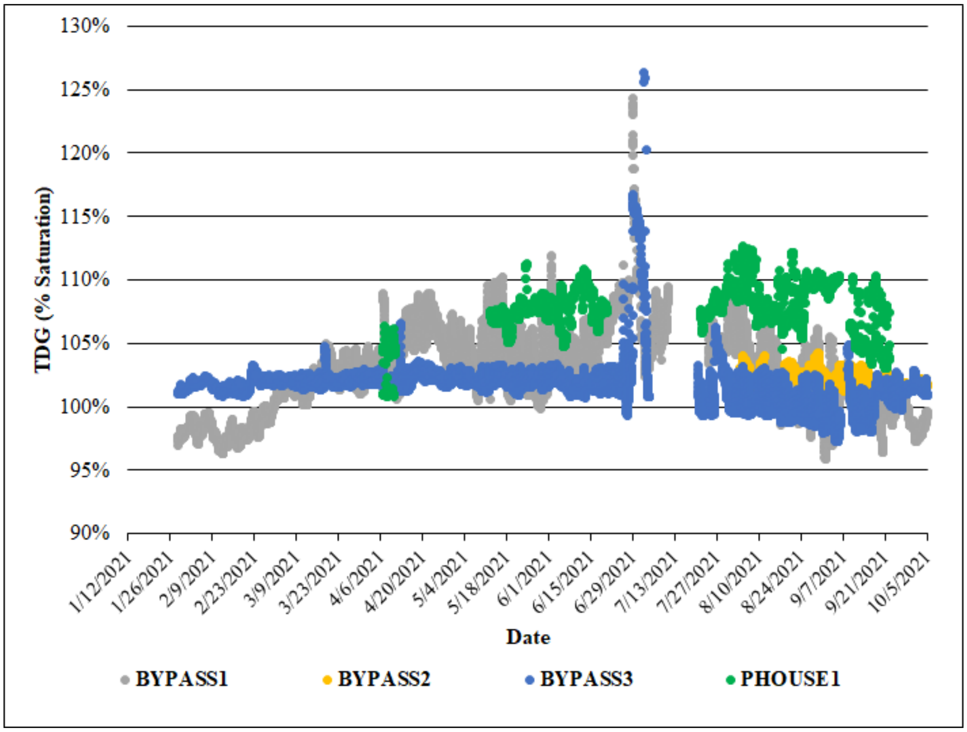


Figure 5.2-9. **Time-series of total dissolved gas at the Gorge bypass reach and Powerhouse sites, January 28 through October 5, 2021.**

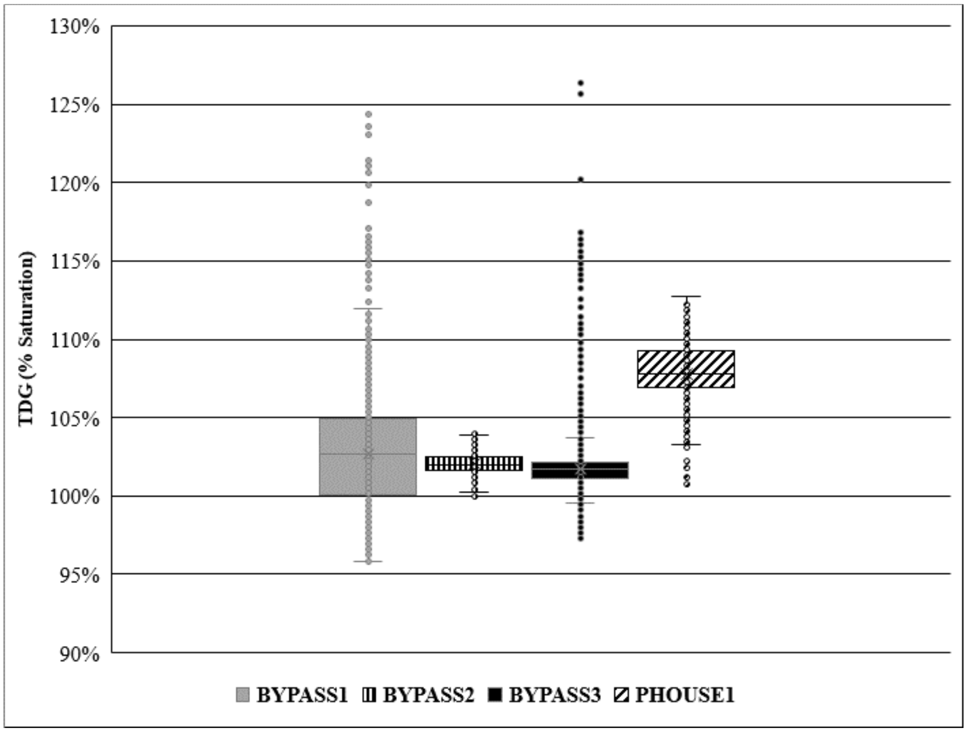


Figure 5.2-10. **Box-and-whisker plots of total dissolved gas at the Gorge bypass reach and Powerhouse sites, 2021.**

As noted above, the maximum TDG concentration observed at the monitoring sites to date, 124 percent saturation, was recorded at BYPASS1 during a sustained spill at Gorge Dam in late June, following record heat. Spills over the last 23 years have primarily occurred from June through August (Figure 5.2-11). City Light flow and spill records indicate that the maximum spill in June/July of 2021 (7,486 cfs on June 29) was approximately five times greater than the median spill event that occurred between 1997 and 2020 (Figure 5.2-12).

TDG data collected during the late June spill event are shown in Figure 5.2-13. Active sites at this time included BYPASS1 and BYPASS3. Data were not collected at the Gorge Powerhouse due to external battery failure and safety issues precluding access to the datasonde for maintenance.

TDG levels at BYPASS1 and BYPASS3 rose quickly in response to rapid increases in spill over a short duration on June 25 and 28 (increases of 2,900 and 2,650 cfs, respectively, over 1-hour periods). Levels at BYPASS3 increased by approximately seven percent over values just prior to the spill on both days, while effects at BYPASS1 are less evident. With the onset of the much larger spill on June 29, TDG rose steeply at both sites; values reached 124 percent saturation at BYPASS1 and 117 percent at BYPASS3. Changes in TDG levels at BYPASS1 tracked spill levels closely, while values downstream at BYPASS3 are not as closely correlated as those at BYPASS1. As the volume of spill declined, TDG at BYPASS3 decreased more gradually than at BYPASS1, possibly due to reaeration as water flowed through the cascade located upstream of BYPASS3. TDG at both sites remained greater than 110 percent until spill declined to approximately 4,000 cfs. However, as noted above, data from the BYPASS3 sonde are qualified because sand was observed in the TDG membrane, and the sonde did not meet deviation thresholds during the QC check conducted on July 20 (deviation threshold is 10-mm; BYPASS3 recorded a difference of 30-mm).

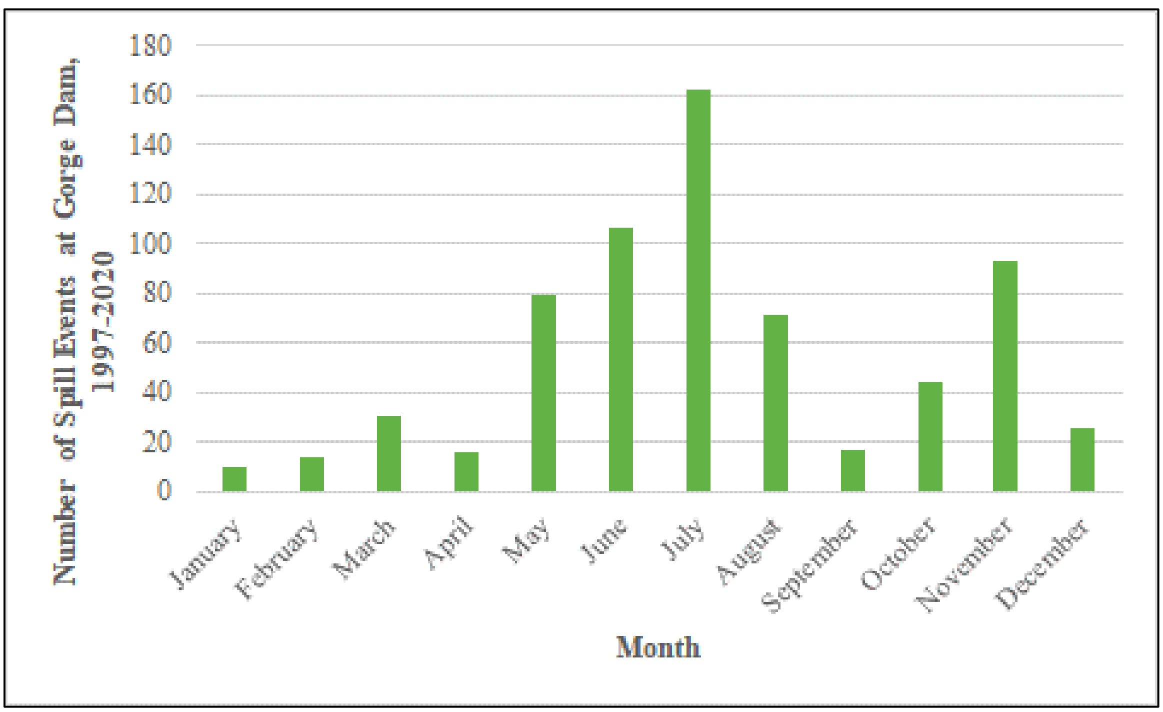


Figure 5.2-11. Monthly spill events at Gorge Dam, 1997-2020.

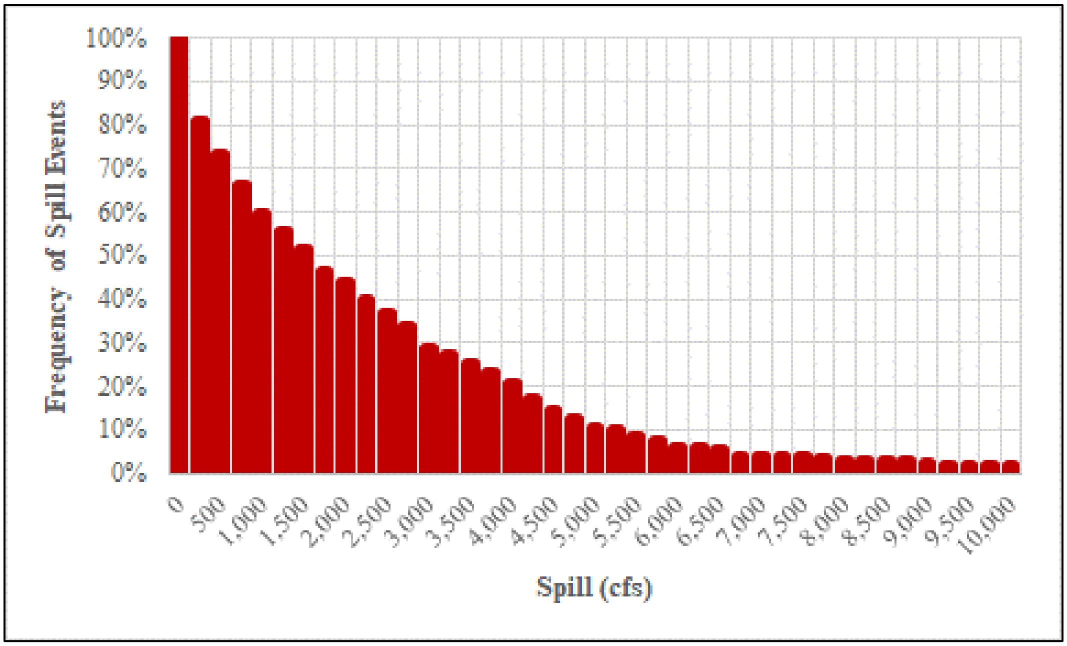


Figure 5.2-12. Frequency distribution of spill volume at Gorge Dam, 1997-2020.

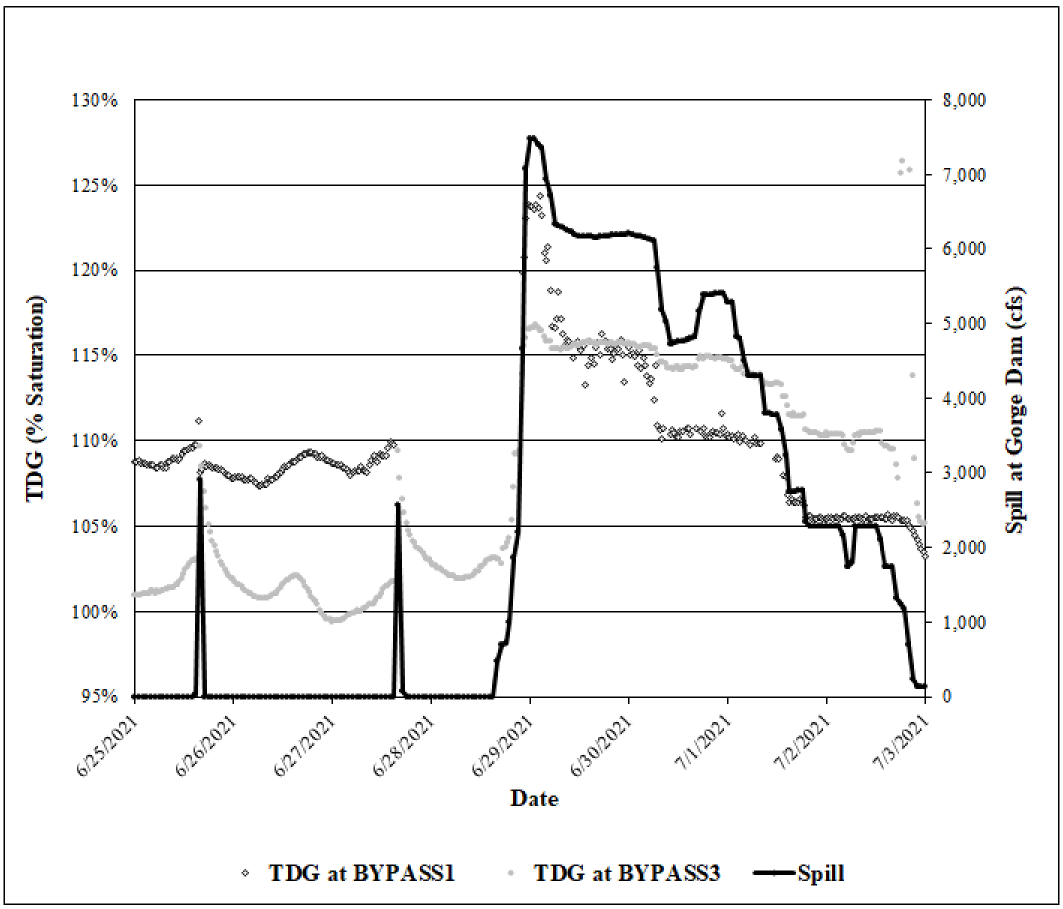


Figure 5.2-13. Total dissolved gas and spill in the Gorge bypass reach during late June/early July 2021.

A regression of TDG at BYPASS1 and spill volume at Gorge Dam supports the above observation regarding the 4,000 cfs threshold; spill in excess of 4,000 cfs resulted in TDG values exceeding 110 percent saturation (Figure 5.2-14). For these data, a large fraction of the variation in TDG is explained by increasing spill (r^2=0.79). Based on the frequency distribution shown previously, this threshold is a relatively uncommon event; 20 percent of spill events recorded from 1997-2020 have exceeded 4,000 cfs.

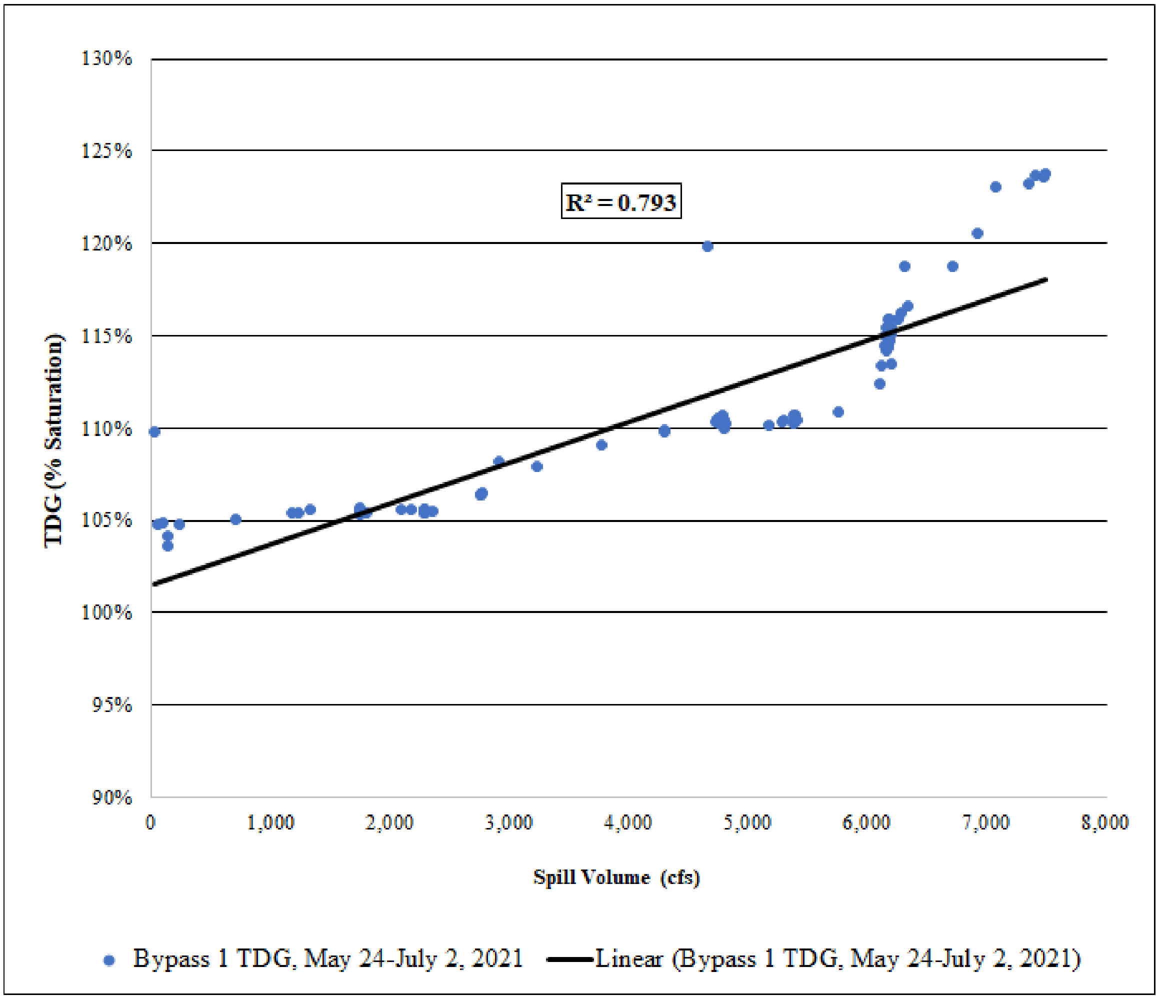


Figure 5.2-14. Regression of total dissolved gas at BYPASS1 vs. spill at Gorge Dam, May 24 through July 2, 2021.

City Light's TDG data collection included a planned spill event in July 2021 as a component of the FA-05 Skagit River Gorge Bypass Reach Hydraulic and Instream Flow Model Development Study (City Light 2022b). Controlled spill levels were selected in coordination with LPs and Gorge Dam operators. Stable daily flows of approximately 1,200, 500, 250, and 50 cfs were targeted for the period from July 26-29, 2021. Pre-spill TDG levels at BYPASS3 were between 100 and 103 percent, increasing to 106 percent with the onset of the 1,200 cfs release (Figure 5.2-15). TDG at BYPASS3 returned to pre-spill levels as flows were reduced over the next three days. The pre-spill pattern of TDG observed at BYPASS1 was altered, although levels remained near 105 percent over the four-day release.

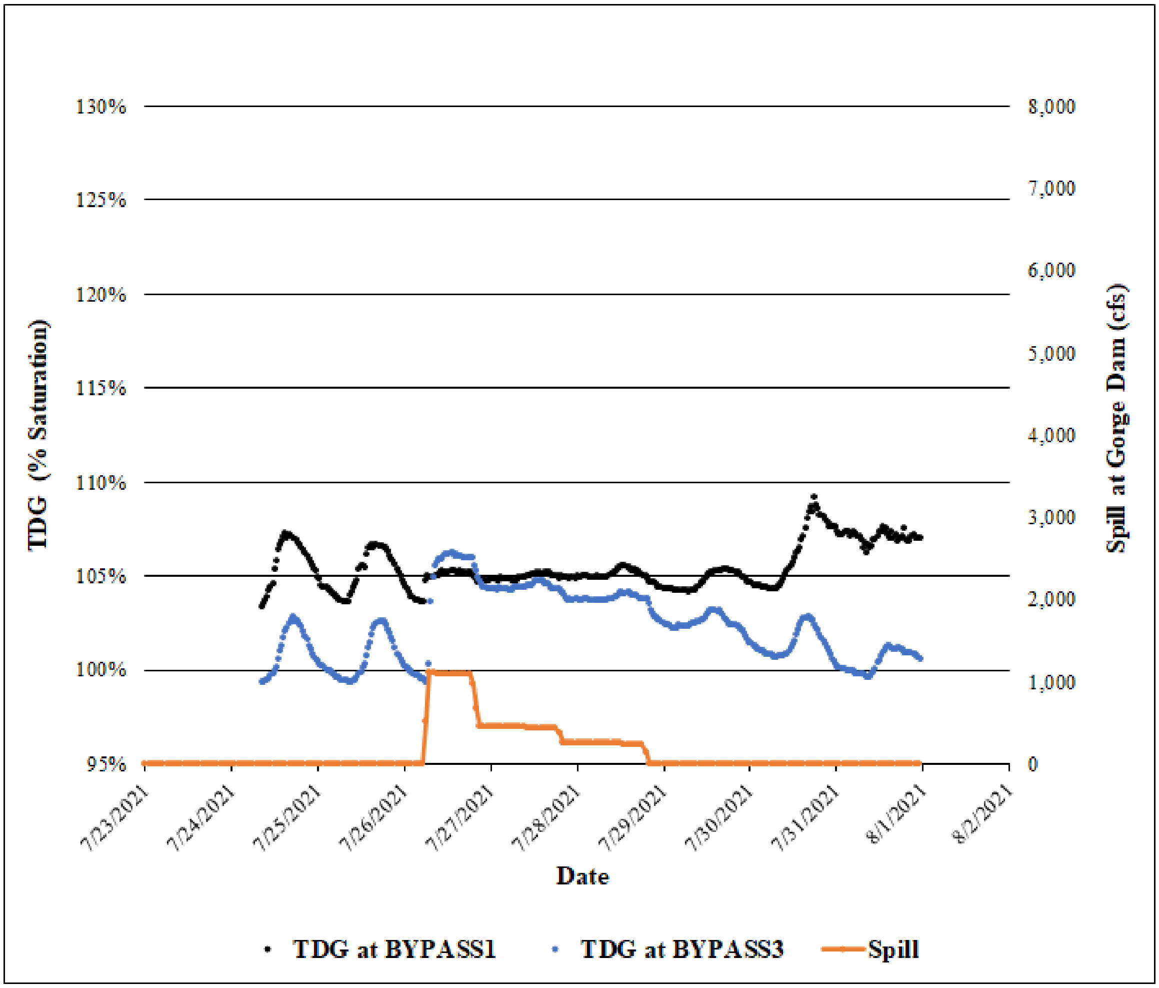


Figure 5.2-15. Total dissolved gas at BYPASS1 and BYPASS3 during planned spill at Gorge Dam, July 2021.

5.2.6 TDG Downstream of Gorge Powerhouse

As noted in Section 4.4.3 of this study report, TDG monitoring at the Bypass and Powerhouse locations is being augmented with measurement of TDG during spill events at locations downstream of Gorge Powerhouse. These measurements are opportunistic; not all spill events are monitored. Measurements of TDG are being made from bridges in the vicinity of the Powerhouse and may include Ladder Creek falls bridge, the suspension bridge to Trail of the Cedars, or the bridge at Newhalem Campground. Data collected during each spill event will be included in the USR in 2023. Preliminary data from a spill event monitored in October 2021 are presented below.

Beginning on October 25, 2021, and extending through October 31, 2021, City Light conducted a planned operational spill to evacuate water out of Ross Lake to achieve a safer margin between lake elevation and the flood control curve. Target flow at Newhalem during this period was 9,000 cfs. Assuming maximum discharge through the generators at Gorge Powerhouse, planned spill at Gorge Dam over this period was 2,000 cfs.

During the planned spill event, TDG measurements were recorded at the three bridges noted above: Ladder Creek Falls bridge (LADDER1) nearest to the Powerhouse, the Trail of Cedars bridge (CEDARS1), and the Newhalem Campground bridge (NEWCG1). TDG data were collected over a 2-hour period at 2-minute intervals at each site, at a depth of approximately 2-m. Monitoring was conducted using a calibrated Hydrolab DS-5 datasonde.

Start and end times and Skagit River flows at the USGS Newhalem gage during the monitoring periods are shown below (Table 5.2-1). Skagit River flow (Gorge Powerhouse generation and spill combined) and spill at Gorge Dam remained constant at approximately 8,500 cfs and 2,000 cfs, respectively.

Table 5.2-1. Locations, times, and Skagit River flow at the USGS Newhalem Gage during total dissolved gas monitoring, October 26, 2021.

Site ID	Start Time	End Time	Flow at Newhalem (cfs)
LADDER1	09:00	11:00	8,580 – 8,640
CEDARS1	11:30	13:30	8,610 – 8,530
NEWCG1	14:00	16:00	8,560 – 8,610

TDG at all three bridge sites remained at or near 105 percent saturation (Figure 5.2-16). Hydrolab datasondes recording TDG data in the Gorge bypass reach could not be accessed at the time and remain unavailable due to a combination of high flows, landslides, and road closures. If recovered, these data will be presented in the USR along with TDG data reported above.

TDG was also recorded following the above procedure at all three bridge sampling sites on November 6, 2021, during normal operations at Gorge Powerhouse. TDG at all three sites remained between 102 and 104 percent saturation during this monitoring event (10:00 to 14:30). Flows recorded at the USGS Newhalem gage (Gage 12178000) during the monitoring period were between 4,500 and 4,600 cfs.

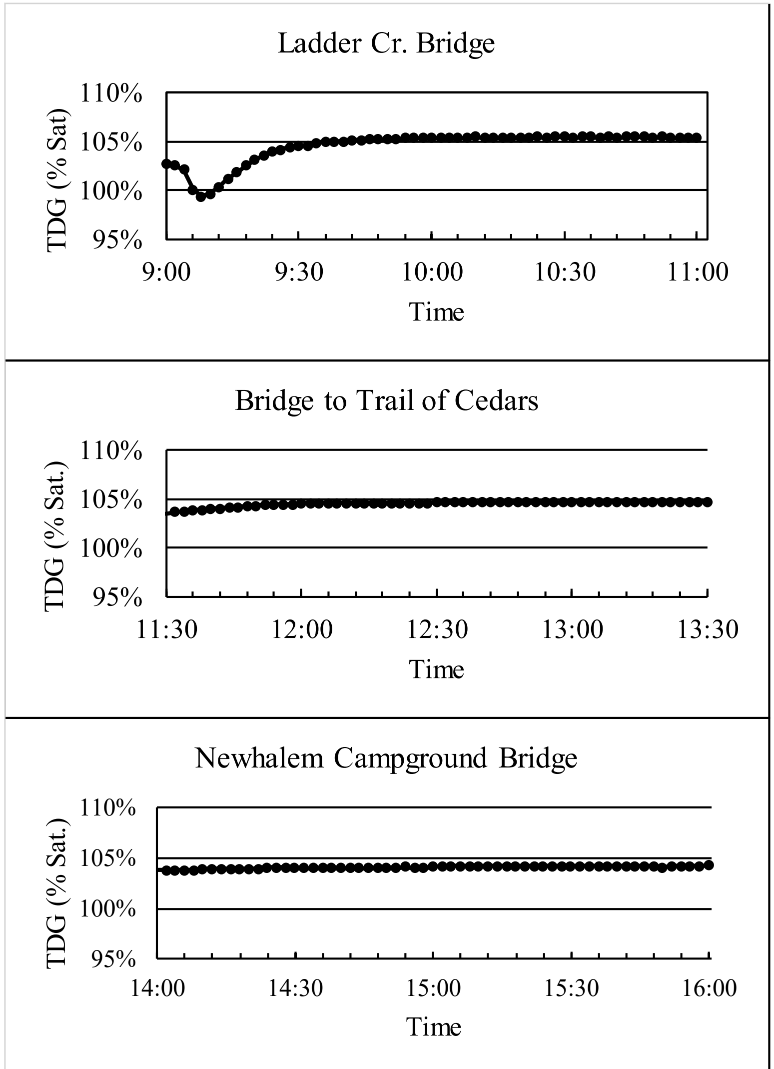


Figure 5.2-16. Total dissolved gas sampled at bridges downstream of Gorge Powerhouse during planned spill, October 2021.

5.2.7 TSS at Gorge Powerhouse

Per the Water Quality Monitoring Study RSP, TSS would be measured "as needed" downstream of Gorge Powerhouse. City Light collected a TSS sample for analysis on July 22, 2021, and the resulting TSS concentration was 2 mg/L. Powerhouse flows at the time and over the previous several days were relatively stable at approximately 3,000 cfs. Given the relatively low and constant flows, the 2 mg/L TSS likely represents a baseline value. Future TSS samples at PHOUSE2 will be collected when turbidity is elevated or during spill events at Gorge Dam.

5.2.8 QA/QC

A summary of mid-deployment check results and actions taken during each of the site visits is shown below (Table 5.2-2). With the exception of the paired test for turbidity on September 8 (covering the period from August 17 to September 8), all paired tests on datasondes deployed at BYPASS1 met criteria per the project QAPP and Ecology SOP EAP002 for TDG (Ecology 2006), and for other parameters as described in SOP EAP129 (Ecology 2019c). Failed mid-deployment checks at other sites were followed by re-calibration for all but turbidity at BYPASS3 on September 8, and pH at PHOUSE1 on August 17 and October 5.

As described in Section 4.1 of this study report, if a parameter did not meet performance standards during a mid-deployment check, all data extending to the last passed paired test or recalibration are qualified, but not removed from processed data.

Table 5.2-2. Summary of mid-deployment checks at the Gorge bypass reach and Powerhouse sites, January through October 2021.

Dates	Temperature	TDG	DO	Turbidity	pH[1]
BYPASS1					
1/28 – 2/11	D	D	D	D	-
2/11 – 3/11	D	D	D	D	-
3/11 – 4/6	P	P/R	P	P	-
4/6 – 5/12	D	D	D	P	-
5/12 – 6/17	D	R	D	D	-
6/17 – 7/21	P	P	P	P	-
7/21 – 8/17	P	P	P	P	-
8/17 – 9/08	P	P	P	F	-
9/08 – 10/5	P	P	P	P	-
BYPASS2					
8/02 – 8/17	P	P	F/R	P	-
8/17 – 9/08	F	P	P	P	-
9/08 – 10/05	P	P	P	P	-
BYPASS3					
1/28 – 2/11	D	D	D	D	-
2/11 – 3/11	D	D	D	D	-
3/11 – 4/6	P	P/R	P	D	-
4/6 – 5/12	D	D	D	P	-
5/12 – 7/20	P	F/R	P	P	-
7/21 – 8/17	P	P/R	P	P	-
8/17 – 9/08	P	F/R	P	F	-
9/8 – 10/5	P	P	P	P	-
PHOUSE1					
2/11 – 3/11	D	D	D	D	-
3/11 – 4/6	P	P	P	D	-
4/6 – 5/12	D	D	D	P	-
5/12 – 6/20	P	P	P	P	-
7/21 – 8/17	P	P	P	P	F
8/17 – 9/8	P	F/R	P	P	F/R
9/8 – 10/5	P	P	P	P	F

1 pH measurements only collected at the PHOUSE1 site after July 21, 2021.
D = Download only; P = Passed; P/R = Passed/Recalibrated; F = Failed; F/R = Failed/Recalibrated.

The goal of 90 percent data completeness, as stated in the QAPP, was met for all parameters in the Gorge bypass reach but not at Gorge Powerhouse (Table 5.2-3). The low percent completion for all parameters at PHOUSE1 is due to extended periods of exposure (dewatering of the sonde) and battery failure, as well as periods during February and March when the TDG sensor did not appear to be functioning properly. The pH readings at PHOUSE1 are all either qualified (due to failure of the side-by-side checks) or rejected due to battery failure.

Table 5.2-3. Percent data completeness results for the Gorge bypass reach and Powerhouse from January 28 to October 5, 2021.

Parameter	Site	Accepted	Qualified	Rejected	Total Planned Results	Percent Complete
Temperature	BYPASS1	11,232	0	183	11,415	98.4%
	BYPASS2	1,741	1,047	288	3,076	90.6%
	BYPASS3	11,216	0	281	11,497	97.6%
	PHOUSE1	7,083	0	2,735	9,818	72.1%
DO	BYPASS1	11,229	0	186	11,415	98.4%
	BYPASS2	2,346	442	288	3,076	90.6%
	BYPASS3	11,004	0	493	11,497	95.7%
	PHOUSE1	6,614	0	3,204	9,818	67.4%
TDG	BYPASS1	11,226	0	189	11,415	98.3%
	BYPASS2	2,785	0	291	3,076	90.5%
	BYPASS3	5,997	5,188	312	11,497	97.3%
	PHOUSE1	3,989	915	4,914	9,818	49.9%
Turbidity	BYPASS1	10,276	939	200	11,415	98.2%
	BYPASS2	2,795	0	281	3,076	90.9%
	BYPASS3	10,195	932	370	11,497	96.8%
	PHOUSE1	7,081	0	2,737	9,818	72.1%
pH	PHOUSE1	0	2,843	810	3,653	77.8%

5.2.8.1 Overview of Data Collection Outcomes

A summary of data collection outcomes during the period reported in this study report, from January 28 to October 5, 2021, is shown below (Figure 5.2-17). The charts for each parameter and site display whether data collected during a given week are accepted, qualified, or rejected, or the reason data were not collected during a given week (access, manufacturing delays/supply chain, or site not yet included in the RSP).

During the early data collection period (January 28 to June 2, 2021, prior to the onset of data collection identified in the RSP), BYPASS2 was not included in the study plan and data was not collected at this site. Supply chain issues further delayed deployment at BYPASS2 until early August. High flows were an important factor limiting data collection at the PHOUSE1 and BYPASS3 sites in early to mid-July. In general, the charts below show that the majority of data collected at each site are accepted (Figure 5.2-16). The greatest number of qualified observations are for TDG due to failure during paired tests during mid-deployment checks. PHOUSE1 has the greatest number of rejected observations due to extended periods of exposure, battery failure, and TDG values that appeared inaccurate and therefore rejected.

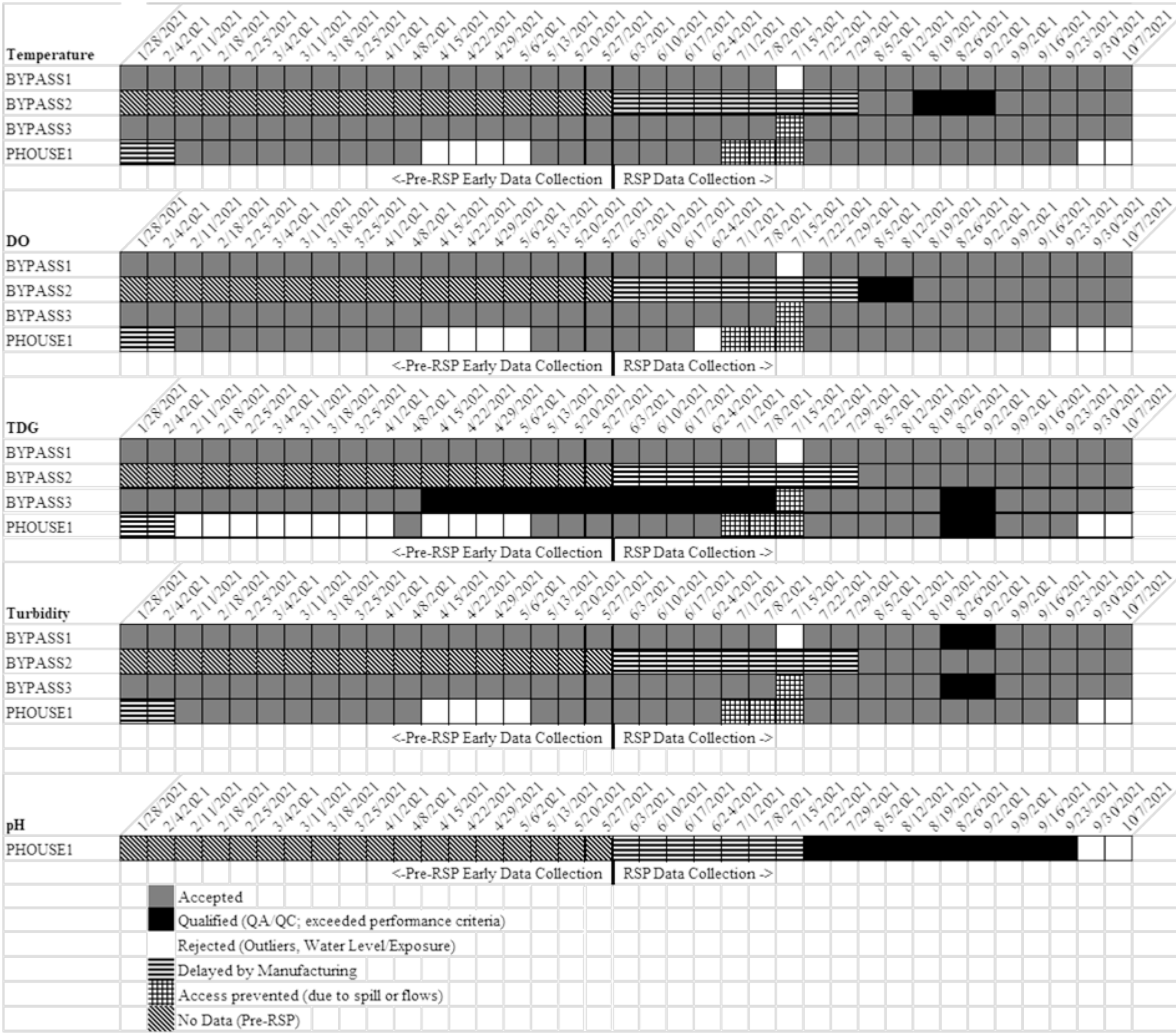


Figure 5.2-17. Weekly summary of data collection outcomes for continuous monitoring at the Gorge bypass reach and Gorge Powerhouse sites, January 28 to October 5, 2021.

5.3 Skagit River Downstream of Gorge Powerhouse and Sauk River

This section of the study report addresses monitoring activities in the Skagit River downstream of Gorge Powerhouse, including continuous water temperature data collection and BMI sample collection.

5.3.1 Water Temperature

As described in Section 4.1.5 of this study report, Onset temperature loggers (thermographs) are deployed at six sites in the Skagit River downstream of Gorge Powerhouse and at one site in the lower Sauk River. Site locations are shown in Figure 4.1-2 and listed in Table 4.1-1. The six Skagit River sites are dispersed along 37 miles of the mainstem Skagit River.

The monthly minimum, mean, and maximum water temperatures for each site during the monitoring period are reported in Table 5.3-1. The 30-minute water temperature regimes for each monitoring site are presented in Figure 5.3-1.

Thermographs are generally deployed at a depth of around 1-m; however, stage fluctuations occasionally exposed loggers to air, most notably the PRM 75.6 site (SKAGIT4), which was dewatered from July 18 through August 22. This site is located in a campground near a boat launch, and dewatering could have been a result of stage fluctuations or members of the public pulling up the thermograph.

In 2021, the highest 30-minute water temperature recorded was 19.3°C at the PRM 60.8 site (SKAGIT6) on September 6, 2021. The highest hourly water temperatures recorded at each site are presented in Table 5.3-1.

All thermograph sites are located well downstream of any tributaries and reflect conditions within the Skagit River. Only the thermograph deployed at PRM 60.8 (SKAGIT6) is in an area that is not well mixed, and where large woody debris has racked on the shoreline. Since deployment, smaller branches and fine sediment have started to accumulate and form a small backwater pool at this site, which may cause localized warming at lower river flows. Relocation of this thermograph is under evaluation.

Table 5.3-1. Monthly minimum, mean, and maximum hourly water temperatures recorded at lower Skagit and Sauk river sites, June through September 2021.

Month	Site ID	Location	Min Water Temp (°C)	Mean Water Temp (°C)	Max Water Temp (°C)
June	SKAGIT2	PRM 91.6	7.7	9.0	12.3
	SKAGIT3	PRM 85.9	7.8	9.3	12.5
	SKAGIT4	PRM 75.6	7.2	9.7	13.3
	SKAGIT5	PRM 69.3	9.5	11.7	13.6
	SKAGIT6	PRM 60.8	9.0	11.3	13.8
	SKAGIT7	PRM 54.5	10.1	12.0	13.4
	SAUK1	Sauk River	9.0	11.7	14.5
July	SKAGIT2	PRM 91.6	9.6	10.7	12.2
	SKAGIT3	PRM 85.9	9.8	11.0	13.3
	SKAGIT4	PRM 75.6	10.2	11.8	14.6
	SKAGIT5	PRM 69.3	10.6	12.9	16.3
	SKAGIT6	PRM 60.8	10.7	13.7	13.8
	SKAGIT7	PRM 54.5	11.2	13.6	15.5
	SAUK1	Sauk River	10.4	13.8	16.4
August	SKAGIT2	PRM 91.6	10.6	11.5	12.7
	SKAGIT3	PRM 85.9	10.7	11.7	13.7
	SKAGIT4	PRM 75.6	10.5	12.5	15.4
	SKAGIT5	PRM 69.3	10.8	13.3	16.7
	SKAGIT6	PRM 60.8	11.7	14.6	18.9
	SKAGIT7	PRM 54.5	12.5	14.2	15.4
	SAUK1	Sauk River	11.2	14.9	17.2
September	SKAGIT2	PRM 91.6	9.9	10.6	11.7
	SKAGIT3	PRM 85.9	10.0	10.7	12.4
	SKAGIT4	PRM 75.6	9.7	11.5	14.8
	SKAGIT5	PRM 69.3	10.0	11.7	14.4
	SKAGIT6	PRM 60.8	10.3	12.8	19.3
	SKAGIT7	PRM 54.5	11.1	13.1	15.2
	SAUK1	Sauk River	9.7	12.9	17.3

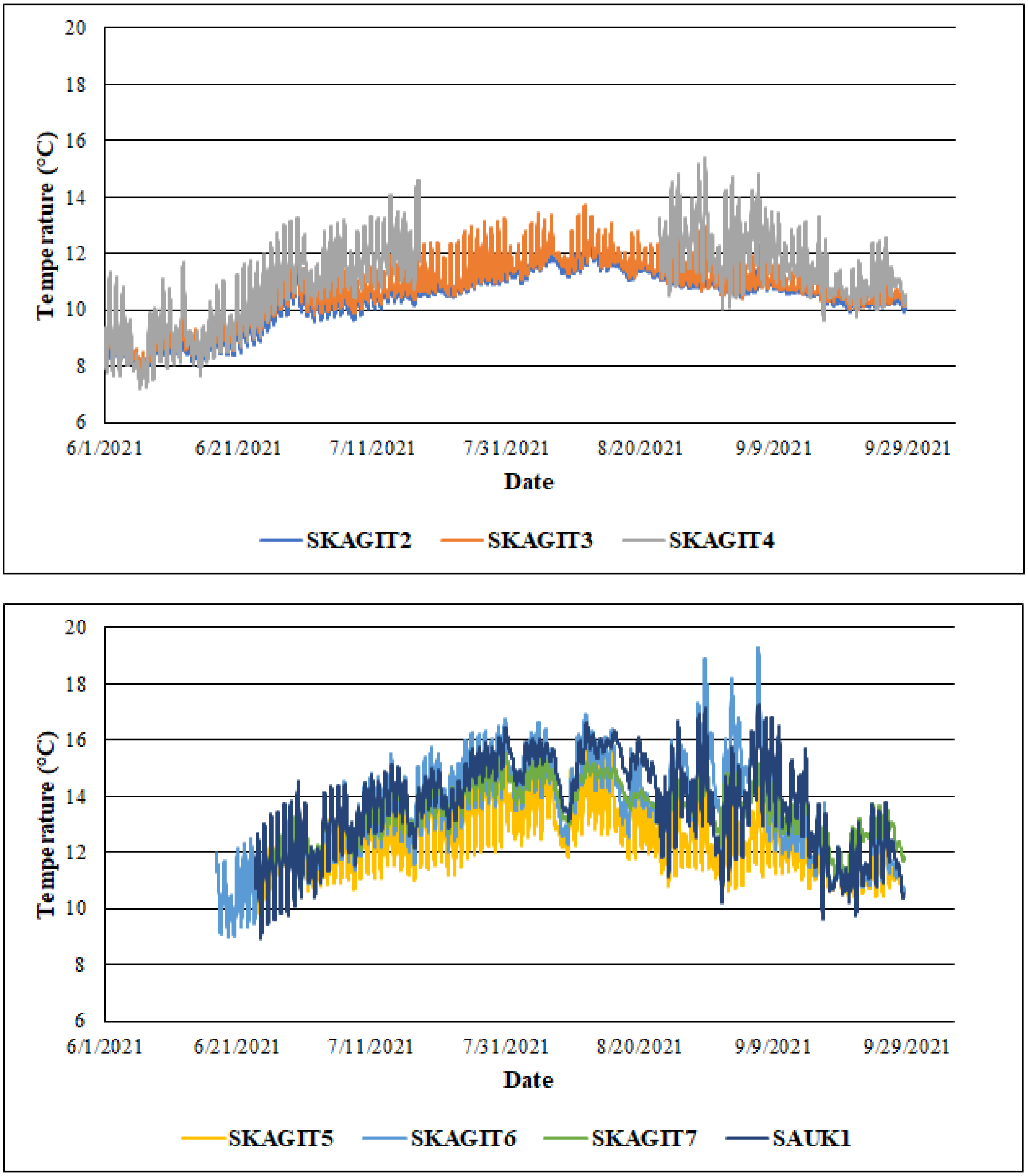


Figure 5.3-1. 30-minute water temperatures at Skagit River sites upstream from Marblemount (SKAGIT2-4), June through September 2021 (top), 30-minute water temperatures at Skagit River sites from Marblemount downstream to Concrete including the Sauk River site (SKAGIT5-7, SAUK1), June through September 2021.

Flows in the Skagit River downstream of the Project are a function of releases from Gorge Powerhouse, tributary inflow, groundwater accretion, and spill at Gorge Dam. Figure 5.3-2 shows the water temperatures recorded at the upper two sites on the Skagit River, PRM 91.6 and 85.9 (SKAGIT2 and 3), and river flows as recorded at the USGS gage at Newhalem, the gage that is closest to these two sites.

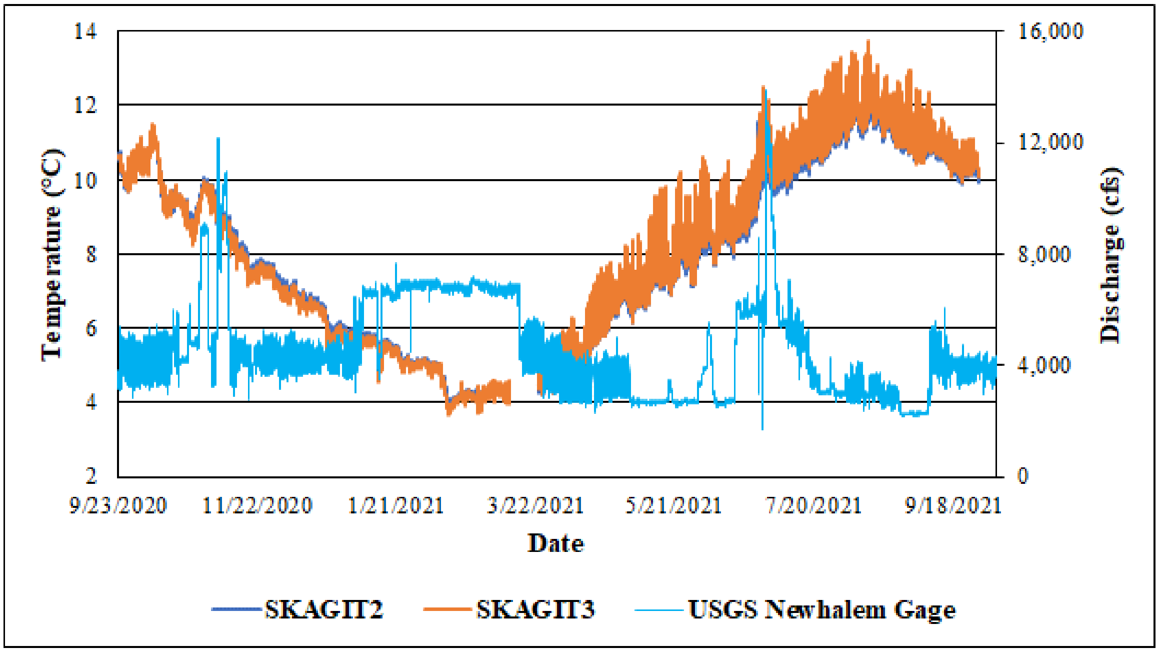


Figure 5.3-2. 30-minute water temperatures at SKAGIT2 and 3 (PRM 91.6 and 85.9) and Skagit River discharge monitored at the USGS Newhalem gage, September 2020 through September 2021.

Several tributaries enter the Skagit River between Newhalem and Marblemount, adding flow and affecting water temperatures within this reach of the mainstem. Figure 5.3-3 shows water temperatures at PRM 75.6 and 69.3 (SKAGIT4 and 5) and the Skagit River flow at Marblemount at PRM 78.7, the USGS gage nearest these sites.

The Sauk River enters the Skagit River approximately 2.5 miles downstream of SKAGIT5 (PRM 69.3) and upstream of SKAGIT6 (PRM 60.8). Discharge in the Skagit River downstream of the Sauk River and upstream of the Baker River confluence is not monitored. The proportion of Skagit River flow that can be attributed to the Sauk River is highly variable throughout the water year. Figure 5.3-4 shows water temperatures at PRM 60.8 (SKAGIT6) and the flows recorded in the Skagit River at Marblemount and the Sauk River flow recorded at the Sauk River USGS gaging station.

The Baker River enters the Skagit River approximately 2.2 miles upstream of PRM 54.5 (SKAGIT7). Flows in the Baker River are managed by the Baker River Hydroelectric Project (owned and operated by Puget Sound Energy) and are typically between 1,000 and 5,600 cfs. Figure 5.3-5 shows water temperatures at PRM 54.5 (SKAGIT7) and the flows recorded in the Skagit River at USGS Concrete gaging station (USGS 12194000) and the Baker River flow recorded at the Baker River USGS gaging station at Henry Thompson Bridge at Concrete (USGS 12193400).

The Sauk River thermograph is located approximately 5.4 miles upstream of the Skagit River confluence, coincident with the USGS Sauk River gage. Figure 5.3-6 shows water temperatures at the Sauk River site (SAUK1) and flows at the Sauk River USGS gaging station.

Time series of 7-DADMax temperatures at Skagit and Sauk river sites are shown below (Figure 5.3-7), along with Ecology temperature standards applicable to this section of the Skagit River. The core summer salmonid habitat standard is 16°C, and applies from June 15 to September 15. The supplemental spawning/incubation standard is 13°C and applies from September 16 to June 14. The highest 7-DADMax water temperature recorded during the monitoring period was 17.2°C (at SKAGIT6 (PRM 60.8) at the end of August) (Table 5.3-2).

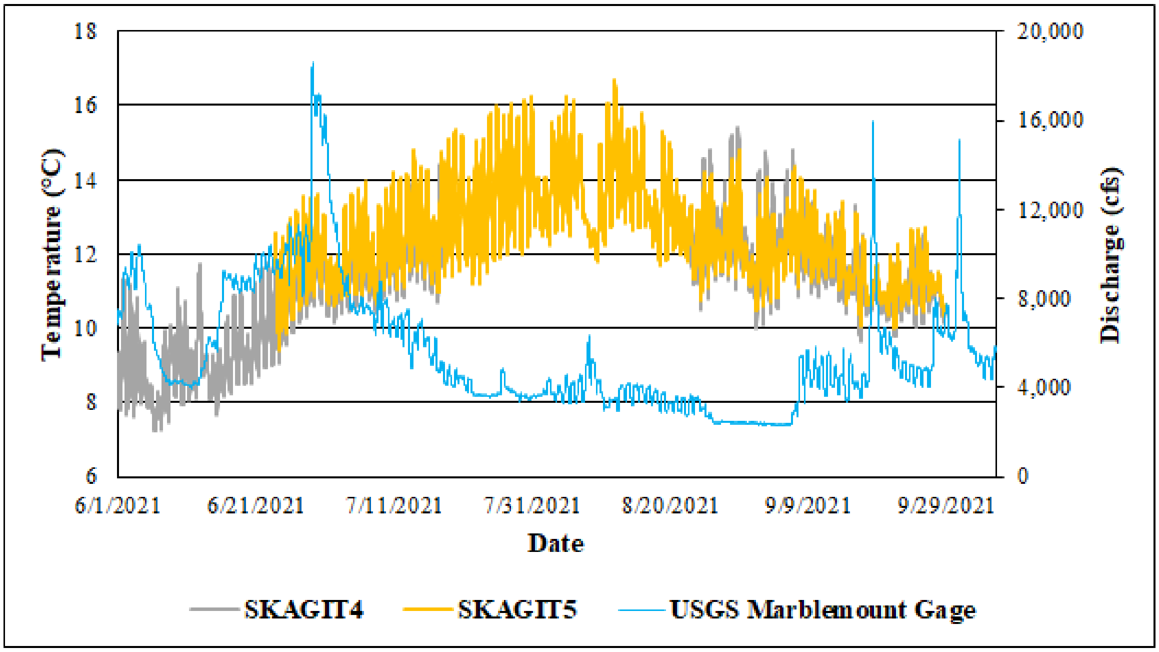


Figure 5.3-3. 30-minute water temperatures at SKAGIT4 and 5 (PRM 75.6 and 69.3) and Skagit River discharge as monitored at the USGS Marblemount gage, June through September 2021.

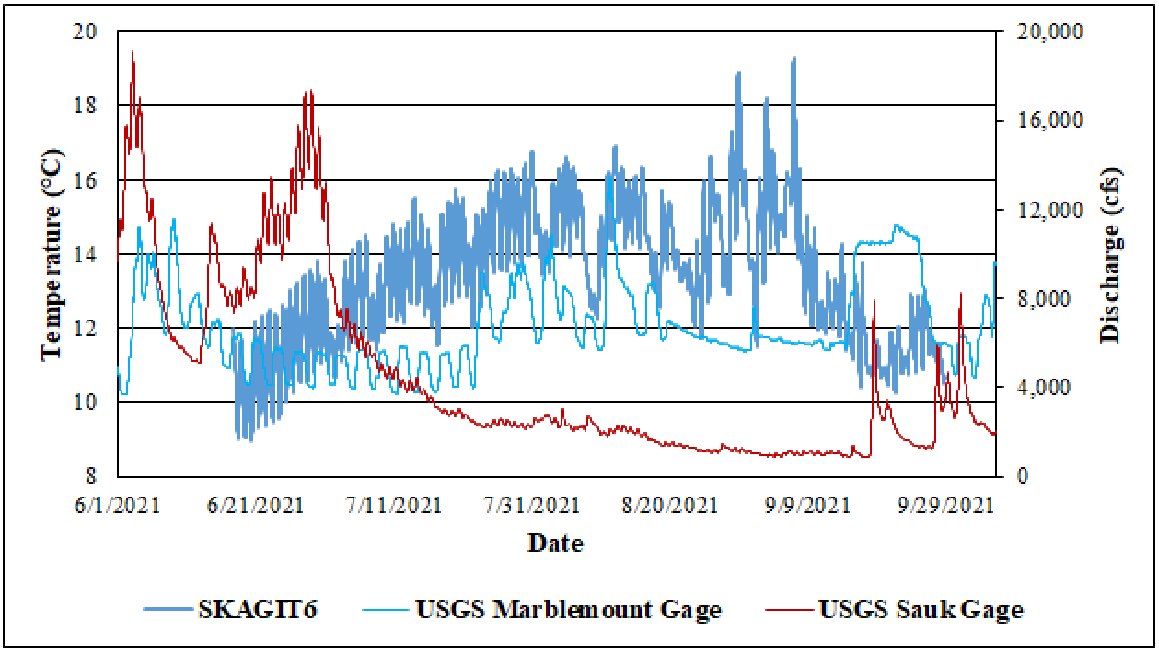


Figure 5.3-4. 30-minute water temperatures at SKAGIT6 (PRM 60.8) and Skagit River discharge as monitored at the USGS Marblemount gage and Sauk River discharge as monitored at the USGS Sauk River gage, June through September 2021.

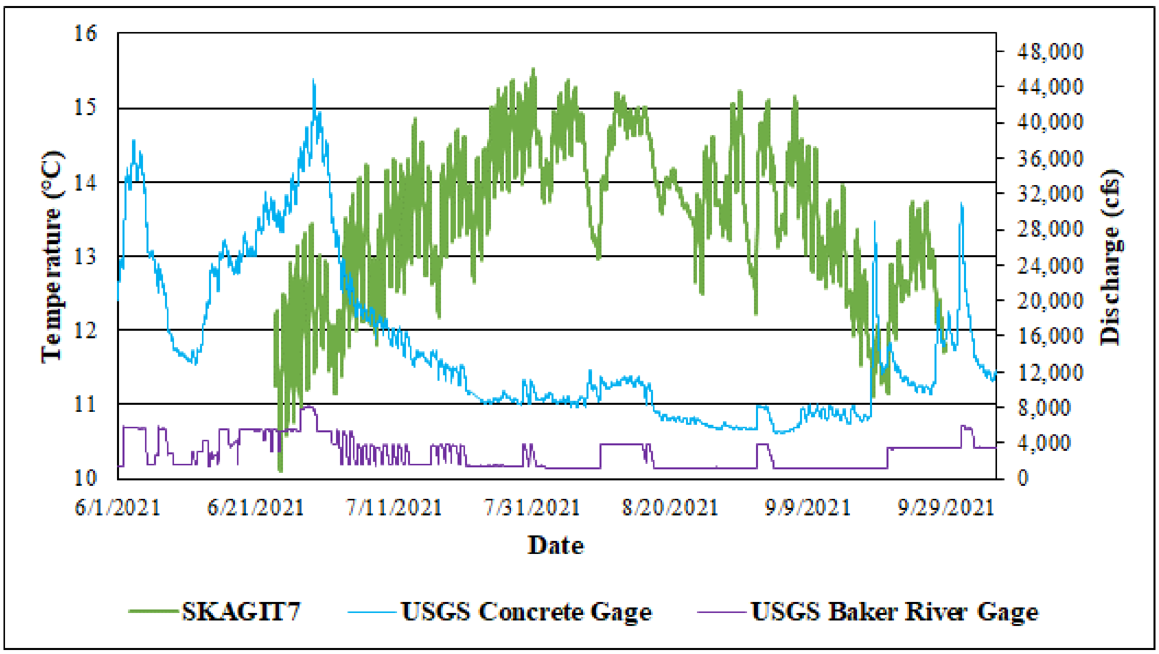


Figure 5.3-5. 30-minute water temperatures at SKAGIT7 (PRM 54.5) and Skagit River discharge as monitored at the USGS Concrete gage, and Baker River discharge as monitored at the USGS Baker River gage, June through September 2021.

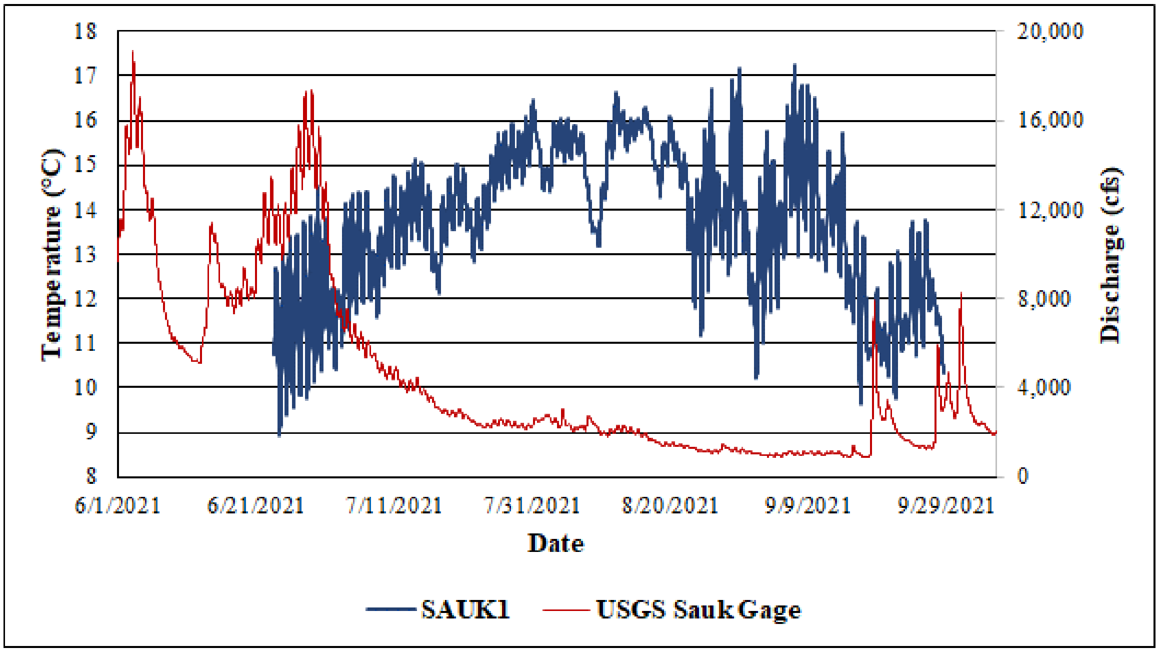
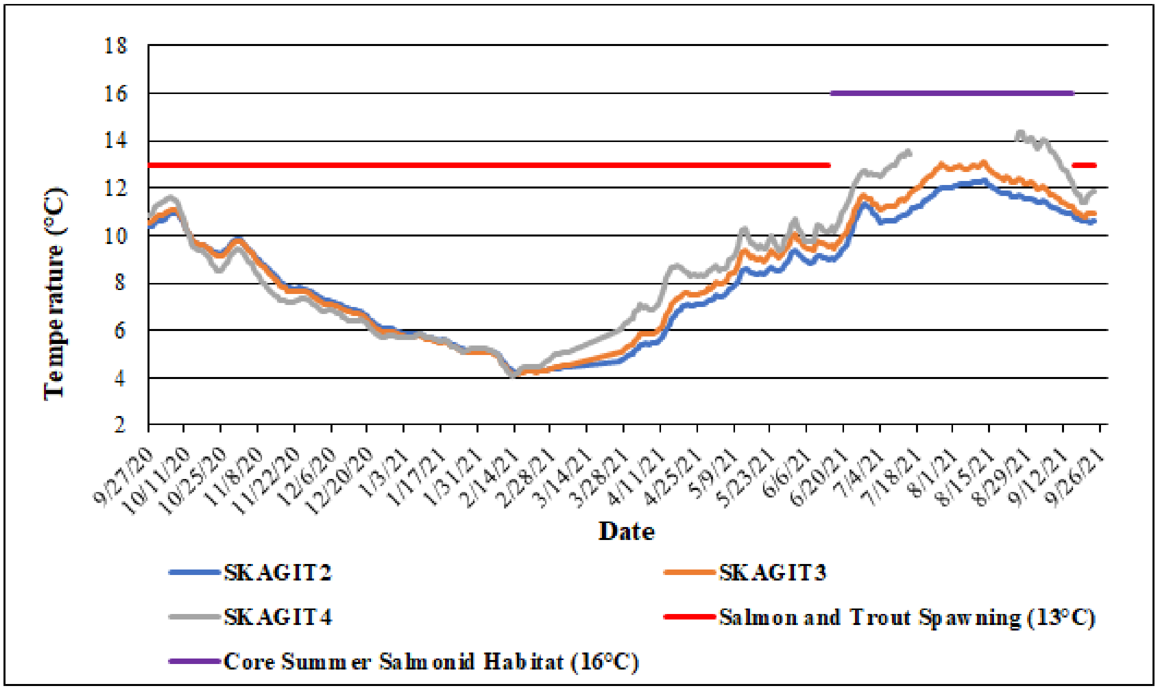


Figure 5.3-6. 30-minute water temperatures at SAUK1 and discharge as monitored at the USGS Sauk gage, June through September 2021.



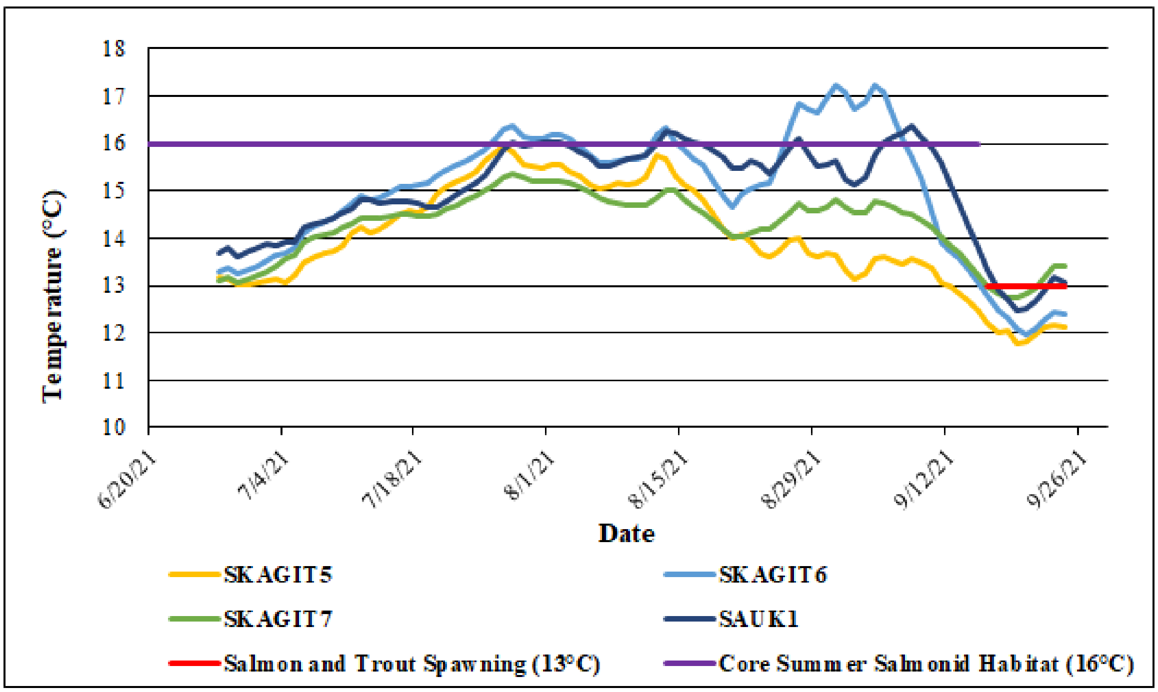


Figure 5.3-7. 7-DADMax water temperatures at Skagit River sites upstream from Marblemount (SKAGIT2-4), September 2020 through September 2021 (top), 7-DADMax water temperatures at Skagit River sites from Marblemount downstream to Concrete including the Sauk River site (SKAGIT5-7, SAUK1), June through September 2021. Horizontal lines show Ecology temperature standards.

Table 5.3-2. The highest 7-DADMax water temperature recorded at each lower Skagit River site during the 2020-2021 monitoring period.

Site ID	Location	Highest 7-DADMax Water Temperature Recorded (°C)	Date
SKAGIT2	PRM 91.6	12.34	8/12/21
SKAGIT3	PRM 85.9	13.15	8/12/21
SKAGIT4	PRM 75.6	14.36	8/27/21
SKAGIT5	PRM 69.3	16.0	7/27/21
SKAGIT6	PRM 60.8	17.2	8/31/21
SKAGIT7	PRM 54.5	15.4	7/28/21
SAUK1	Sauk River	16.4	9/8/21

7-DADMax temperatures at the three sites initially deployed in 2020 (SKAGIT2, 3, and 4 (PRM 91.6, 85.9, and 75.6, respectively) were nearly identical from the end of September through February 2021. Following that period, temperatures at these sites began to diverge with distance downstream. In general, temperatures at the four downstream sites added in June 2021 are warmer, but with little difference seen among them until mid-summer.

Elevated 7-DADMax water temperatures recorded at SKAGIT6 (PRM 60.8) are unique to this location and are not evident at the sites immediately upstream and downstream (PRM 69.3 and 54.5, respectively). As discussed above, these elevated temperatures may reflect localized pooling caused by sediment deposition around the deployment site. As noted above, relocation of this thermograph is under evaluation.

5.3.2 Benthic Macroinvertebrates

As described in Section 4.1.5 of this study report, BMI sampling occurred over three days in August 2021 near each of the six thermograph sites in the Skagit River downstream of Gorge Powerhouse and one site in the lower Sauk River. Site locations are shown in Figure 4.1-2 and listed in Table 4.1-1. Specific BMI sampling locations were selected based on wadable riffle habitat in close proximity to the thermograph locations.

The Sauk River BMI site was sampled on August 22, 2021. River flows were below normal for the system but were generally stable before the sampling event (Figure 5.3-8). BMI sampling occurred from downstream to upstream in the Skagit River, with the four sites downstream of Marblemount sampled on August 23, 2021 and the two sites upstream of Marblemount sampled on August 24, 2021. Skagit River conditions at Concrete, Marblemount, and Newhalem during BMI sampling were slightly below the median daily flow, but generally stable before the sampling event (Figures 5.3-9, 5.3-10, and 5.3-11).

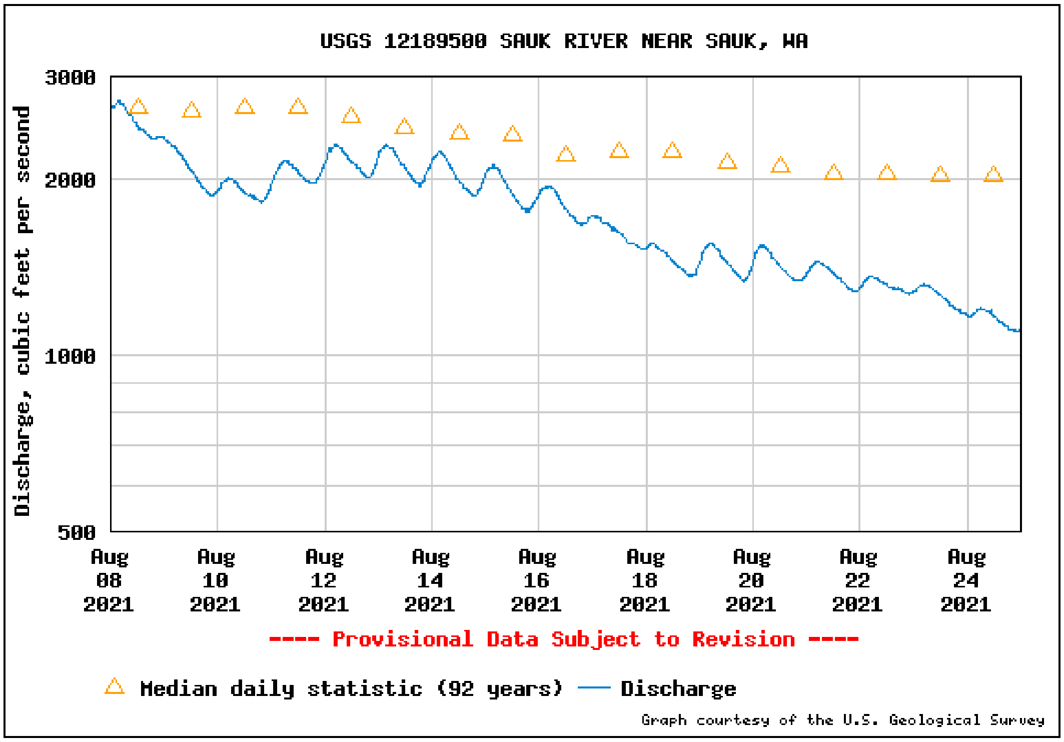


Figure 5.3-8. **Sauk River discharge during BMI sampling on August 22, 2021, as recorded at USGS 12189500 Sauk River gage.**

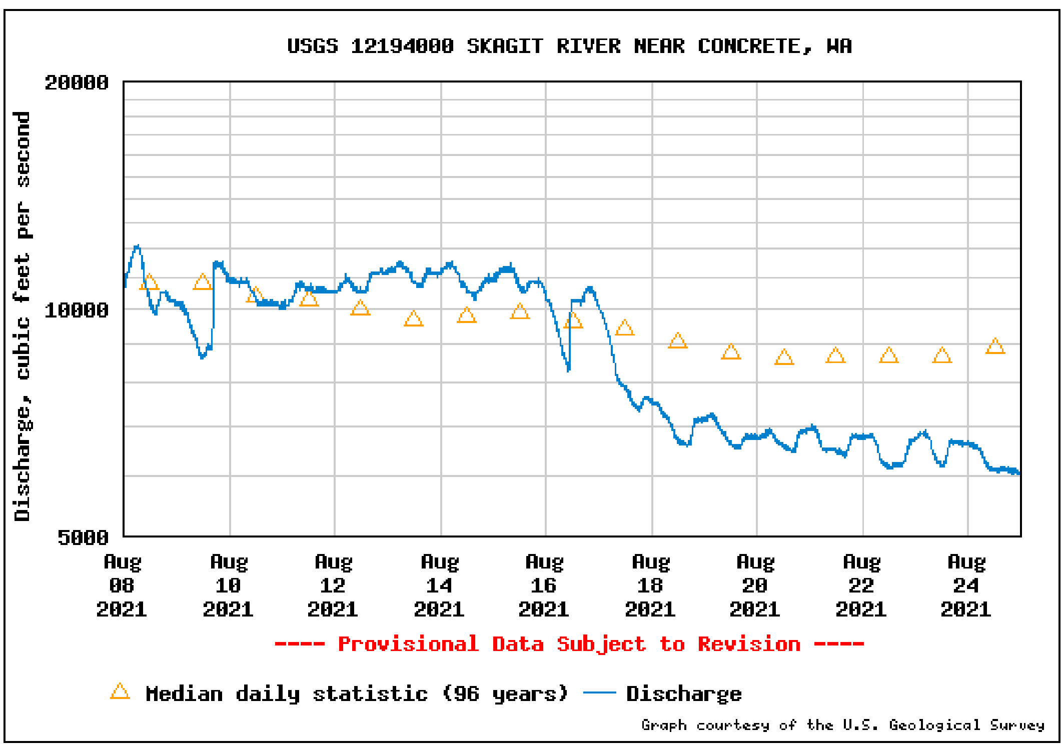


Figure 5.3-9. **Skagit River discharge during BMI sampling on August 23, 2021, as recorded at USGS 12194000 Skagit River gage at Concrete.**

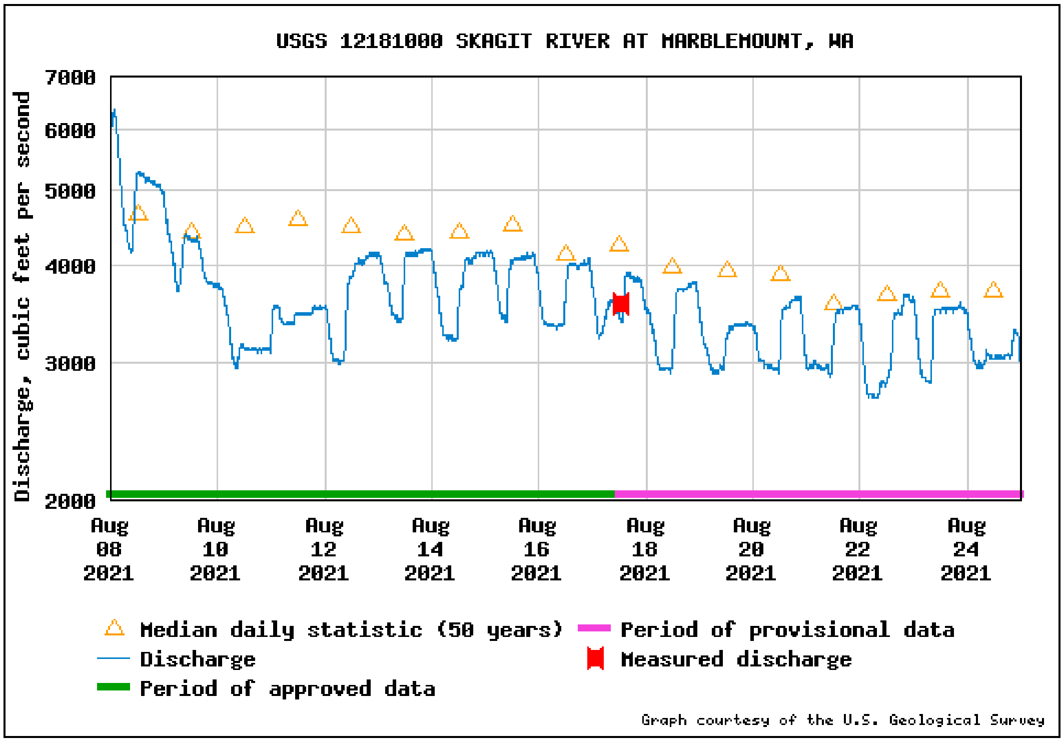


Figure 5.3-10. Skagit River discharge during BMI sampling on August 23, 2021, as recorded at USGS 12181000 Skagit River gage at Marblemount.

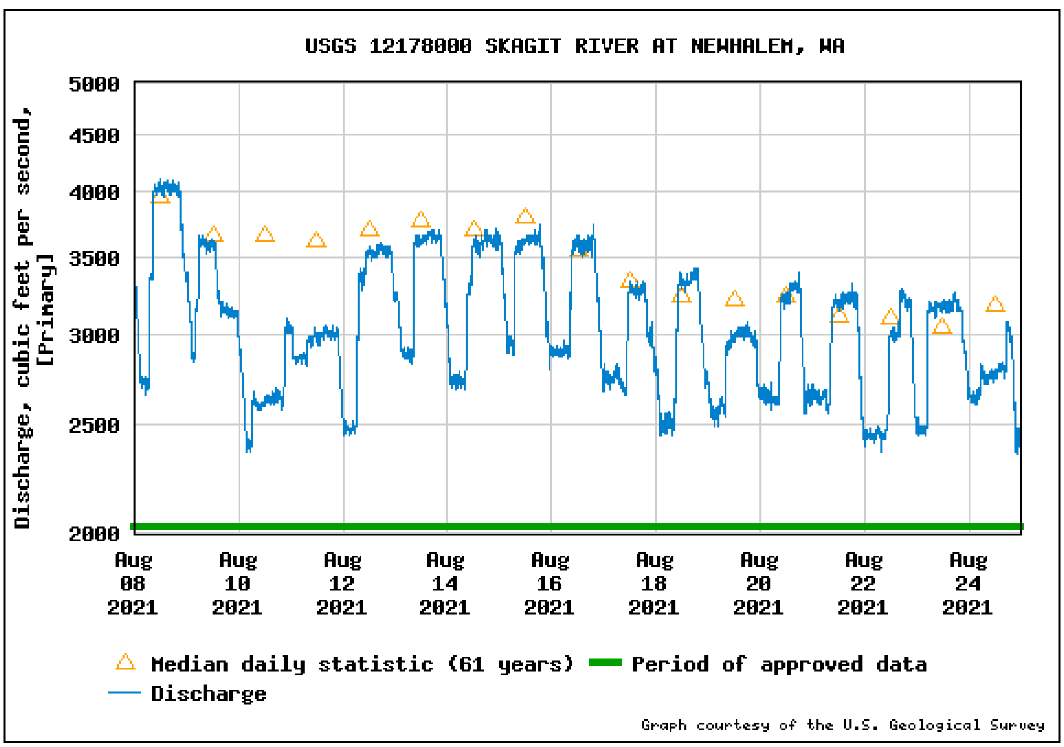


Figure 5.3-11. Skagit River discharge during BMI sampling on August 24, 2021, as recorded at USGS 12178000 Skagit River gage at Newhalem.

Laboratory identification of BMI samples is being conducted by EcoAnalysts. As described in Attachment C, samples are quantitatively subsampled by systematically removing 500 individual organisms, at a minimum, from each sample. Individual specimens are identified to the lowest practical taxonomic level, and the Lower Puget Sound benthic index of biotic integrity (B-IBI) is calculated using the fine level resolution for each sample. The final categorization of the biological integrity for each sample location is based on the Lower Puget Sound B-IBI and range from "Poor" to "Good" (Table 5.3-3).

Table 5.3-3. Skagit River B-IBI metric score.

Metric	SKAGIT 2X	SKAGIT 3X	SKAGIT 3X[1]	SKAGIT 4X	SKAGIT 5X	SKAGIT 6X	SKAGIT 7X	SAUK 1X
Total Taxa Richness	3.45	6.55	2.41	6.21	7.59	7.24	6.21	7.24
Ephemeroptera (mayfly) Richness	4.29	8.57	7.14	5.71	10.00	8.57	8.57	10.00
Plecoptera (stonefly) Richness	2.86	10.00	0.00	5.71	10.00	2.86	5.71	5.71
Trichoptera (caddisfly) Richness	3.75	3.75	0.00	2.50	3.75	8.75	8.75	10.00
Intolerant Taxa Richness	7.14	10.00	5.71	8.57	10.00	5.71	5.71	10.00
Clinger Taxa Richness	4.71	6.47	3.53	5.88	8.82	10.00	9.41	10.00
Long-lived Taxa Richness	1.25	1.25	0.00	0.00	1.25	2.50	0.00	5.00
Percent Tolerant Individuals	8.72	9.25	9.19	9.47	9.59	9.55	9.69	9.82
Percent Predator Individuals	5.30	1.40	0.00	3.78	1.75	1.64	0.55	5.42
Percent Dominant (top 3)	6.54	0.25	0.00	9.25	8.25	8.45	8.17	5.47
Final B-IBI Score	48.0	57.5	28.0	57.1	71.0	65.3	62.8	78.7
Final B-IBI Biological Condition Rating[2]	Fair	Fair	Poor	Fair	Good	Good	Good	Good

1 A duplicate sample was taken at SKAGIT3X.
2 Colors are applied to categories based on the Lower Puget Sound B-IBI Scoring, where:
Red: Very Poor (Individual metric 0-2, Final B-IBI Score 0-20).
Orange: Poor (Individual metric 2-4, Final B-IBI Score 20-40).
Yellow: Fair (Individual metric 4-6, Final B-IBI Score 40-60).
Green: Good (Individual metric 6-8, Final B-IBI Score 60-80).
Blue: Excellent (Individual metric 8-10, Final B-IBI Score 80-100).

Overall biological condition based on the B-IBI calculations are categorized as "Good" for SAUK1X, SKAGIT7X, SKAGIT6X, and SKAGIT5X sample locations. Scores are lower at the SKAGIT4X, SKAGIT2X and SKAGIT3X, which are categorized as "Fair." The IBI score for the duplicate sample from SKAGIT3X is categorized as "Poor." The score for Plecoptera richness is "Excellent" for the SKAGIT3X sample and "Poor" for the SKAGIT3X duplicate sample, likely a result of microhabitat differences, e.g., substrate or velocity, among kick-net deployments. Given the differences between SKAGIT3X and the duplicate sample, and more than adequate volume of the duplicate, a subsample was reanalyzed. Overall IBI rating for the reanalyzed duplicate sample was "Very Poor." Scores for long-lived taxa richness and percent predator individuals tend to be lower across all of the sample locations. More detail on BMI analysis is provided in Attachment C.

6.0 SUMMARY

The results of the field data collection described in this study report extend from early action data collection beginning in September 2020 (thermograph sites SKAGIT2, SKAGIT3 and SKAGIT4) through early October 2021. Based on the planned May 2023 completion date (per the RSP), data reported represent 5 of 24 months or roughly 20 percent of the total monitoring period. Therefore, conclusions would be premature at this time, but results are nonetheless informative in terms of preliminary trends and patterns, as summarized below.

6.1 Reservoir Sampling

Vertical profiles of water temperature, DO, and pH in Diablo and Gorge lakes are consistent with characterization of Project reservoirs in the PAD as oligotrophic (City Light 2020). Surface water temperatures were highest in July at DIABLO2 (24°C). TSS and turbidity are typically low at all three Project reservoirs, with values near or below laboratory detection limits.

With the exception of July, FC levels measured in Ross and Diablo lakes from June through September were low and below the Ecology criterion of 200 CFU/100 mL. A sample collected in July at the Ross Lake Resort, however, measured 600 CFU/100 mL, three times the Ecology criterion.

TDG monitoring in Gorge Lake suggests that Diablo Powerhouse may at times increase TDG levels in upper Gorge Lake, near the Diablo Powerhouse, but TDG levels dissipate prior to reaching Gorge Dam. Discussion with City Light engineering staff indicates that elevated TDG observed in September 2021 is likely due to an air admission system, designed to improve operating efficiency at low generation. Further evaluation will be conducted during the 2022 field season.

6.2 Gorge Bypass Reach and Gorge Powerhouse

Water temperature, DO, TDG, and turbidity are continuously monitored at three sites in the Gorge bypass reach. Temperatures at BYPASS1 near Gorge Dam are warmer than other sites in the Bypass, likely because of greater exposure to solar radiation and lack of flow (excluding periods of spill). Temperatures downstream at PHOUSE1, originating at depth from Gorge Lake, are cooler and less variable than those measured in the Gorge bypass reach.

Average DO concentrations over the reporting period were highest at Gorge Powerhouse (PHOUSE1; 11.6 mg/L) and lowest at BYPASS2 (9.9 mg/L). DO at PHOUSE1 is generally higher (and temperatures lower); values remained above 9.5 mg/L, and concentrations demonstrated comparatively little variability. BYPASS2 was much more variable, but given comparatively late instrument deployment, data cannot be directly compared to other sites for the majority of the monitoring period.

TDG remained near 100 percent saturation most of the time at Gorge bypass reach sites, and 107 percent at PHOUSE1. Values at BYPASS1 reached 124 percent during the approximately 7,300 cfs spill event at Gorge Dam in late June. Preliminary analysis of spill and TDG during this period suggests that flows in excess of 4,000 cfs may increase TDG to levels greater than 110 percent.

Turbidity at Gorge bypass reach and Powerhouse sites is generally low, averaging less than 1 NTU. Higher values were observed at BYPASS1 and PHOUSE1 sites (greater than 125 NTUs), although these were of short duration and may have been due to debris blocking the turbidity sensor.

6.3 Skagit River Downstream of Gorge Powerhouse

6.3.1 Water Temperatures

With few exceptions, water temperatures recorded at the three upstream sites in the Skagit River downstream of Gorge Powerhouse (SKAGIT2, 3, and 4 [PRM 91.6, 85.9, and 75.6]) remained less than the summer core salmonid criterion of 16°C (7-DADMax) from late September 2020 through February 2021. Water temperatures at the four downstream sites are warmer; temperatures among these sites were nearly identical until mid-summer 2021. The highest 7DADMax among Skagit River sites was measured at SKAGIT6 (PRM 60.8) in late July (17.2 °C). 7DADMax temperatures at other Skagit River sites were less than 16°C, while the Sauk River at 7DADMax of 16.4°C was warmer than all Skagit River sites on September 8, including temperatures at Skagit site PRM 60.8.

6.3.2 Benthic Macroinvertebrates

Overall biological condition based on the B-IBI calculations are categorized as “Good” for SAUK1X, SKAGIT 7X, 6X, and 5X sample locations. Scores are lower at the SKAGIT 4X, 3X, and 2X locations, which are categorized as “Fair.” The IBI score for the duplicate sample from SKAGIT 3X is categorized as “Poor.” Results of BMI analyses are presented in Attachment C. It should be recognized that these results are particularly limited, reflecting only one sampling date among the many planned over the course of the FERC-approved study. Thus, no conclusions should be drawn from these preliminary data.

6.4 Status of June 9, 2021 Notice

The June 9, 2021 Notice included five items of discussion related to the implementation of the FA-01a WQ Monitoring Study. The status of each is summarized in Table 6.4-1.

Table 6.4-1. Status of WQ Monitoring Study modifications identified in the June 9, 2021 Notice.

Study Modifications Identified in the June 9, 2021 Notice	Status
Seattle City Light (“SCL”) will modify FA-01 to include development of a CE-QUAL-W2 model to evaluate temperature impacts from the Project on aquatic resources. SCL will seek and incorporate the input of Scott Wells and the Oregon and Washington USGS Water Science Centers in the development of the CE-QUAL-W2 model. The model will be developed and implemented within the two-year study timeframe. The CE-QUAL-W2 model will be used to evaluate, among other things, the impact of cold-water releases from Ross reservoir on fishery resources. Action item: SCL will schedule one or more workshops with the LPs, as needed, to collaborative develop this model.	All material related to the CE-QUAL-W2 model is housed in the accompanying FA-01b Water Quality Model Development Study Interim Report (City Light 2022a). Dr. Scott Wells is under contract to serve as an additional technical expert on CE-QUAL-W2 development. The CE-QUAL-W2 temperature model is expected to be developed and calibrated within the two-year timeframe, pending sufficient availability of input data. The model may be used to evaluate, among other things,

Study Modifications Identified in the June 9, 2021 Notice	Status
	the impact of cold-water releases from Ross Lake on fisheries resources. City Light is actively discussing CE-QUAL-W2 model development and calibration with LPs in a series of Water Quality Resource Work Group meetings.
SCL will provide a QAPP that meets Ecology's standards and judge existing data based on the QAPP. If the existing data cannot be confirmed, the data will be reviewed on a case-by-case basis in collaboration with the LPs. Action item: SCL to provide provisional data summary by the end of July 2021 to identify gaps and ensure those gaps are addressed through data collection in the study time frame, followed by a full summary in the Initial Study Report. Action item: The existing data will be reviewed to determine data gaps that need to be filled through the implementation of the study plan.	The QAPP, which is based on Ecology's Standard Operating Procedures, was included as an attachment to the FA-01a Water Quality Monitoring Study RSP. City Light submitted the provisional data summary to LPs on September 3, 2021. An updated water quality data summary and analysis is attached to this interim report.
SCL will modify FA-01 to clarify that SCL will evaluate measures of biological productivity including primary producers and will collaborate with the LPs to develop a sampling study. In addition, SCL will execute an expanded benthic macroinvertebrate sampling program to include the Project reservoirs, Skagit River to the estuary (through reference reach sampling mutually agreed to by SCL and the LPs), varying seasons, varying habitat types, and invertebrate drift. The sampling program will be developed in collaboration with the LPs and informed by NPS Appendix A.	City Light has worked with LPs in the Water Quality Resource Work Group to (1) develop a sampling plan that allows for the modeling of a range of water quality parameters, including nutrient dynamics to address questions of productivity, and (2) arrive at a sampling plan for BMI and invertebrate drift, in the Project reservoirs, tributaries to the reservoirs in the reservoirs' varial zones, and the Skagit River downstream of the Project, including a downstream expansion of sampling sites. As of the filing of this ISR, the scope of the WQ Monitoring Study has been significantly expanded in consultation with LPs to include additional data collection to support development and calibration of the CE-QUAL-W2 model and BMI/invertebrate drift data.
SCL will modify the study plan to conduct an initial assessment of nitrogen and phosphorous in the Project Reservoirs, representative major reservoir tributaries, and Skagit River to the estuary (through mutually agreed sampling program including reference reaches). An assessment for nutrient data collection will be developed in coordination with tributary habitat sampling, water quality modeling, and the food web study. The sampling design will be developed in collaboration with the LPs. SCL will also modify the study plan to initiate modelling of nutrient and productivity components after 1) the CE-Qual-W2 model for temperature is developed, and 2) data sources and years available are evaluated against the objectives of the LPs. Concurrently SCL would continue to collect proposed water quality parameter data and develop the CE-Qual-W2 framework and integration with Operations model and other modelling tools in order to perform a sensitivity analysis to determine the accuracy and sensitivity of the tool (and data needs) for illustrating nutrient dynamics under alternative operational scenarios. SCL anticipates that this effort	City Light is currently discussing CE-QUAL-W2 model development and calibration in a series of Water Quality Resource Work Group meetings. One outcome of these discussions is the sampling plan being implemented to support model development that allows for the modeling of nutrient dynamics. A sampling plan that addresses information needs identified through the Water Quality Resource Work Group meetings will be provided to LPs in March 2022 and discussed at the April 2022 Water Quality Work Group meeting.

Study Modifications Identified in the June 9, 2021 Notice	Status
will be initiated during the second year of study and completed prior to the filing of the Updated Study Report.	
SCL will convene a workshop with concerned LPs to discuss parameters, frequency, monitoring locations, and temporal overlap with existing data. This workshop will occur in August 2021 after the data gaps in the QA/QC analysis are presented by SCL. The workshop will also identify the parameters to be modeled by CE-QUAL-W2, potential gaps in the model, and the approach to filling the gaps. Where the model will not adequately describe the effects of Project operation scenarios on water quality parameters, empirical data collection requirements will be developed by SCL in collaboration with the LPs and informed by NPS Appendix A.	City Light is currently discussing CE-QUAL-W2 model development and calibration in Water Quality Resource Work Group meetings. As of the filing of this ISR, the scope of the WQ Monitoring Study has been significantly expanded in consultation with LPs, to include additional data to support development and calibration of the CE-QUAL-W2 model and BMI/invertebrate drift data. Existing data, as well as sampling already identified in the RSP, were factored into decision-making about what parameters should be sampled and the general locations of sampling. Refinements are underway to select final monitoring locations based on field reconnaissance.

7.0 VARIANCES FROM FERC-APPROVED STUDY PLAN AND PROPOSED MODIFICATIONS

7.1 Proposed Modifications

As discussed in Section 4.4 of this study report, monitoring under the WQ Monitoring Study now includes opportunistic monitoring of TDG downstream of Gorge Powerhouse during spill events to evaluate the downstream extent of potentially elevated levels of TDG and an additional transect in Diablo Lake to measure turbidity and TSS during drawdown conditions. Additional monitoring also includes modifications to the WQ Monitoring Study made under the June 9, 2021 Notice.

7.2 Variances from Revised Study Plan

Per the RSP, City Light planned to collect monthly water quality grab samples (DO, pH, turbidity, and TSS) in the Skagit River upstream of Ross Lake beginning in June 2021. However, travel across the U.S.-Canada border was restricted beginning in March 2020 due to Covid-19. City Light is instead relying on data being collected by the USGS at the Skagit River inflow. USGS is measuring all parameters identified by City Light in the RSP except TSS (City Light is measuring TSS on the U.S. side of the international border during the drawdown cycle, per Table 4.4-1). However, in addition to DO, pH, and turbidity, which are measured continuously, USGS is also continuously measuring SC and fluorescent dissolved organic matter (fDOM) (data collected by USGS at this location from August 2019 – November 2020 are presented in Attachment D).

Per the April 2021 RSP, turbidity at Project reservoirs was analyzed by the analytical laboratory using Standard Method 2130 with Formazin polymer used as the reference turbidity standard. On occasion, turbidity was also measured in Ross Lake using *in situ* instrumentation. Results obtained from both methods have been reported in this Study Report.

Ross Lake turbidity and TSS transects are identified as 100-m long transects in the RSP. These transects were modified to be 400-m long in order to capture the extent of potentially erosive substrates at the sampling sites.

As required by FERC's SPD, turbidity and TSS samples are being collected during drawdown at the mouths of 11 tributaries to Ross Lake. FERC's SPD modifies sampling identified in the RSP at Big Beaver and Ruby Creeks. The RSP prescribed sampling at BBEAVER1 and RUBY1 in fall, winter, and spring of 2021-2022 and 2022-2023; the SPD instead identifies sampling at TRIB8 (Big Beaver Creek) and TRIB11 (Ruby Creek) sampled twice between fall and spring of 2021-2022 and 2022-2023. Two of the tributary sites, TRIB6 and TRIB7, were not sampled during the fall 2021 event. The reservoir elevation at the time of sampling (1,591-1,592 feet NAVD 88) did not expose any appreciable vadose zone or erosive substrates at TRIB6 (Devil's Creek). Erosive substrates may be exposed at other elevations, and samples may be collected during other drawdown sampling events. The existing ROSS6 transect, to be sampled three times per year, captures conditions at the mouth of TRIB7 (May Creek), and this site has been removed from the sampling protocol.

FC sampling was conducted as required per the RSP. In addition, *E. coli* samples were collected at Ross Lake Resort (ROSS8) during the August event and at all FC sites during the September event. *E. coli* samples were added for the latter two events because of a change in Washington

State water quality standards to the use of *E. coli* rather than FC for water contact recreation bacterial criteria that came into effect on January 1, 2021 [WAC 173-201A-200(2)(b)]. City Light communicated the addition of *E.coli* samples to Ecology on September 2, 2021 (Fisher 2021).

Covid-19 and related supply-chain impacts on equipment availability delayed water quality monitoring activities at several sites in the study area. The Hydrolab datasondes needed for long-term *in situ* monitoring at GORGE3, GORGE4, and BYPASS2 were delayed at the manufacturer. Consequently, the start of the monitoring program at these sites was moved from June 2021 to August 2, 2021 (BYPASS2) and September 9, 2021 (GORGE3 and GORGE4). Equipment availability issues also delayed pH monitoring at PHOUSE1. The MS5 datasonde previously deployed at the PHOUSE1 location was not capable of sampling additional parameters, and a larger DS5 datasonde was not available from the manufacturer until July 2021. The DS5 datasonde was deployed at PHOUSE1 on July 21, 2021.

BMI were sampled at all downstream sites (SKAGIT2-7X, SAUK1X) in August 2021. The RSP indicates that BMI sampling would occur in July and September. Sampling in July was not possible due to the high flows previously discussed in Section 5.2 of this study report. These unusually high flows would have forced field crews to sample in inundated shoreline habitat that would not have been occupied by BMI at lower, more stable flows, thereby resulting in misrepresentation of the BMI community. Suitable conditions for BMI sampling were not present until late August. Similarly, the September BMI sampling event was not possible due to early onset of fall rains and associated high flows that inundated the previously sampled sites. Suitable conditions for BMI sampling were not again present through October 15, 2021, the end of the sampling season identified in Ecology SOP EAP073 (Ecology 2019a).

Per the RSP, SAUK1 was to be deployed at River Mile 2.8. River conditions at this location are braided with variable shorelines. The SAUK1 thermograph was therefore deployed at River Mile 5.4 where conditions are stable and consistently wetted.

8.0 REFERENCES

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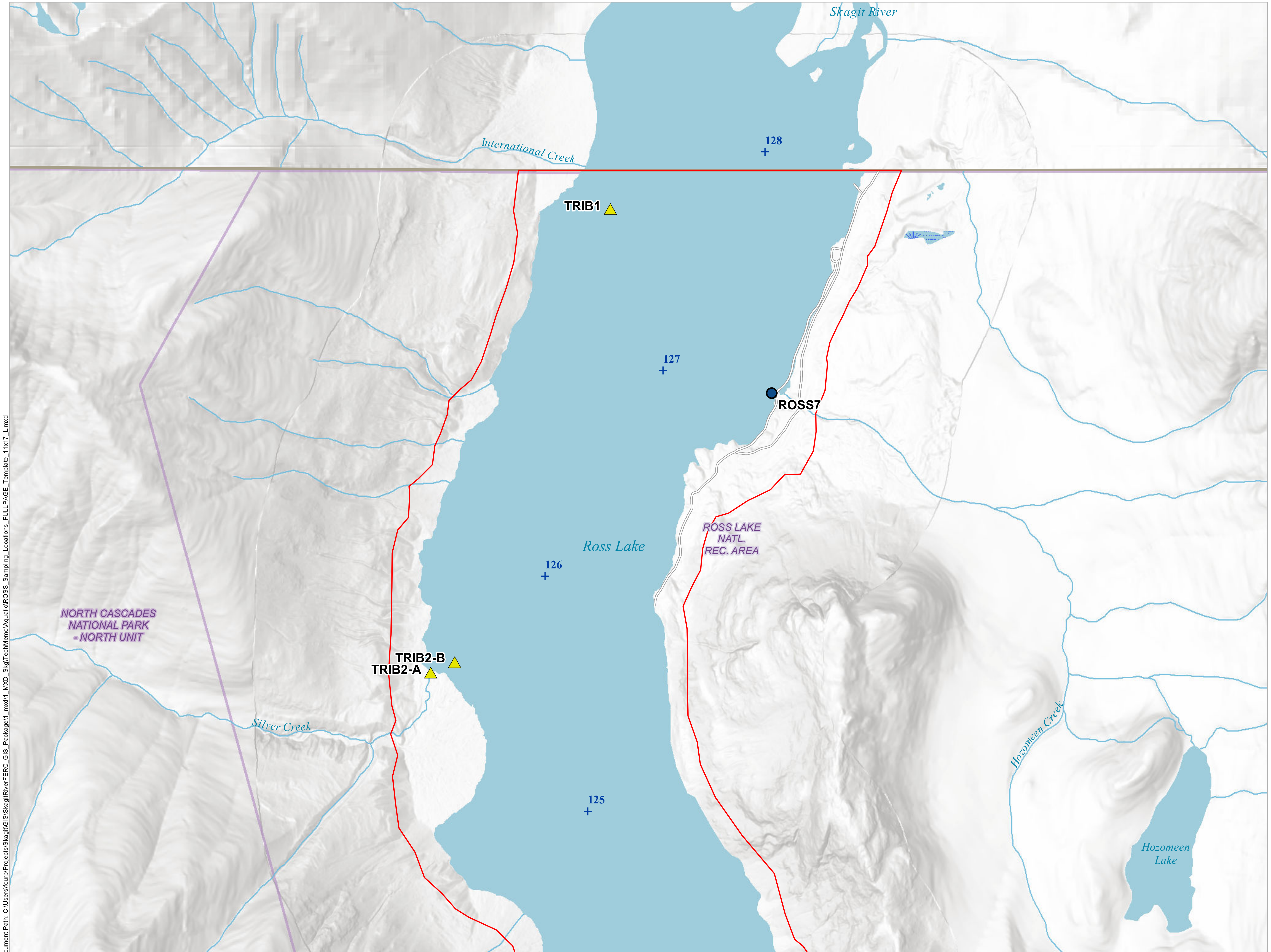
WATER QUALITY MONITORING STUDY INTERIM REPORT

ATTACHMENT A

WATER QUALITY SAMPLING LOCATIONS MAPBOOK



FA-01 WQ MONITORING STUDY
FIGURE 1
ROSS LAKE HOZOMEEN (SKAGIT, HOZOMEEN, SILVER CREEKS)

FERC Project Boundary
Project River Miles (PRM)
National Park / National Recreation Area Boundary
Fecal Coliform & E. coli, Surface
Tributary TSS & Turbidity, Surface

0 1,600 3,200 Feet

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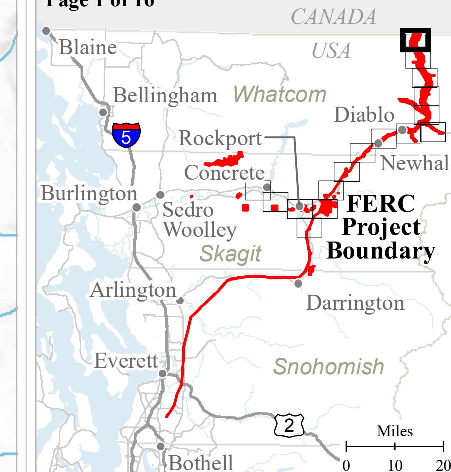

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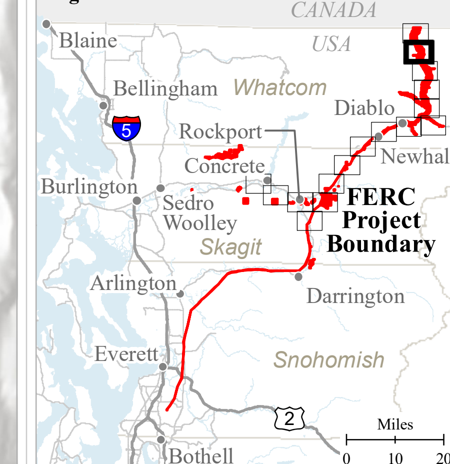
FA-01 WQ MONITORING STUDY
FIGURE 2
ROSS LAKE DESOLATION (LITTLE BEAVER, ARCTIC CREEKS)

FERC Project Boundary
Project River Miles (PRM)
National Park / National Recreation Area Boundary
Fecal Coliform & E. coli, Surface
Monthly TSS & Turbidity, 1m and 5m
Tributary TSS & Turbidity, Surface
TSS & Turbidity during drawdown, Surface Grab

N
0 1,600 3,200 Feet



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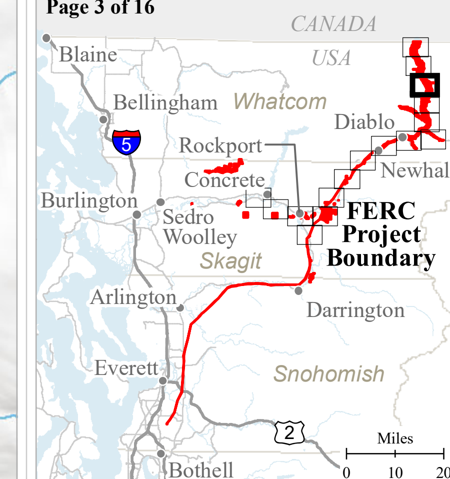
SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)

FA-01 WQ MONITORING STUDY
FIGURE 3
ROSS LAKE DESOLATION (NO NAME, LIGHTNING) / PUMPKIN (SKYMO, DRY CREEKS)

- FERC Project Boundary
- Project River Miles (PRM)
- National Park / National Recreation Area Boundary
- Fecal Coliform & E. coli, Surface
- Monthly TSS & Turbidity, 1m and 5m
- Tributary TSS & Turbidity, Surface
- TSS & Turbidity during drawdown, Surface Grab

N

0 1,600 3,200 Feet



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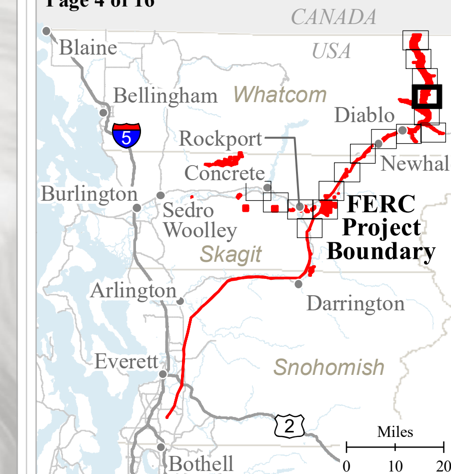
FA-01 WQ MONITORING STUDY
FIGURE 4
ROSS LAKE PUMPKIN (DEVILS, MAY CREEKS)

- FERC Project Boundary
- Project River Miles (PRM)
- National Park / National Recreation Area Boundary
- Monthly TSS & Turbidity, 1m and 5m
- Tributary TSS & Turbidity, Surface
- TSS & Turbidity during drawdown, Surface Grab

N

0 1,600 3,200 Feet



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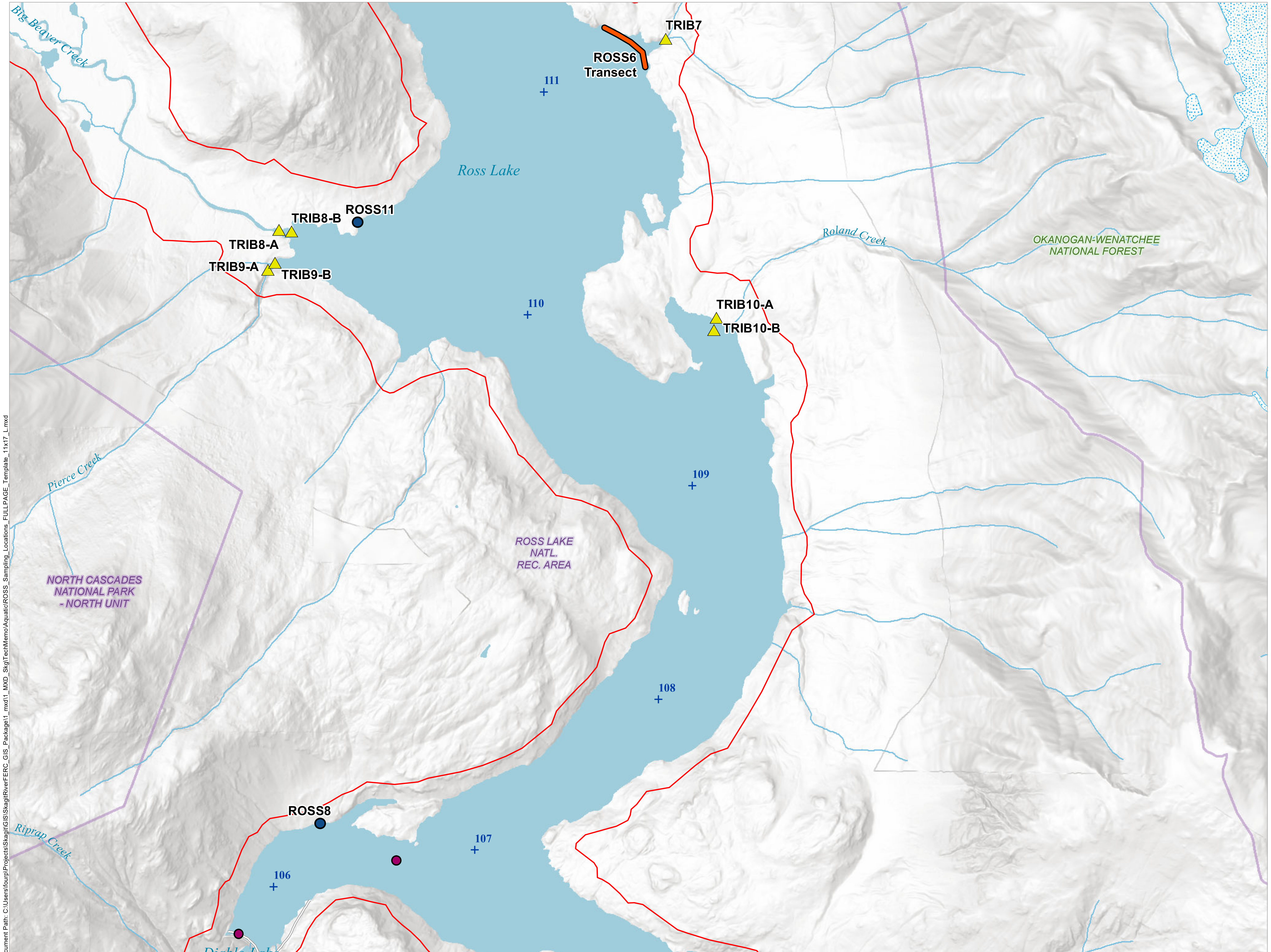

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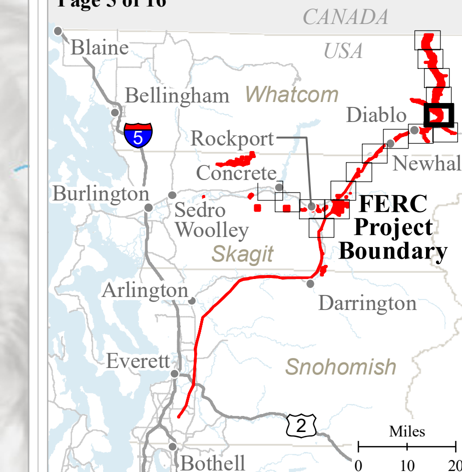
FA-01 WQ MONITORING STUDY
FIGURE 5
ROSS LAKE PUMPKIN (PIERCE, ROLAND, BIG BEAVER CREEKS)

- FERC Project Boundary
- Project River Miles (PRM)
- National Park / National Recreation Area Boundary
- Fecal Coliform & E. coli, Surface
- Tributary TSS & Turbidity, Surface
- Thermistor (Acoustic Study)
- TSS & Turbidity during drawdown, Surface Grab

0 1,600 3,200 Feet



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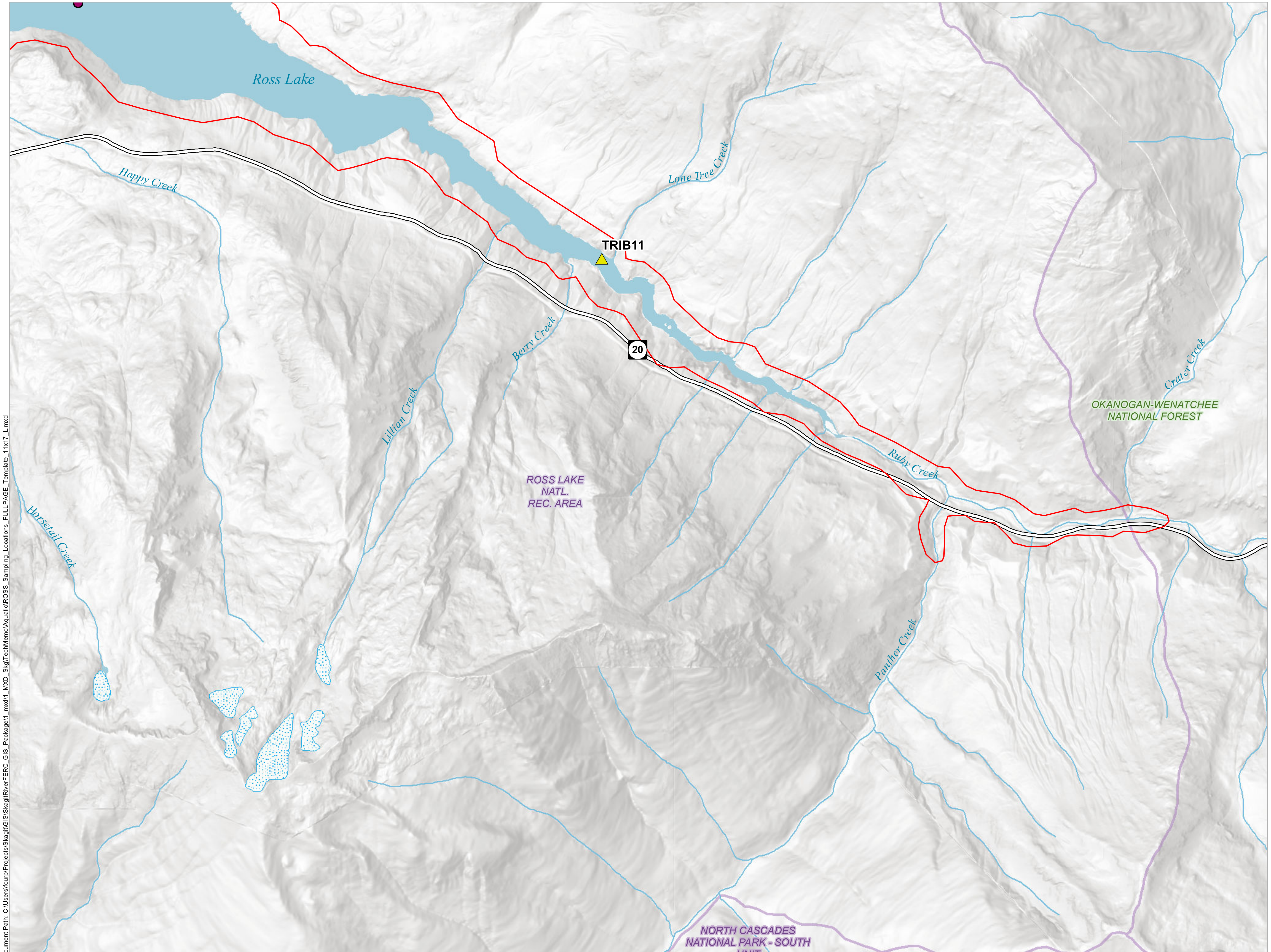
FA-01 WQ MONITORING STUDY
FIGURE 6
ROSS LAKE RUBY (RUBY CREEK)



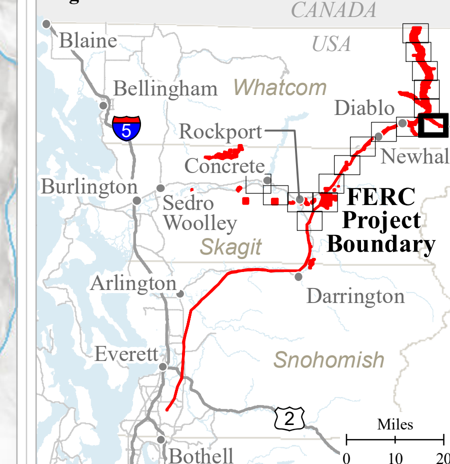
FERC Project Boundary

National Park / National Recreation Area Boundary

Tributary TSS & Turbidity, Surface

Thermistor (Acoustic Study)

0 1,600 3,200 Feet



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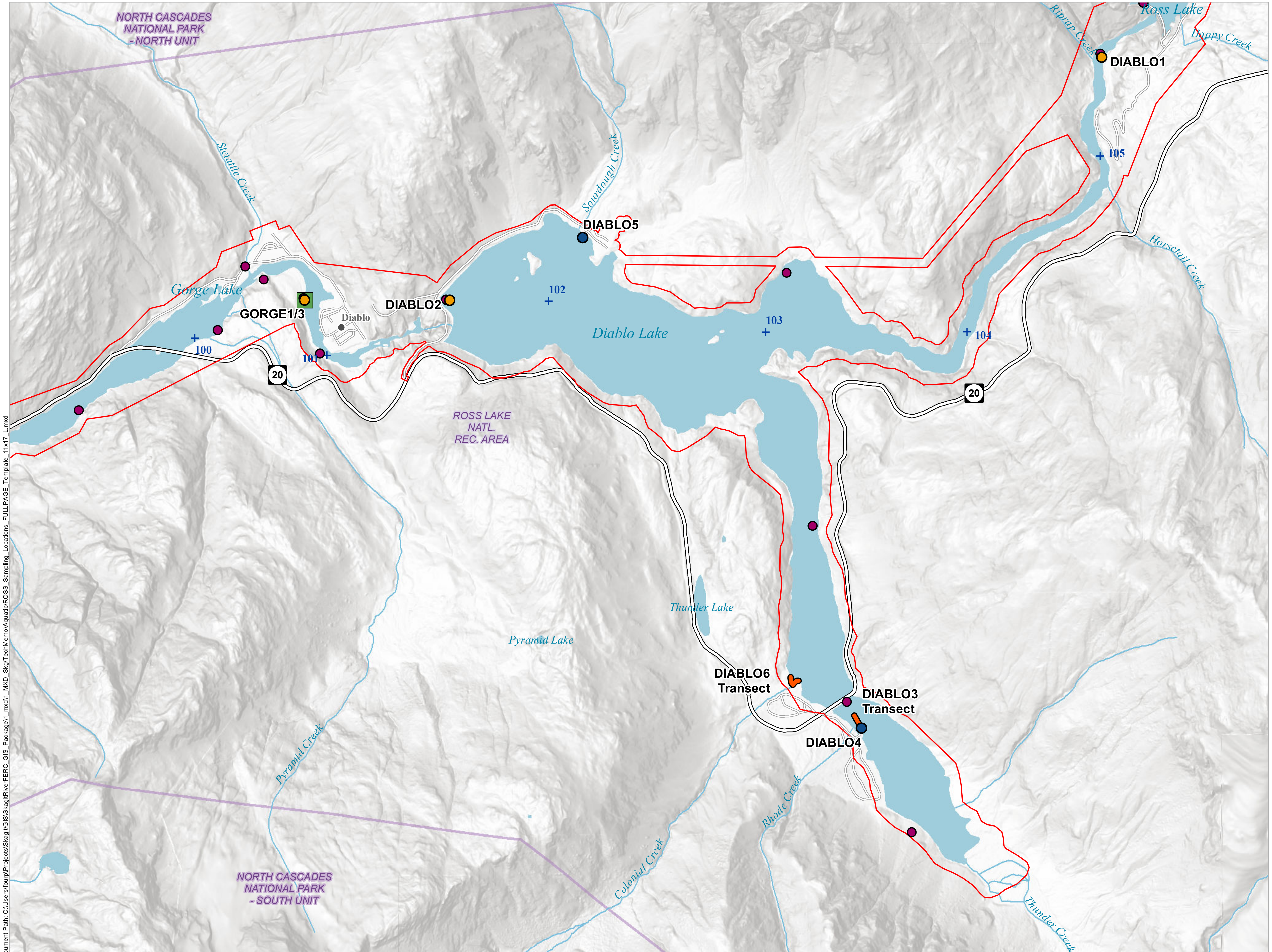


FA-01 WQ MONITORING STUDY
FIGURE 7
DIABLO AND UPPER GORGE LAKES (THUNDER, COLONIAL, STETATTLE CREEKS)

FERC Project Boundary

Project River Miles (PRM)

National Park / National Recreation Area Boundary

Fecal Coliform & E. coli, Surface

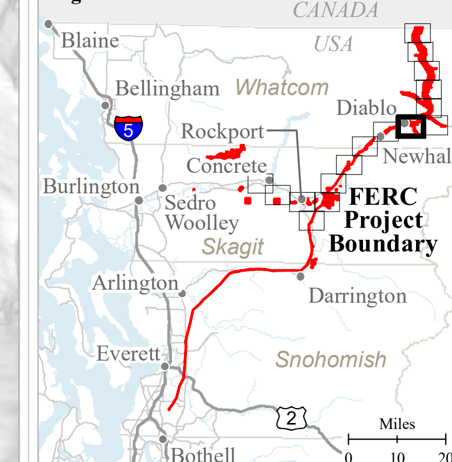
Monthly TSS & Turbidity, 1m and 5m, Vertical Profile (Temp, DO, pH)

Thermistor (Acoustic Study)

Continuous Monitoring (TDG)

TSS & Turbidity during drawdown, Surface Grab

0 1,600 3,200 Feet



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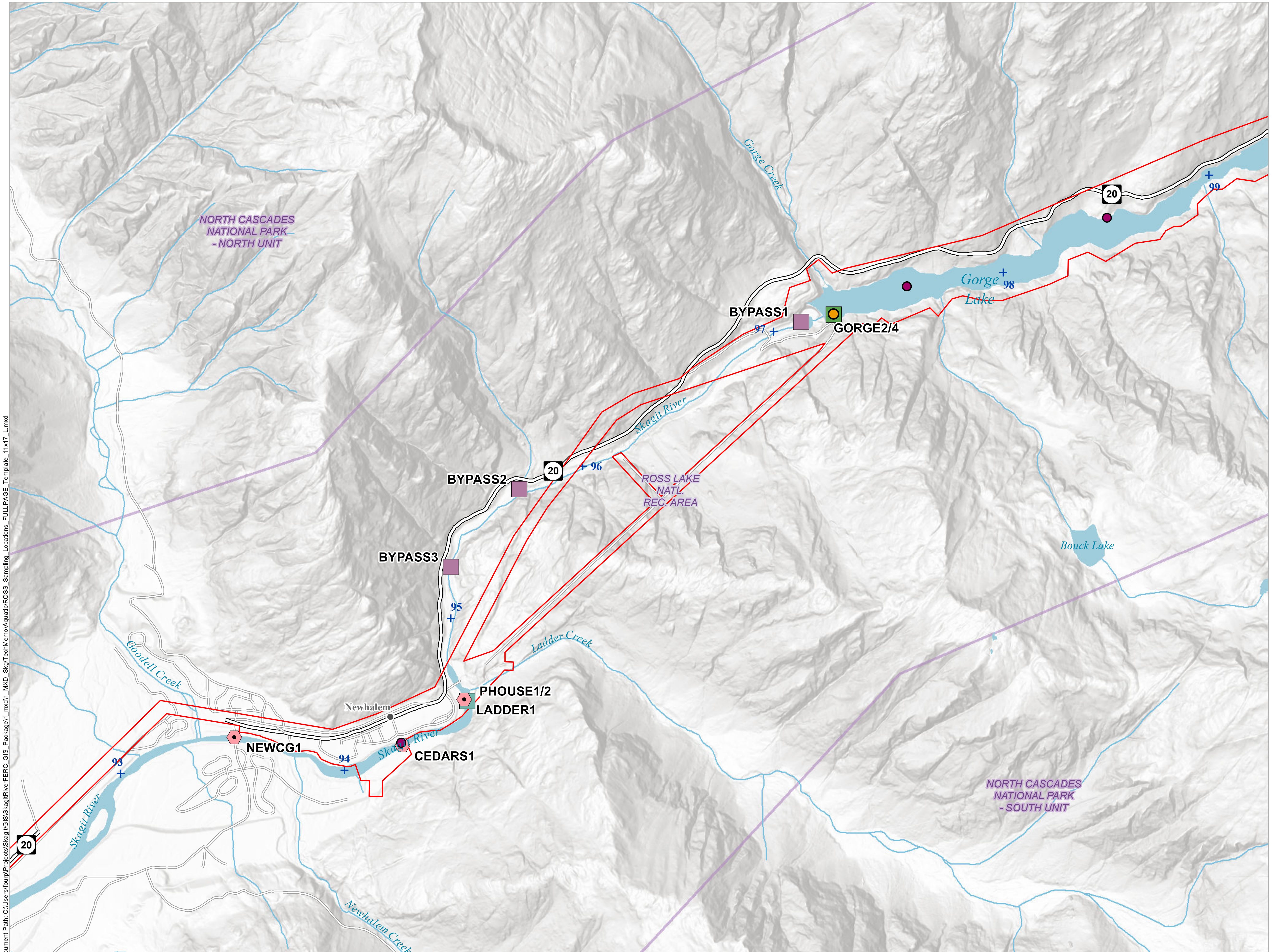
FA-01 WQ MONITORING STUDY
FIGURE 8
GORGE LAKE AND BYPASS REACH TO NEWHALEM



FERC Project Boundary

Project River Miles (PRM)

National Park / National Recreation Area Boundary

Monthly TSS & Turbidity, 1m and 5m, Vertical Profile (Temp, DO, pH)

Thermistor (Acoustic Study)

Continuous Monitoring (TDG)

Continuous Monitoring (Temp, DO, TDG, Turb)

Continuous Monitoring (Temp, DO, TDG, Turb, pH)

Opportunistic TDG Monitoring During Spill

N

0 1,600 3,200 Feet

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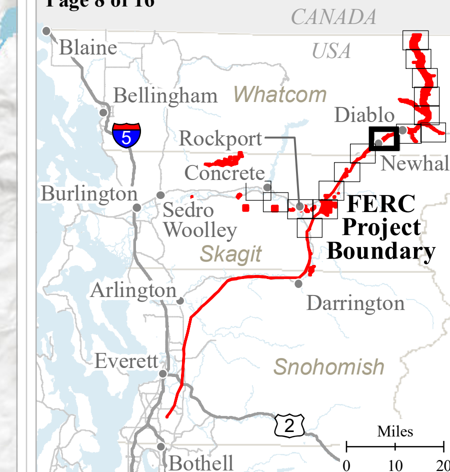

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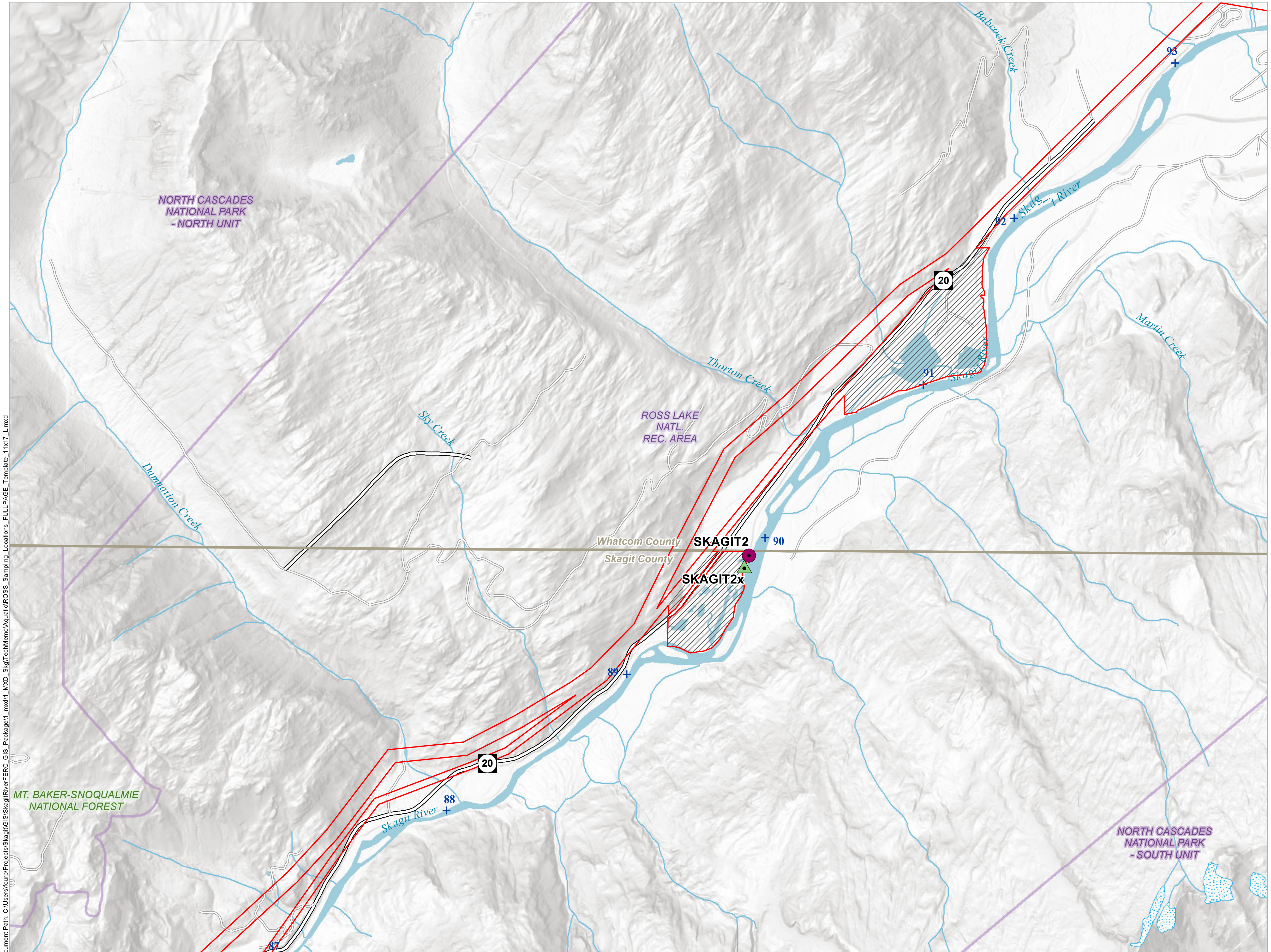
FA-01 WQ MONITORING STUDY
FIGURE 9
SKAGIT RIVER - DAMNATION



FERC Project Boundary
Mitigation Parcel
Project River Miles (PRM)
National Park / National Recreation Area Boundary
BMI Sampling
Thermistor (RSP)

N

0 1,600 3,200 Feet

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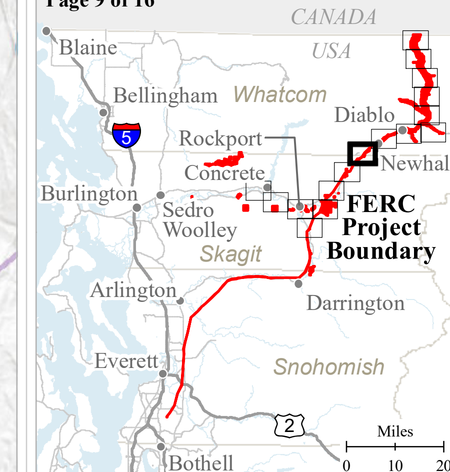

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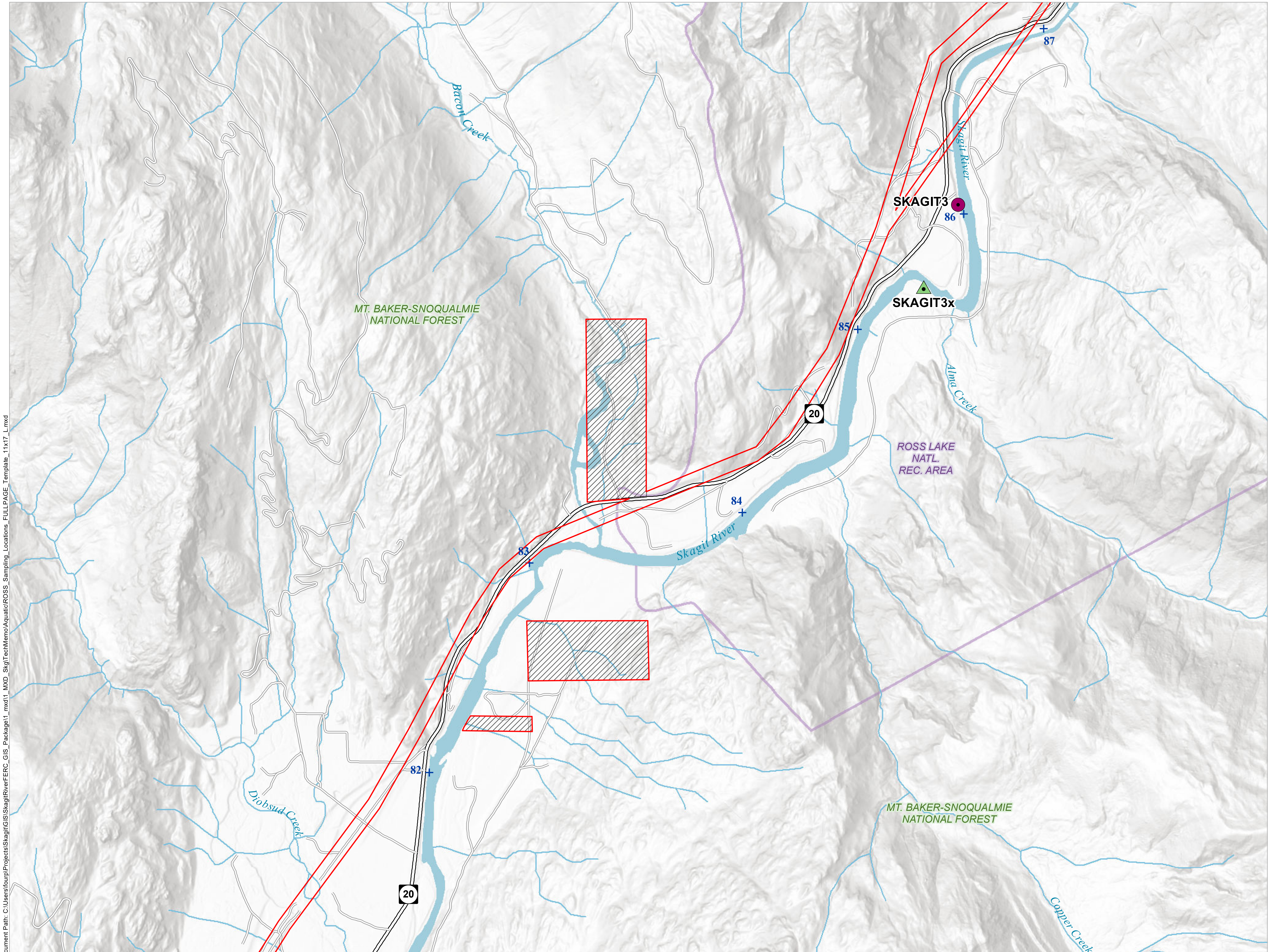
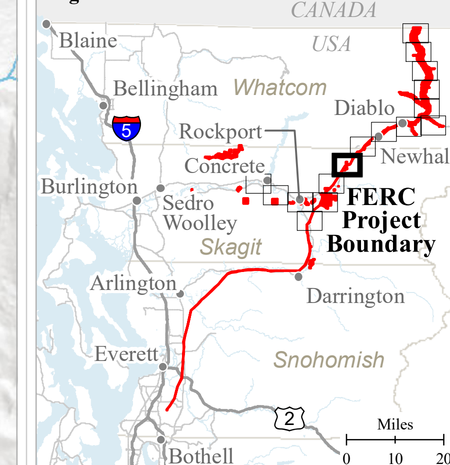


FA-01 WQ MONITORING STUDY
FIGURE 10
SKAGIT RIVER - BACON

FERC Project Boundary
Mitigation Parcel
Project River Miles (PRM)
National Park / National Recreation Area Boundary
BMI Sampling
Thermistor (RSP)

0 1,600 3,200 Feet



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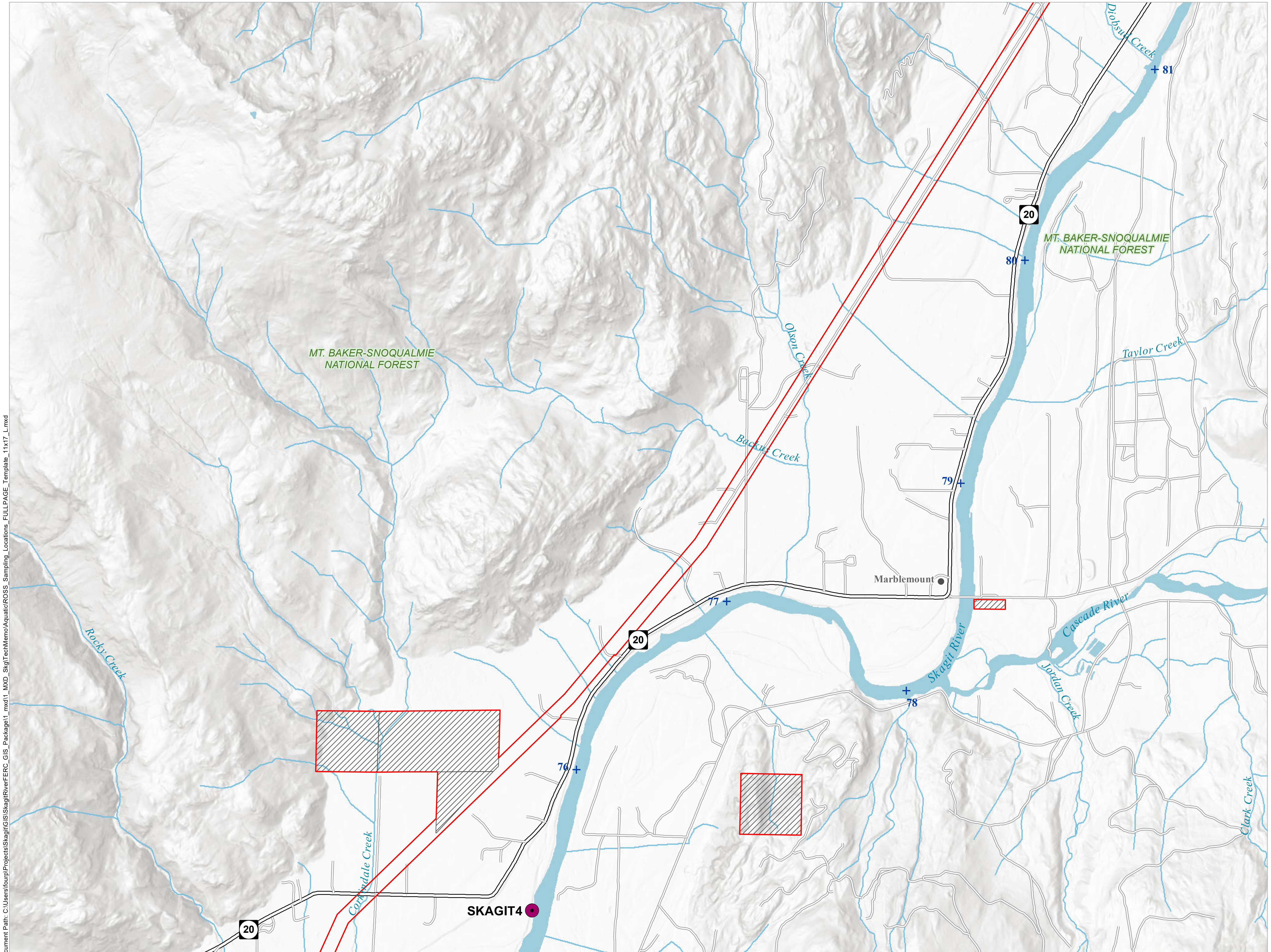
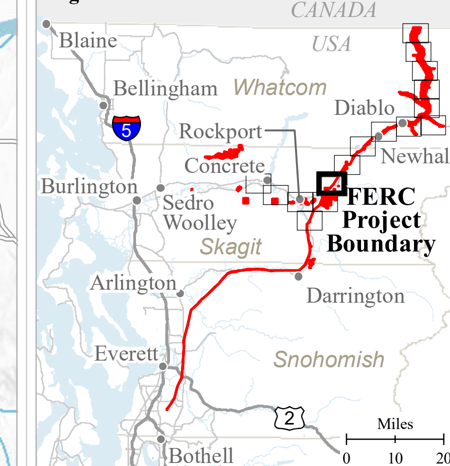
FA-01 WQ MONITORING STUDY
FIGURE 11
SKAGIT RIVER - CASCADE



FERC Project Boundary
Mitigation Parcel
Project River Miles (PRM)
Thermistor (RSP)

0 1,600 3,200 Feet



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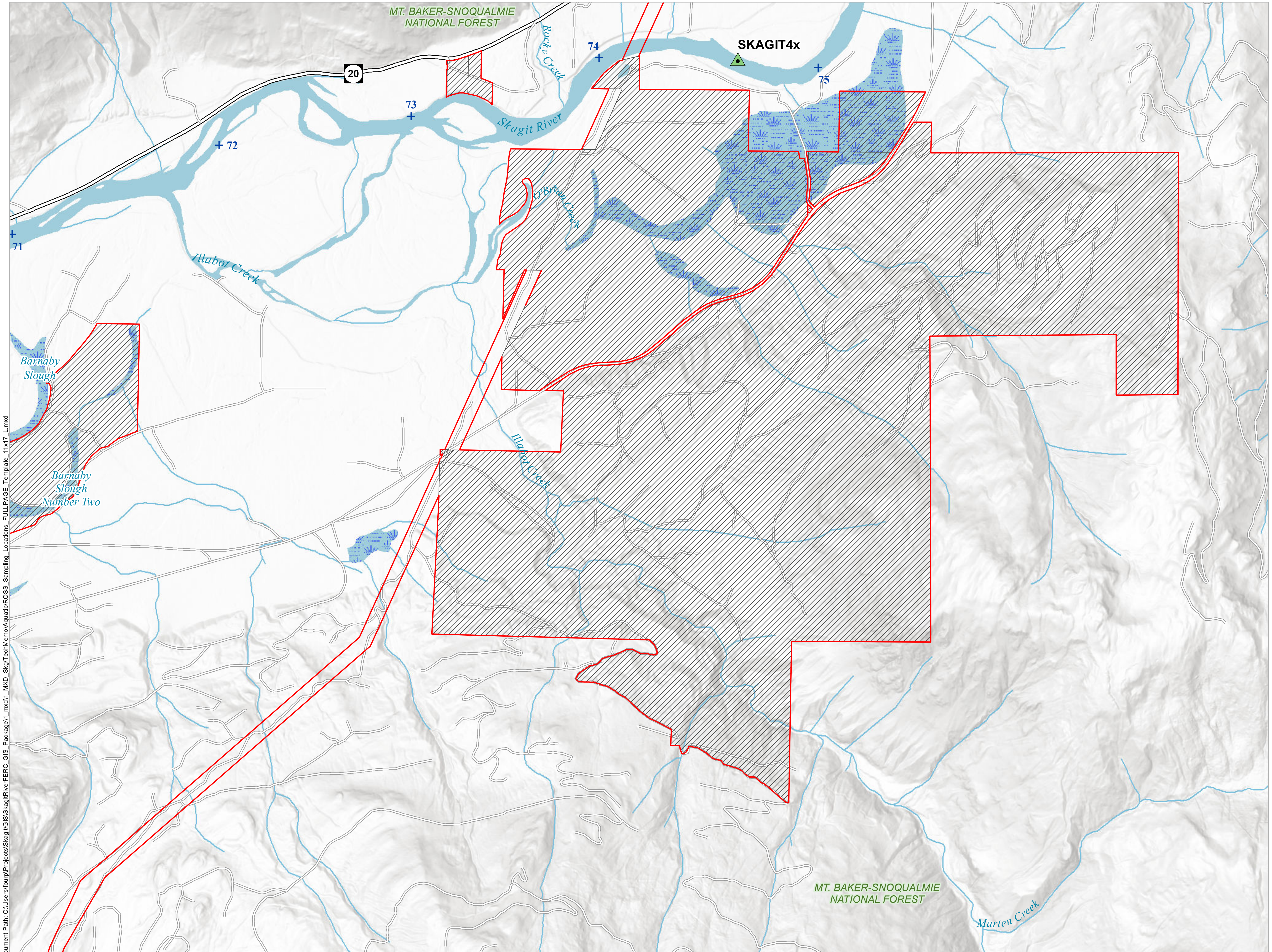
FA-01 WQ MONITORING STUDY
FIGURE 12
SKAGIT RIVER - BARNABY

- FERC Project Boundary
- Mitigation Parcel
- + Project River Miles (PRM)
- BMI Sampling



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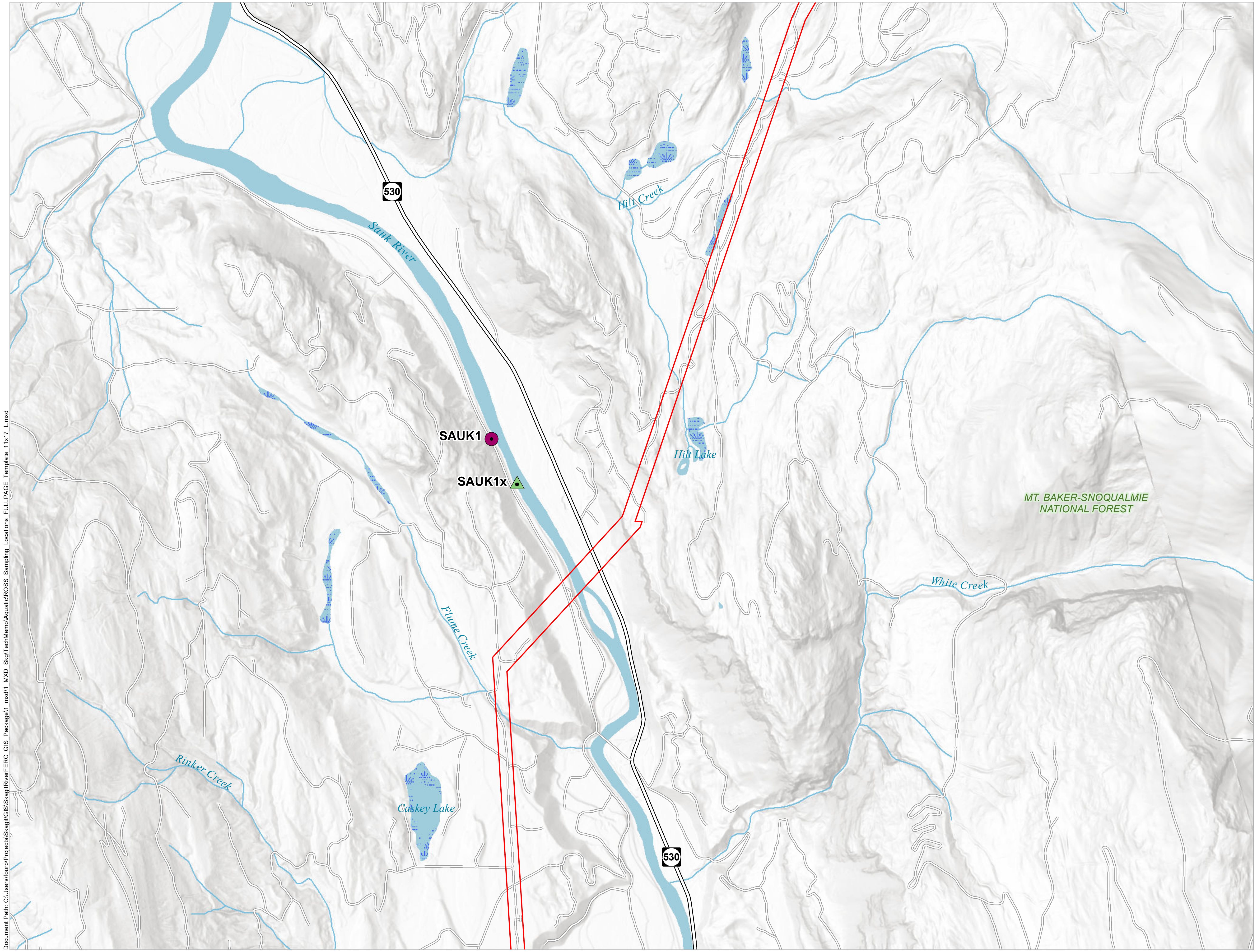
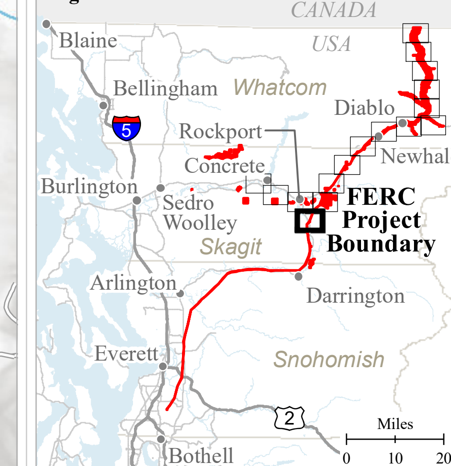


FA-01 WQ MONITORING STUDY
FIGURE 13
SAUK RIVER

FERC Project Boundary
BMI Sampling
Thermistor (RSP)

0 1,600 3,200 Feet



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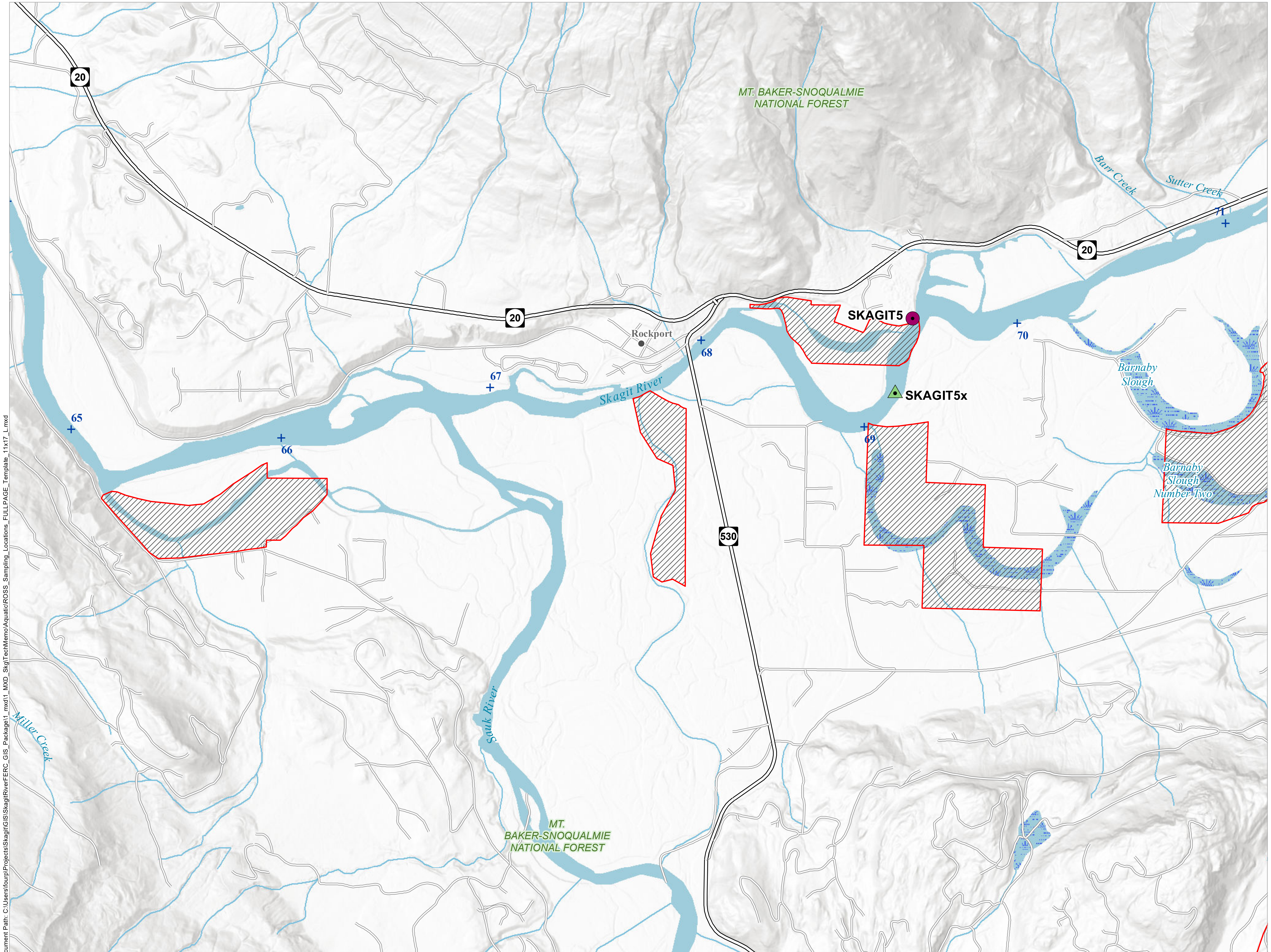
FA-01 WQ MONITORING STUDY
FIGURE 14
SKAGIT RIVER - SAUK ALLUVIAL FAN



FERC Project Boundary
Mitigation Parcel
Project River Miles (PRM)
BMI Sampling
Thermistor (RSP)

0 1,600 3,200 Feet

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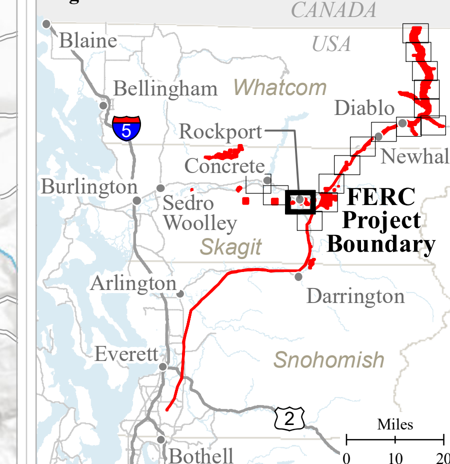

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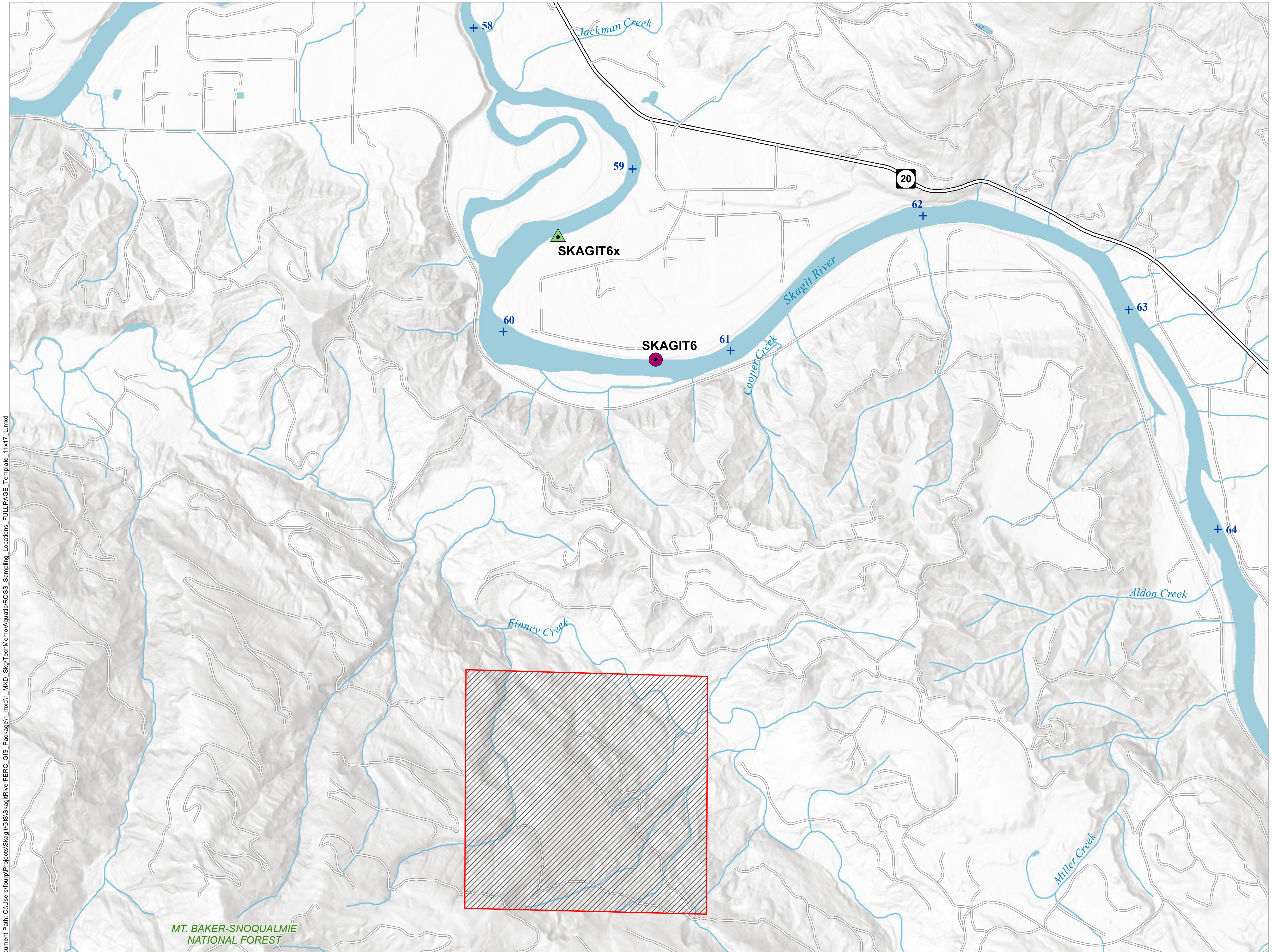
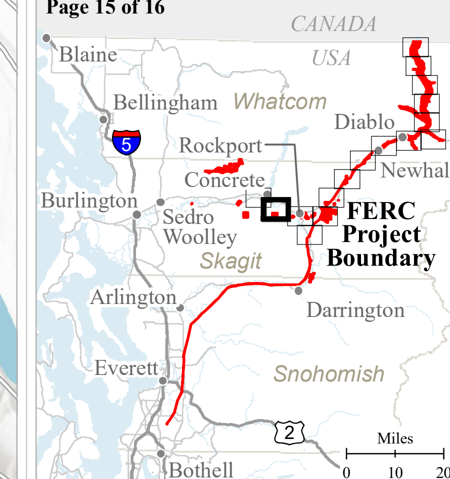
FA-01 WQ MONITORING STUDY
FIGURE 15
SKAGIT RIVER- JACKMAN



- FERC Project Boundary
- Mitigation Parcel
- Project River Miles (PRM)
- BMI Sampling
- Thermistor (RSP)

N

0 1,600 3,200 Feet



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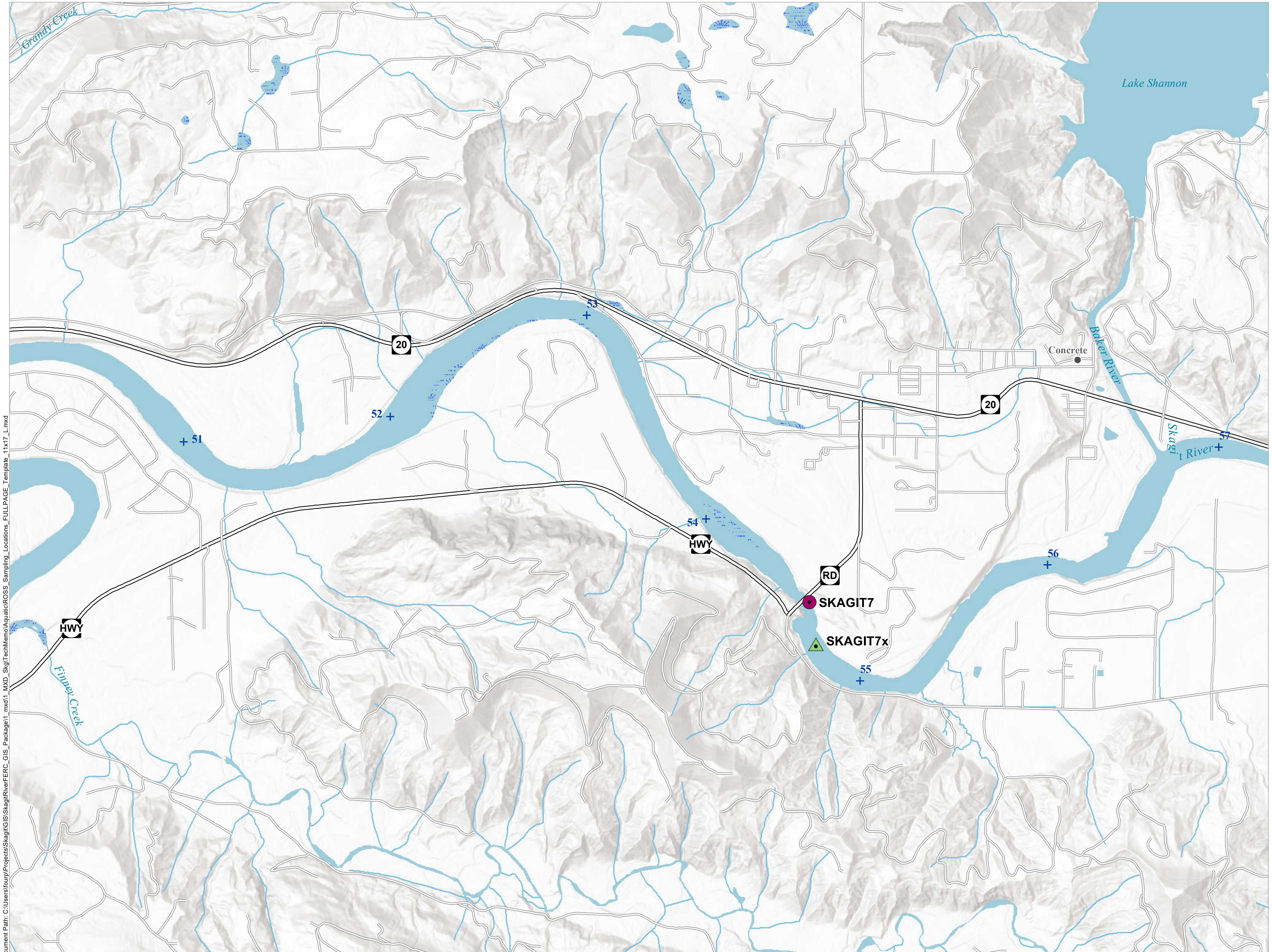

FA-01 WQ MONITORING STUDY
FIGURE 16
SKAGIT RIVER - FINNEY

+ Project River Miles (PRM)
BMI Sampling
Thermistor (RSP)

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SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)

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WATER QUALITY MONITORING STUDY INTERIM REPORT

ATTACHMENT B

WATER QUALITY SAMPLING LOCATIONS PHOTOS

List of Figures

Figure B-1. **Skagit River at International Boundary (TRIB1) turbidity and TSS sampling (November 30, 2021).**

Figure B-2. **Silver Creek confluence with Ross Lake (TRIB2) turbidity and TSS sampling (November 30, 2021).**

Figure B-3. **ROSS4 turbidity transect, located at the Ross Lake Shoreline erosional area (North) (December 1, 2021).**

Figure B-4. **Little Beaver Creek confluence with Ross Lake (ROSS9/TRIB3) turbidity and TSS sampling site (November 30, 2021).**

Figure B-5. ROSS5 turbidity transect, located at the Ross Lake Shoreline erosional area (Central) (December 1, 2021).

Figure B-6. Lightning Creek confluence with Ross Lake (TRIB4) turbidity and TSS sampling (November 30, 2021).

Figure B-7. Dry Creek confluence with Ross Lake (TRIB5) turbidity and TSS sampling (November 30, 2021).

Figure B-8. ROSS6 turbidity transect, located at the Ross Lake Shoreline erosional area (South) (December 1, 2021).

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Figure B-10. Pierce Creek confluence with Ross Lake (TRIB7) turbidity and TSS sampling (November 30, 2021).

Figure B-11. Roland Creek confluence with Ross Lake (TRIB8) turbidity and TSS sampling (November 30, 2021).

Figure B-12. Ruby Creek Arm (TRIB9) turbidity and TSS sampling location (November 30, 2021).

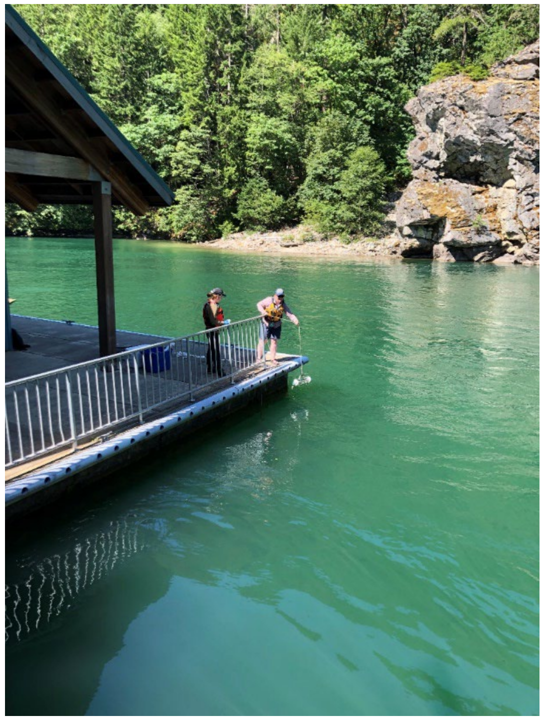

Figure B-13. DIABLO1, vertical profile and turbidity/TSS grab sample site, located at the upper end of Diablo Lake (July 29, 2021).

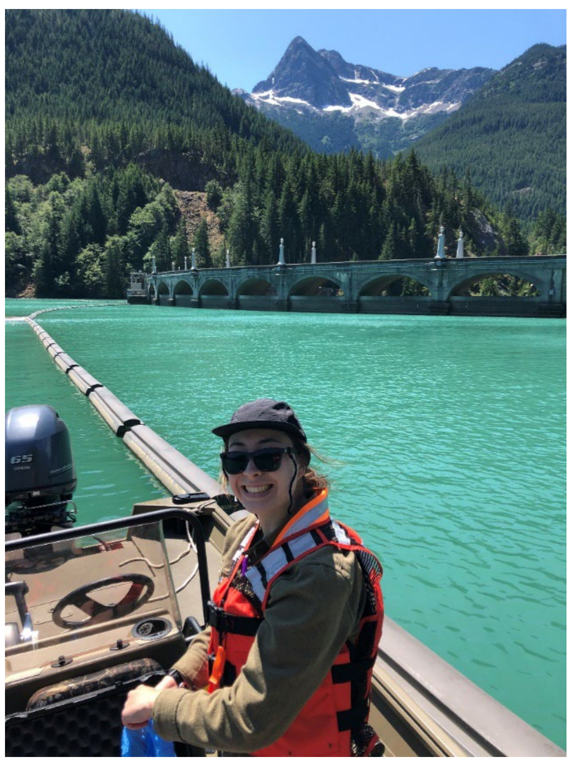

Figure B-14. DIABLO2, vertical profile and turbidity/TSS grab sample site, located at the Diablo Lake Forebay (July 29, 2021).

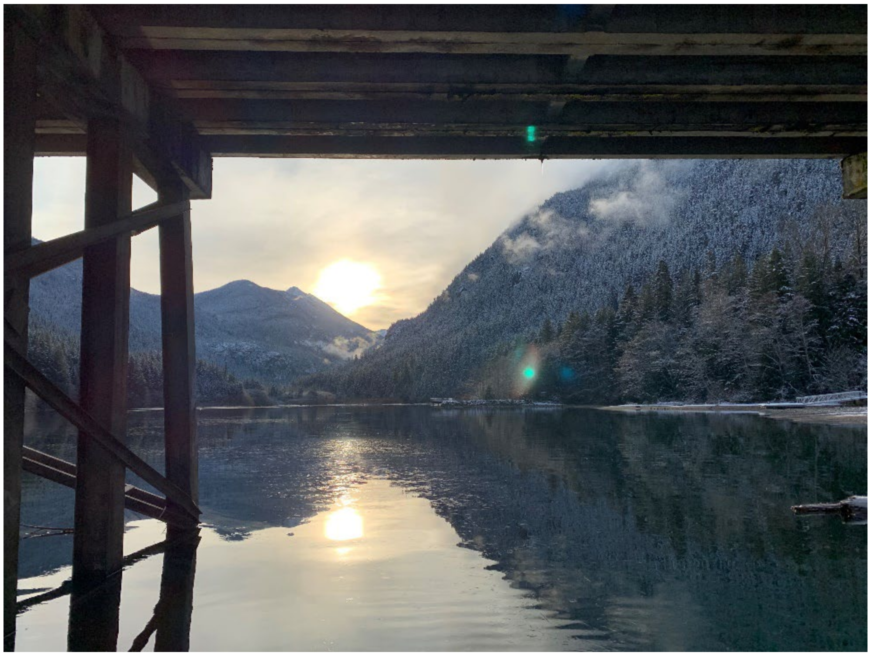

Figure B-15. DIABLO3, turbidity/TSS transect site at the Thunder Creek confluence at Colonial Creek Campground at Rhode Creek (December 17, 2021).

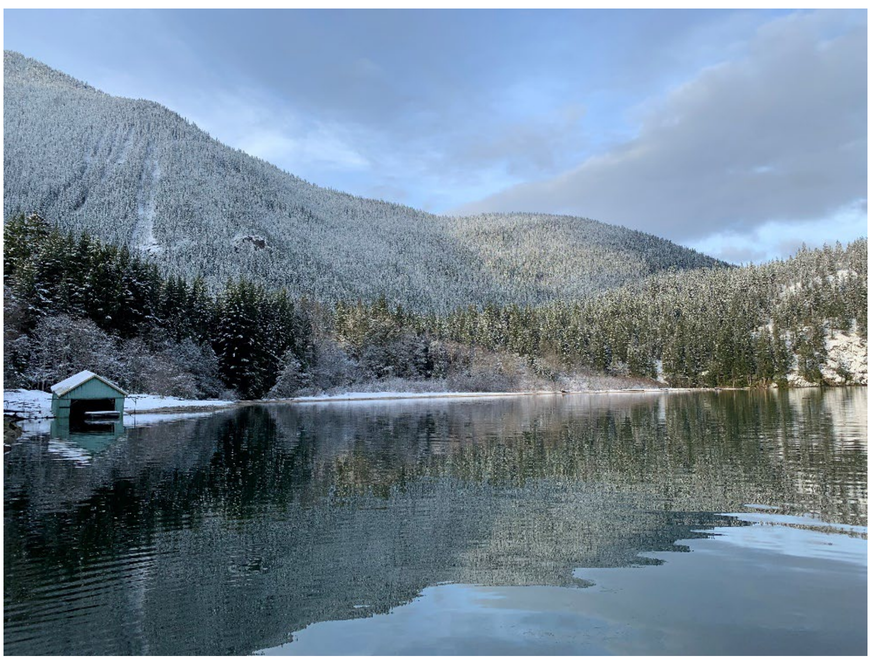

Figure B-16. DIABLO6, turbidity/TSS transect site at the Thunder Creek confluence at Colonial Creek Campground at Colonial Creek (December 17, 2021).

Figure B-17. **GORGE1/3, vertical profile, turbidity/TSS grab sample, and TDG monitoring site, located at the upper end of Gorge Lake at Reflector Bar (June 24, 2021).**

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Figure B-19. BYPASS1, temperature, DO, TDG, and turbidity sampling site, located at the plunge pool immediately downstream of Gorge Dam (June 17, 2021).

Figure B-20. BYPASS2, temperature, DO, TDG, and turbidity sampling site, located at the approximately 1.5 miles upstream of Gorge Powerhouse.

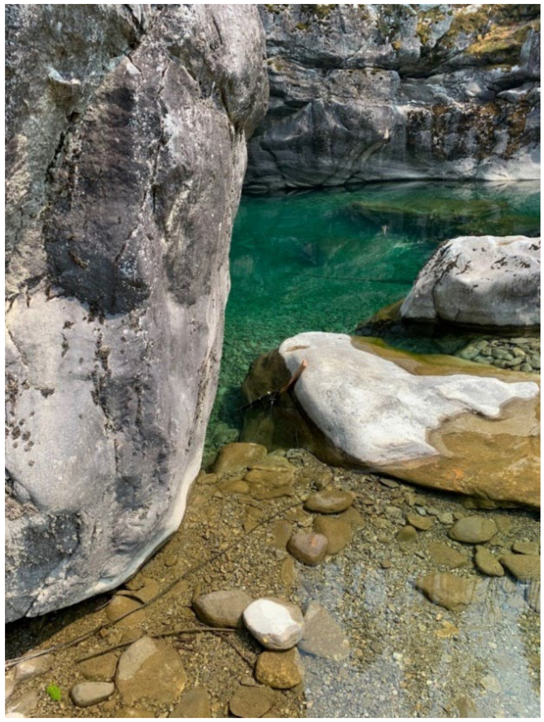

Figure B-21. BYPASS3, temperature, DO, TDG, and turbidity sampling site, located at the approximately 0.6 miles upstream of Gorge Powerhouse (August 2, 2021).

Figure B-22. PHOUSE1, temperature, DO, TDG, turbidity and pH sampling site, located immediately downstream of the Gorge Powerhouse.

Figure B-23. LADDER1, opportunistic sampling site for TDG during spill, located immediately downstream of the Gorge Powerhouse (October 25, 2021).

Figure B-24. SKAGIT2, temperature sampling site, located at PRM 91.6 (August 24, 2021).

Figure B-25. SKAGIT2X, BMI sampling site, located downstream of PRM 91.6 (August 24, 2021).

Figure B-26. SKAGIT3, temperature sampling site, located at PRM 85.9 (June 23, 2021).

Figure B-27. SKAGIT3X, BMI sampling site, located downstream of PRM 85.9 (August 24, 2021).

Figure B-28. SKAGIT4, temperature sampling site, located at PRM 75.6 (August 22, 2021).

Figure B-29. SKAGIT4X, BMI sampling site, located downstream of PRM 75.6 (August 23, 2021).

Figure B-30. SKAGIT5, temperature sampling site, located at PRM 69.3 (May 12, 2021).

Figure B-31. SKAGIT5X, BMI sampling site, located downstream of PRM 69.3 (August 23, 2021).

Figure B-32. SKAGIT6, temperature sampling site, located at PRM 60.8 (August 22, 2021).

Figure B-33. SKAGIT6X, BMI sampling site, located downstream of PRM 60.8 (August 23, 2021).

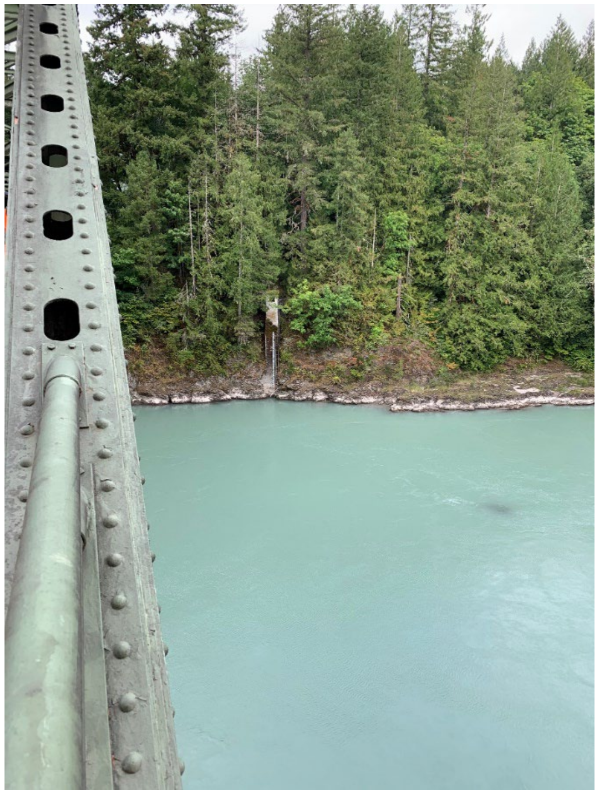

Figure B-34. SKAGIT7, temperature sampling site, located at PRM 54.5 (August 22, 2021).

Figure B-35. SKAGIT7X, BMI sampling site, located upstream of PRM 54.5 (August 23, 2021).

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WATER QUALITY MONITORING STUDY INTERIM REPORT

ATTACHMENT C

SKAGIT RIVER BENTHIC MACROINVERTEBRATE ASSESSMENT

SKAGIT RIVER BENTHIC MACROINVERTEBRATE ASSESSMENT

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1. EXECUTIVE SUMMARY

The Skagit River benthic macroinvertebrate assessment detailed in this report was performed as part of the relicensing for the Skagit River Hydroelectric Project. The benthic macroinvertebrate samples were collected using a 500-µm mesh kick net for eight riffle locations to make one final composite sample for each location. In the lab, these samples were quantitatively subsampled by systematically removing 500 individual organisms, at a minimum, from each sample. Individual specimens were identified to the lowest practical taxonomic level by qualified taxonomists. The Lower Puget Sound benthic index of biotic integrity (B-IBI) was calculated using the fine level resolution for each sample based on the laboratory analysis. The final categorization of the biotic integrity for the locations where benthic macroinvertebrate samples were collected based on the Lower Puget Sound B-IBI ranged from "Poor" to "Good."

2. BACKGROUND

EcoAnalysts, Inc. provided the sorting and identification for benthic macroinvertebrate samples collected by Meridian Environmental, Inc. (Meridian Environmental) as part of the relicensing for the Skagit River Hydroelectric Project. The objective of this project was to define the biological conditions present at sampling locations along the Skagit River downstream of the hydroelectric project. The results of the macroinvertebrate analyses are presented in this report.

3. METHODS

3.1 Field Collection

Field scientists from Meridian Environmental collected eight benthic macroinvertebrate samples (seven primary and one duplicate) following protocols developed for wadable streams (Plotnikoff, 2019) from August 22 to 24, 2021. Sampling dates were within the recommended index period between July 1 and October 15. The index period is recommended because this is the most stable timeframe for stream biological communities, most insect larvae have time to get large enough for accurate identifications, and most of these communities will be at their maximum before some of the taxa begin to emerge (Adams, 2010).

The macroinvertebrate samples were collected using a D-frame fixed with a 500-µm mesh net. Each sample represented a composite of eight 1ft^2 riffle locations that were randomly selected. Sample material that was retained by the net was placed in a wide chamber and the material was inspected for non-target organisms (fish, amphibians, freshwater mussels, etc.). Non-target organisms were removed, and the sample material was poured into a 500-µm mesh sieve and transferred to the sample containers. The sample material was preserved in the field using 95% ethanol. The samples were decanted following shipping regulations on September 7th, 2021.

3.2 Macroinvertebrate laboratory analysis

Benthic macroinvertebrate samples were processed and identified by EcoAnalysts, Inc. in Moscow, Idaho. These samples were received on September 8th, 2021 and each sample was immediately filled with 70% ethanol upon receipt.

Macroinvertebrates were quantitatively subsampled using a Caton tray. Individual grids were processed until a minimum of 500 organisms were removed from each sample. The initial sorting process was assessed for quality by re-sorting 20% of the processed material for each sample by a sorting technician that did not perform the primary sort. Any organisms that were found during the quality check were used to assess sort efficacy. If the primary sort did not remove 95% of the organisms based on this assessment, a second sort of the processed material and an additional quality check was performed.

All organisms removed during the sorting process were identified to the lowest practical taxonomic level (LPTL) by a qualified taxonomist. The initial identifications were assessed for quality by re-identifying 10% of the samples by a qualified taxonomist that did not perform the original identifications. If discrepancies in identifications were noted between the primary and QC taxonomists identification, the identifications were resolved prior to final data submittal. A synoptic reference collection was created that included three to five organisms that represented each taxa identification.

3.3 Lower Puget Sound Benthic Index of Biotic Integrity

The Lower Puget Sound Benthic Index of Biotic Integrity (B-IBI) is a quantitative tool used to assess the biological condition of streams in the Puget Sound region. This index is composed of 10 individual metrics. Table 1 provides a list of these metrics as well as a description and how the metric would respond to an impact. Each metric uses an observed value from the result of the macroinvertebrate analysis which is then converted to a metric score using a formula developed for the B-IBI. The final B-IBI score is a sum of the metric scores and rates the stream biological condition on a scale that ranges from 0 – 100, where a higher score represents a better stream biological condition. The B-IBI can be calculated using three different taxa identification resolution: coarse, medium, and fine resolution. The B-IBI results presented in this report were calculated using the fine resolution taxa identifications. Table 2 provides categorical descriptions for the final B-IBI score. Table 3 provides the scoring and color-coded ratings for the B-IBI.

Table 1. Lower Puget Sound Benthic Index of Biotic Integrity Metric Descriptions (Puget Sound Stream Benthos, 2021)

Lower Puget Sound B-IBI Metric	Description and Significance	Response to impacts
Total Taxa Richness	Total number of unique macroinvertebrate taxa. The biodiversity of a stream declines as flow regimes are altered, habitat is lost, chemicals are introduced, energy cycles are disrupted, and alien taxa invade. Total taxa richness includes all the different invertebrates collected from a stream site.	**Decrease**
Ephemeroptera (Mayfly) Taxa Richness	Total number of unique mayfly taxa. The diversity of mayflies declines in response to most types of human influence. Many mayflies graze on algae and are particularly sensitive to chemical pollution (e.g., from mine tailings) that interferes with their food source. Mayflies may disappear when heavy metal concentrations are high while caddisflies and stoneflies are unaffected. In nutrient-poor streams, livestock feces and fertilizers can increase the numbers and types of mayflies present. If many different taxa of mayflies are found while the variety of stoneflies and caddisflies is low, enrichment may be the cause.	**Decrease**
Plecoptera (Stonefly) Taxa Richness	Total number of unique stonefly taxa. Stoneflies are the first to disappear from a stream as human disturbance increases. Many stoneflies are predators that stalk their prey and hide around and between rocks. Hiding places between rocks are lost as sediment washes into a stream. Many stoneflies are shredders and feed on leaf litter that drops from an overhanging tree canopy. Most stoneflies, like salmonids, require cool water temperatures and high oxygen to complete their life cycles.	**Decrease**
Trichoptera (Caddisfly) Taxa Richness	Total number of unique caddisfly taxa. Different caddisfly taxa feed in a variety of ways: some spin nets to trap food, others collect or scrape food on top of exposed rocks. Many caddisflies build gravel or wood cases to protect them from predators; others are predators themselves. Even though they are very diverse in habit, taxa richness of caddisflies declines steadily as humans eliminate the variety and complexity of their stream habitat.	**Decrease**
Intolerant Taxa Richness	Total number of unique taxa considered intolerant to organic pollution. Animals identified as intolerant are the most sensitive taxa; they represent approximately 5-10 percent of the taxa present in the region. These animals are the first to disappear as human disturbance increases.	**Decrease**
Clinger Taxa Richness	Total number of unique clinger taxa. Taxa defined as clingers have physical adaptations that allow them to hold onto smooth substrates in fast water. These animals typically occupy the open area between rocks and cobble along the bottom of the stream. Thus, they are particularly sensitive to fine sediments that fill these spaces and eliminate the variety and complexity of these small habitats. Clingers may use these areas to forage, escape from predators, or lay their eggs. Sediment also prevents clingers from moving down deeper into the stream bed.	**Decrease**
Long-Lived Taxa Richness	Total number of taxa that require more than one year to complete their life cycle. These taxa are exposed to all the human activities that influence the stream throughout one or more years. If the stream is dry part of the year or subject to flooding, these animals may disappear. Loss of long-lived taxa may also indicate an ongoing problem that repeatedly interrupts their life cycles.	**Decrease**

Lower Puget Sound B-IBI Metric	Description and Significance	Response to impacts
Percent Tolerant	Tolerant animals are present at most stream sites, but as disturbance increases, they represent an increasingly large percentage of the assemblage. Invertebrates designated as tolerant represent the 5-10% most tolerant taxa in a region. In a sense, they occupy the opposite end of the spectrum from intolerant taxa.	Increase
Percent Predator	Predator taxa represent the peak of the food web and depend on a reliable source of other invertebrates that they can eat. Predators may have adaptations such as large eyes and long legs for hunting and catching other animals. The percentage of animals that are obligate predators provides a measure of the trophic complexity supported by a site. Less disturbed sites support a greater diversity of prey items and a variety of habitats in which to find them.	Decrease
Percent Dominance	As diversity declines, a few taxa come to dominate the assemblage. Opportunistic species that are less particular about where they live replace species that require special foods or particular types of physical habitat. Dominance is calculated by adding the number of individuals in the three most abundant taxa and dividing by the total number individuals in the sample	Increase

Table 2. Lower Puget Sound Benthic Index of Biotic Integrity Score Descriptions

Biological Condition	Description	B-IBI Score
Excellent	Comparable to least disturbed reference condition; overall high taxa diversity, particularly of mayflies, stoneflies, caddisflies, long-lived, clinger, and intolerant taxa. Relative abundance of predators high.	80-100
Good	Slightly divergent from least disturbed condition; absence of some long-lived and intolerant taxa; slight decline in richness of mayflies, stoneflies, and caddisflies; proportion of tolerant taxa increases.	60-80
Fair	Total taxa richness reduced – particularly intolerant, long-lived, stonefly, and clinger taxa; relative abundance of predator taxa declines; proportion of tolerant taxa continues to increase.	40-60
Poor	Overall taxa diversity depressed; proportion of predators greatly reduced as is long-lived taxa richness; few stoneflies or intolerant taxa present; dominance by three most abundant taxa often very high.	20-40
Very Poor	Overall taxa diversity very low and dominated by a few highly tolerant taxa; mayfly, stonefly, caddisfly, clinger, long-lived, and intolerant taxa largely absent; relative abundance of predators very low.	0-20

Table 3. Lower Puget Sound B-IBI Scoring Categorization

Individual Metric Scores	0-2	2-4	4-6	6-8	8-10
Final B-IBI Score	0-20	20-40	40-60	60-80	80-100
Score Rating	Very Poor	Poor	Fair	Good	Excellent

4. RESULTS

4.1 Sort Quality Assurance

Quantitative subsampling was performed on the benthic macroinvertebrate samples collected for this project. Percent of the sample that was processed to obtain a 500-subsample count ranged from 3.6 to 87.5%. Sorting efficacy was determined based on the removal of organisms during the primary sorting effort. The primary sorting efficacy ranged from 96.3 to 99.4%.

4.2 Lower Puget Sound Benthic Index of Biotic Integrity

The results of the benthic macroinvertebrate community analysis can be found in Appendix A. The observed value for each metric is provided in Table 4 and the B-IBI metric scores are provided in Table 5. Overall biological condition based on the B-IBI calculations was categorized as “Good” for Sauk River, Concrete, Van Horn, and Rockport sample locations. The biological condition was lower at Eatery, RM 118 and RM 113 which were categorized as “Fair.” The lowest biological condition was determined for the Duplicate sample from RM 113 which was categorized as “Poor.”

There was a large amount of variability between some of the metric scores from the RM 113 and Duplicate sample. The score for Plecoptera richness was “Excellent” in the RM 113 sample and “Poor” in the Duplicate sample. There was however agreement from other metric scores. Long-lived taxa richness, Percent predator individuals, and Percent dominant taxa were all categorized as poor for these two samples. Long-lived taxa richness and Percent predator individuals tended to be categorized on the lower side across all of the sample locations. Given the differences between RM 113 and duplicate sample, and more than adequate volume of the duplicate, a subsample was reanalyzed. Metrics for IBI determination are summarized in Table 4; overall IBI rating for the reanalyzed duplicate sample was Very Poor.

Table 4. Observed Values for Metrics included in the Benthic Index of Biotic Integrity

Metric	Sauk River	Concrete	Van Horn	Rockport	Eatery	RM 113	RM 113 (Dup.)	RM 113 (Dup. 2)	RM 118
Project River Mile	**NA**	**54.5**	**60.8**	**69.3**	**75.6**	**85.9**	**85.9**	**85.9**	**91.6**
Total Taxa Richness	48	45	48	49	45	46	34	27	37
Ephemeroptera (mayfly) Richness	10	7	7	9	5	7	6	1	4
Plecoptera (stonefly) Richness	5	5	3	8	5	8	1	2	3
Trichoptera (caddisfly) Richness	10	8	8	4	3	4	1	1	4
Intolerant Taxa Richness	7	4	4	7	6	7	4	1	5
Clinger Taxa Richness	30	23	25	22	17	18	13	6	15
Long-lived Taxa Richness	6	2	4	3	2	3	0	0	3
Percent Tolerant Individuals	0.8	1.3	1.9	1.8	2.3	3.2	3.5	1.8	5.5
Percent Predator Individuals	11.8	2.1	4.3	4.5	8.6	3.8	1.0	1.2	11.6
Percent Dominant (top 3)	48.7	38.8	37.7	38.5	34.8	68.1	79.3	73.7	44.8

Table 5. Benthic Index of Biotic Integrity Metric Score

Metric	Sauk River	Concrete	Van Horn	Rockport	Eatery	RM 113	RM 113 (Dup.)	RM 113 (Dup. 2)	RM 118
Project River Mile	**NA**	**54.5**	**60.8**	**69.3**	**75.6**	**85.9**	**85.9**	**85.9**	**91.6**
Total Taxa Richness	7.24	6.21	7.24	7.59	6.21	6.55	2.41	0.00	3.45
Ephemeroptera (mayfly) Richness	10.00	8.57	8.57	10.00	5.71	8.57	7.14	0.00	4.29
Plecoptera (stonefly) Richness	5.71	5.71	2.86	10.00	5.71	10.00	0.00	1.43	2.86
Trichoptera (caddisfly) Richness	10.00	8.75	8.75	3.75	2.50	3.75	0.00	0.00	3.75
Intolerant Taxa Richness	10.00	5.71	5.71	10.00	8.57	10.00	5.71	1.43	7.14
Clinger Taxa Richness	10.00	9.41	10.00	8.82	5.88	6.47	3.53	0.00	4.71
Long-lived Taxa Richness	5.00	0.00	2.50	1.25	0.00	1.25	0.00	0.00	1.25
Percent Tolerant Individuals	9.82	9.69	9.55	9.59	9.47	9.25	9.19	9.58	8.72
Percent Predator Individuals	5.42	0.55	1.64	1.75	3.78	1.40	0.00	0.10	5.30
Percent Dominant (top 3)	5.47	8.17	8.45	8.25	9.25	0.25	0.00	0.00	6.54
Final B-IBI Score	78.7	62.8	65.3	71.0	57.1	57.5	28.0	12.5	48.0
Final B-IBI Biological Condition Rating	Good	Good	Good	Good	Fair	Fair	Poor	Very Poor	Fair

5. DISCUSSION

Benthic macroinvertebrate samples collected as part of the relicensing of the Skagit River Hydroelectric Project in 2021 were assessed using the Lower Puget Sound Benthic Index of Biotic Integrity (LPS IBI). The latter categorized the biological condition of these communities from “fair” to “good,” and results characterized the communities further upstream as more impaired.

6. REFERENCES

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Plotnikoff, R. (2019). *Standard Operating Procedures for the Collection of Benthic Macroinvertebrates Using a Surber Sampling Device in Rivers and Streams.* Snohomish County Surface Water Management Resource Monitoring Group.

Puget Sound Stream Benthos. (2021). *About the Benthic Index of Biotic Integrity*. Retrieved from https://pugetsoundstreambenthos.org/About-BIBI.aspx

APPENDIX A

MACROINVERTEBRATE RESULTS

PG - Meridian Skagit BMI 2021
Data are not adjusted for subsampling

EcoAnalysts, Inc.
LIFE IN WATER

	Site ID	Sauk	PRM 545	PRM 60.8	PRM 69.3	PRM 75.6	PRM 85.9	PRM 85.9 Duplicate	PRM 91.6	PRM 85.9 Duplicate (Subsample2)
	Site Name	**Sauk River**	**Concrete**	**Van Horn**	**Rockport**	**Eatery**	**Rm 113**	**Rm 113**	**Rm 118**	**Rm 113**
	Collection Date	**08-22-2021**	**08-23-2021**	**08-23-2021**	**08-23-2021**	**08-23-2021**	**08-24-2021**	**08-24-2021**	**08-24-2021**	**08-24-2021**
	Percent Subsampled	**87.50**	**15.50**	**33.33**	**29.17**	**25.00**	**5.17**	**3.67**	**3.62**	**4.17**
	EcoAnalysts Sample ID	**8260.1-1**	**8260.1-2**	**8260.1-3**	**8260.1-4**	**8260.1-5**	**8260.1-6**	**8260.1-7**	**8260.1-8**	**8260.1-9**
Ephemeroptera	Acentrella insignificans	9	26	17	17	1	0	0	0	0
	Acentrella turbida	7	37	20	44	3	0	0	0	0
	Ameletus sp.	1	0	0	1	0	1	0	3	0
	Attenella margarita	0	0	0	0	0	0	1	0	0
	Baetis sp.	0	0	0	0	0	0	2	0	5
	Baetis tricaudatus	27	32	35	59	0	12	0	38	0
	Cinygmula sp.	2	0	0	2	4	2	2	0	0
	Drunella doddsii	9	2	2	1	0	0	1	0	0
	Drunella grandis	15	6	13	0	1	1	2	4	0
	Epeorus sp.	0	0	0	1	0	1	0	0	0
	Ephemerella sp.	1	0	0	0	0	0	0	0	0
	Ephemerella tibialis	3	13	16	11	0	4	0	4	0
	Ephemerellidae	0	0	0	0	0	0	1	0	0
	Rhithrogena sp.	20	17	61	87	11	1	0	0	0
Plecoptera	Capniidae	0	0	0	4	5	2	0	4	1
	Chloroperlidae	3	2	3	7	22	4	0	0	1
	Eucapnopsis brevicauda	0	0	0	1	0	1	0	0	0
	Hesperoperla pacifica	1	0	0	0	0	0	0	3	0
	Perlodidae	26	2	0	1	3	1	0	0	0
	Skwala sp.	18	2	10	2	7	3	0	0	0
	Suwallia sp.	0	1	1	1	0	1	0	0	0
	Sweltsa sp.	0	1	0	2	9	2	0	0	0
	Zapada cinctipes	0	0	0	2	0	1	2	6	0
	Zapada columbiana	2	0	0	0	0	0	0	0	0
Trichoptera	Amiocentrus aspilus	0	0	0	0	0	1	0	0	0
	Arctopsyche grandis	2	3	3	8	2	0	0	40	0
	Arctopsyche sp.	0	0	0	0	0	2	0	0	0
	Brachycentrus americanus	2	2	0	0	0	0	0	1	0
	Brachycentrus occidentalis	25	13	5	6	0	0	0	0	0
	Glossosoma sp.	21	10	23	12	0	0	0	0	0
	Hydropsyche sp.	42	35	69	13	3	0	0	0	0
	Hydroptila sp.	0	3	2	0	0	0	0	0	0
	Limnephilidae	1	1	3	0	0	0	0	0	0
	Micrasema sp.	2	0	0	0	0	0	0	1	0
	Oligophlebodes sp.	15	2	3	0	0	0	0	0	0
	Rhyacophila angelita gr.	1	0	0	0	0	0	0	0	0
	Rhyacophila arnaudi	0	0	0	0	1	0	0	0	0
	Rhyacophila brunnea/vemna gr.	0	0	1	0	0	1	0	6	0
	Rhyacophila coloradensis gr.	2	0	0	0	0	1	1	0	2
Coleoptera	Hydroporinae	0	0	0	0	0	1	0	0	0
	Lara sp.	1	0	0	0	0	0	0	0	0
	Narpus sp.	3	0	5	1	0	0	0	0	0
	Zaitzevia parvula	2	0	1	0	0	0	0	0	0
Diptera-Chironomidae	Brillia sp.	1	0	0	3	0	0	1	0	0
	Chaetocladius sp.	2	0	0	0	0	0	0	0	0

	Cladotanytarsus sp.	0	2	9	0	3	0	0	0	0
	Corynoneura sp.	0	0	0	0	0	5	2	0	2
	Cricotopus bicinctus gr.	0	12	0	0	0	0	0	1	0
	Cricotopus sp.	0	116	9	18	52	86	112	64	58
	Eukiefferiella brehmi gr.	2	11	6	2	1	0	1	6	0
	Eukiefferiella claripennis gr.	0	0	7	0	0	0	0	0	0
	Eukiefferiella coerulescens gr.	0	0	0	2	0	0	0	0	1
	Eukiefferiella devonica gr.	0	3	3	0	0	18	12	2	13
	Eukiefferiella gracei gr.	0	0	1	10	0	187	146	13	165
	Micropsectra sp.	0	0	4	2	4	3	1	10	1
	Microtendipes pedellus gr.	0	6	6	0	7	0	0	0	0
	Orthocladius (Euorthocladius)	1	1	0	0	0	0	0	0	0
	Orthocladius (Euorthocladius) rivicola gr.	0	0	8	7	0	0	0	0	0
	Orthocladius (Euorthocladius) rivulorum	0	0	0	4	5	0	0	0	0
	Orthocladius sp.	0	43	33	51	79	85	152	95	139
	Pagastia sp.	2	2	1	2	7	16	18	26	8
	Paracladopelma sp.	0	0	0	0	1	0	0	1	0
	Parakiefferiella sp.	0	1	3	0	5	1	0	2	1
	Paratanytarsus sp.	0	1	1	0	7	3	0	0	0
	Pentaneurini	0	0	0	0	0	0	0	0	2
	Phaenopsectra sp.	0	0	1	0	1	0	0	0	0
	Polypedilum sp.	0	3	0	7	8	1	1	0	0
	Potthastia gaedii gr.	0	8	1	1	2	1	0	0	0
	Potthastia longimana gr.	0	0	0	0	0	2	3	22	0
	Rheocricotopus sp.	0	0	0	0	0	1	0	3	0
	Rheosmittia sp.	0	0	0	1	0	0	0	0	0
	Rheotanytarsus sp.	0	30	7	15	52	2	1	7	3
	Stempellinella sp.	0	0	0	0	3	1	2	2	2
	Sublettea sp.	1	10	17	0	36	1	1	5	1
	Tanytarsus sp.	0	0	1	0	5	0	1	0	0
	Thienemanniella sp.	0	3	1	4	35	2	0	0	4
	Thienemannimyia gr. sp.	0	0	0	1	0	0	1	0	0
	Tvetenia bavarica gr.	0	0	0	8	4	12	11	39	14
Diptera	Antocha sp.	1	1	0	0	0	5	1	0	3
	Atherix sp.	3	0	0	0	0	0	0	1	0
	Bibiocephala grandis	3	0	0	1	0	0	0	0	0
	Ceratopogonidae	0	0	0	0	0	0	0	1	0
	Chelifera/Metachela sp.	0	0	0	0	0	0	0	2	0
	Clinocera sp.	5	0	1	1	0	4	3	6	0
	Empididae	0	0	0	0	1	0	0	0	1
	Neoplasta sp.	0	0	3	0	0	0	0	0	0
	Protanyderus sp.	2	0	4	0	0	0	0	0	0
	Simulium sp.	2	1	4	7	0	0	0	0	0
Annelida	Chaetogaster diastrophus	0	0	0	0	0	0	2	0	3
	Enchytraeidae	2	1	0	49	40	3	1	0	1
	Lumbriculidae	0	0	0	0	0	1	0	0	0
	Nais behningi	1	2	0	9	17	29	24	69	55
	Nais bretscheri	0	0	0	0	4	6	0	0	11
	Stylodrilus heringianus	0	0	0	0	4	0	0	0	0
	tubificoid Naididae w/ cap setae	0	0	1	0	0	0	0	0	0
Acari	Atractides sp.	20	5	12	3	5	0	1	1	1
	Hygrobates sp.	1	0	0	0	4	0	0	0	0
	Lebertia sp.	18	7	8	3	8	3	1	5	1
	Oribatei	1	1	0	1	0	0	0	0	0
	Protzia sp.	3	0	0	0	3	0	0	0	0
	Sperchon sp.	183	45	65	11	32	3	2	1	3
	Torrenticola sp.	0	0	0	0	1	0	0	0	0
Other Organisms	Nematoda	0	1	7	2	11	2	4	6	0
	Polycelis sp.	0	0	0	4	7	0	0	9	0
	TOTAL	**517**	**526**	**517**	**512**	**526**	**526**	**517**	**509**	**502**

PG - Meridian Skagit BMI 2021
Sort Report

EcoA Sample ID	Site ID	Site Name	Notes	Collection Date	Sorter	% Subsampled	Primary Matrix	Estimated Pre-Rinse Volume (L)	Estimated Post-Rinse Volume (L)	QC Sorter	Estimated %Recovery1	Estimated %Recovery2
8260.1-1	Sauk	Sauk River		08/22/2021	L. Smith	87.50	Fine Organic	0.55	0.10	K. Hall	98.32	N/A
8260.1-2	PRM 545	Concrete		08/23/2021	L. Smith	15.50	Fine Organic	0.30	0.05	K. Hall	98.89	N/A
8260.1-3	PRM 60.8	Van Horn		08/23/2021	L. Smith	33.33	Fine Organic	0.75	0.20	K. Hall	99.43	N/A
8260.1-4	PRM 69.3	Rockport		08/23/2021	L. Smith	29.17	Fine Organic	0.90	0.10	K. Hall	98.36	N/A
8260.1-5	PRM 75.6	Eatery		08/23/2021	L. Smith	25.00	Fine Organic	0.23	0.08	K. Hall	97.85	N/A
8260.1-6	PRM 85.9	Rm 113		08/24/2021	L. Smith	5.17	Filamentous Algae	0.50	0.50	K. Hall	96.30	N/A
8260.1-7	PRM 85.9 Duplicate	Rm 113		08/24/2021	L. Smith	3.67	Filamentous Algae	0.35	0.35	K. Hall	96.25	N/A
8260.1-8	PRM 91.6	Rm 118		08/24/2021	L. Smith	3.62	Filamentous Algae	0.70	0.70	K. Hall	96.29	N/A
8260.1-9	PRM 85.9 Duplicate (Subsample2)	Rm 113	2nd subsample of the Duplicate (8260.1-7)	08/24/2021	B. Alexander	4.17	Filamentous Algae	0.68	0.68	K. Hall	98.90	N/A

APPENDIX B

LOWER PUGET SOUND B-IBI SCORES

PG - Meridian Skagit BMI 2021
LPS Fine STE IBI

EcoAnalysts, Inc.
LIFE IN WATER

	Site ID	Sauk	PRM 545	PRM 60.8	PRM 69.3	PRM 75.6	PRM 85.9	PRM 85.9 Duplicate	PRM 91.6	PRM 85.9 Duplicate (Subsample2)
	Site Name	Sauk River	Concrete	Van Horn	Rockport	Eatery	Rm 113	Rm 113	Rm 118	Rm 113
	Collection Date	08-22-2021	08-23-2021	08-23-2021	08-23-2021	08-23-2021	08-24-2021	08-24-2021	08-24-2021	08-24-2021
	Percent Subsampled	87.50	15.50	33.33	29.17	25.00	5.17	3.67	3.62	4.17
	EcoAnalysts Sample ID	8260.1-1	8260.1-2	8260.1-3	8260.1-4	8260.1-5	8260.1-6	8260.1-7	8260.1-8	8260.1-9
LPS B-IBI Metric Values	Total Taxa Richness	48	45	48	49	45	46	34	37	27
	Ephemeroptera Richness	10	7	7	9	5	7	6	4	1
	Plecoptera Richness	5	5	3	8	5	8	1	3	2
	Trichoptera Richenss	10	8	8	4	3	4	1	4	1
	Intolerant Taxa Richness	7	4	4	7	6	7	4	5	1
	Clinger Taxa Richness	30	23	25	22	17	18	13	15	6
	Long-lived Taxa Richness	6	2	4	3	2	3	0	3	0
	Percent Tolerant Individuals	0.8	1.3	1.9	1.8	2.3	3.2	3.5	5.5	1.8
	Percent Predator Individuals	11.8	2.1	4.3	4.5	8.6	3.8	1.0	11.6	1.2
	Percent Dominant (top 3)	48.7	38.8	37.7	38.5	34.8	68.1	79.3	44.8	73.7
LPS B-IBI Scores Fine Resolution	Total Taxa Richness	7.24	6.21	7.24	7.59	6.21	6.55	2.41	3.45	0.00
	Ephemeroptera Richness	12.86	8.57	8.57	11.43	5.71	8.57	7.14	4.29	0.00
	Plecoptera Richness	5.71	5.71	2.86	10.00	5.71	10.00	0.00	2.86	1.43
	Trichoptera Richenss	11.25	8.75	8.75	3.75	2.50	3.75	0.00	3.75	0.00
	Intolerant Taxa Richness	10.00	5.71	5.71	10.00	8.57	10.00	5.71	7.14	1.43
	Clinger Taxa Richness	13.53	9.41	10.59	8.82	5.88	6.47	3.53	4.71	-0.59
	Long-lived Taxa Richness	5.00	0.00	2.50	1.25	0.00	1.25	-2.50	1.25	-2.50
	Percent Tolerant Individuals	9.82	9.69	9.55	9.59	9.47	9.25	9.19	8.72	9.58
	Percent Predator	5.42	0.55	1.64	1.75	3.78	1.40	-0.02	5.30	0.10
	Percent Dominant (top 3)	5.47	8.17	8.45	8.25	9.25	0.25	-2.78	6.54	-1.27
Metric Score (max 10)	Total Taxa Richness	7.24	6.21	7.24	7.59	6.21	6.55	2.41	3.45	0.00
	Ephemeroptera Richness	10.00	8.57	8.57	10.00	5.71	8.57	7.14	4.29	0.00
	Plecoptera Richness	5.71	5.71	2.86	10.00	5.71	10.00	0.00	2.86	1.43
	Trichoptera Richenss	10.00	8.75	8.75	3.75	2.50	3.75	0.00	3.75	0.00
	Intolerant Taxa Richness	10.00	5.71	5.71	10.00	8.57	10.00	5.71	7.14	1.43
	Clinger Taxa Richness	10.00	9.41	10.00	8.82	5.88	6.47	3.53	4.71	0.00
	Long-lived Taxa Richness	5.00	0.00	2.50	1.25	0.00	1.25	0.00	1.25	0.00
	Percent Tolerant Individuals	9.82	9.69	9.55	9.59	9.47	9.25	9.19	8.72	9.58
	Percent Predator	5.42	0.55	1.64	1.75	3.78	1.40	0.00	5.30	0.10
	Percent Dominant (top 3)	5.47	8.17	8.45	8.25	9.25	0.25	0.00	6.54	0.00
	Final Score	**78.7**	**62.8**	**65.3**	**71.0**	**57.1**	**57.5**	**28.0**	**48.0**	**12.5**
	Lower Puget Sound Condtion Rating	**Good**	**Good**	**Good**	**Good**	**Fair**	**Fair**	**Poor**	**Fair**	**Very Poor**

Rating Categories (0-100)	
0-20	Very Poor
20-40	Poor
40-60	Fair
60-80	Good
80-100	Excellent

WATER QUALITY MONITORING STUDY INTERIM REPORT

ATTACHMENT D

SKAGIT RIVER HYDROELECTRIC PROJECT
INTERIM EXISTING DATA SUMMARY

MANAGEMENT AND EVALUATION OF EXISTING WATER QUALITY DATA DRAFT REPORT

SKAGIT RIVER HYDROELECTRIC PROJECT FERC NO. 553

Seattle City Light

Prepared by:
Geosyntec Consultants, Inc.

March 2022

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List of Acronyms and Abbreviations

°C ....degrees Celsius
ANC ....acid neutralizing capacity
BDL...........................below detection limit
BI...............................Business Intelligence (Microsoft Power)
City Light ....Seattle City Light
CoSD.........................City of Seattle datum
DL ....detection limit
DO.............................dissolved oxygen
DOC ....dissolved organic carbon
EAP ....Environmental Analysis Program
Ecology ....Washington State Department of Ecology
fDOM ....fluorescent dissolved organic matter
FERC.........................Federal Energy Regulatory Commission
FNU...........................formazin nephelometric unit
ft ....foot/feet
ISR ....Initial Study Report
mg/L..........................milligrams per liter
(mg C)/L....................milligrams of carbon per liter
(mg N)/L ....milligrams of nitrogen per liter
(mg P)/L....................milligrams of phosphorus per liter
(mg S)/L....................milligrams of sulfur per liter
NAVD 88...................North American Vertical Datum of 1988
NCCN ....North Coast and Cascades Inventory and Monitoring Network
NPS ....National Park Service
PO_4 ....phosphate
Project ....Skagit River Hydroelectric Project
QC ....quality control
QSE ....quinine sulfate equivalent
RSD...........................relative standard deviation
RSP ....Revised Study Plan
RTRM ....relative thermal resistance to mixing

SC..............................specific conductance
SOP ....Standard Operating Procedure
SQL............................Structured Query Language
SR...............................State Route
T ....temperature
TDN ....total dissolved nitrogen
TDP ....total dissolved phosphorus
TDS ....total dissolved solid
USGS .........................U.S. Geological Survey
USR............................Updated Study Report
UTP ....uridine-5’-triphosphate
μeq/L..........................microequivalents per liter
μS/cm ....microsiemens per centimeter

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1.0 INTRODUCTION

This Management and Evaluation of Existing Water Quality Data Draft Report has been drafted to address Seattle City Light's (City Light) commitment in the "Notice of Certain Agreements on Study Plans for the Skagit Relicensing" (June 9, 2021 Notice)[1] and specifically, to provide a summary of existing water quality data in the Initial Study Report (ISR). City Light has collected water quality monitoring data for the Skagit River Hydroelectric Project (Project), the Skagit River upstream of Ross Lake, the Skagit River downstream of the Project, and numerous tributaries to these three water bodies. Some data collection has been conducted through contracting relationships or partnerships with the National Park Service (NPS), the NPS North Coast and Cascades Inventory and Monitoring Network (NCCN), the U.S. Geological Survey (USGS), and private contractors serving City Light. Data sets analyzed herein were contained within approximately 3,800 discrete files appearing in different formats and containing data, summaries of data, and metadata.[2]

1 Referred to by FERC in its July 16, 2021 Study Plan Determination as the "updated RSP."

2 Metadata is information that describes the context of measured values, in this case, information that describes where, when, and how water quality data were collected and curated.

2.0 STUDY AREA

This study began with an inventory of existing historical data collected by a range of organizations and this inventory defined the geographical scope of the interpretation that followed. Sampling by the NCCN was confined to Ross and Diablo lakes. Sampling by NPS focused on tributary streams ranging from Hozomeen Creek upstream to Illabot Creek downstream. USGS data were collected at the inflow to Ross Lake. City Light data were collected mostly near dams, in select tributaries and in multiple locations in Gorge Lake.

3.0 METHODOLOGY

3.1 Data Management

A metadata inventory was created from the set of available files that described the folder path, filename, contents, and available metadata, if any, in each file. Files were sorted by geographical region and characterized as either holding in-reservoir data or riverine data.

A table of available metadata was created to describe each data file. Filenames and folder paths were noted; filenames were never changed. Files were associated with a water body and location, and location names were standardized to match those in Appendix 1. Each file was opened to determine the type of information contained (i.e., data, a summary of data, data from a water quality sonde, or documentation or metadata), the variables for which data were reported, the units in which those variables were measured, and the presence of data in separate sheets in an Excel workbook. The data reporting agency was noted if this information was available in the file, filename, or folder. If the data were described in separate documentation files that provided information about measurement methods or instrument calibration, this was noted.

When files contained data from a continuous temperature sensor, the serial number of that sensor was noted if it existed in the available data or metadata files; sometimes it was found in the file name, the header of the file, alongside data, or the name of a sheet in an Excel workbook. If a file was part of a set that constituted a thermistor chain, this was noted, and the chain was arbitrarily assigned a number for the purposes of grouping related files together for analysis. The metadata inventory was used as an internal resource to facilitate data organization and evaluate whether sufficient metadata were available for quality control (QC) activities and whether data sets could be used in subsequent analyses.

Data files usually contained only dates, times, and the values of the variables measured; they seldom, if ever, contained information about measurement location. Location names were described in file names and folder names. These location names were translated into geographical coordinates using metadata tables created by City Light, maps in the 2019-2020 Stream Sensor Monitoring Report created by the NPS (2020), a narrative description in the 2017-2018 Stream Sensor Monitoring Report (NPS 2018), Project Data Certification Forms from the NCCN (Archambault 2019a; 2019b), and publicly available resources. The source of coordinates for each monitoring location was noted, and the confidence in each location was designated as “low” when the location was estimated with minimal information, “medium” when an approximate location was known and the location was estimated with some certainty, and “high” when metadata containing coordinates were available or when these were supplied by the person who did the sampling.

Available data were read into a Structured Query Language (SQL) database for ease of manipulation and querying. Figures were created using Microsoft Power Business Intelligence (BI) or Python. This database was designed for internal use only; it does not include the functionality for public input or extraction of data that will be part of the database in development by City Light. The database was used to create an inventory of available data collected prior to December 31, 2020. Inventories were created by data type and by variable reported. The database was further interrogated as described below.

3.2 Metadata Quality Control

Metadata received in methodological documentation produced by NPS and NCCN were assumed to be reliable, so metadata QC focused on data sets without accompanying documentation. Discussions and subsequent metadata transmissions between City Light and its consultant team resolved several unknown locations and improved understanding of others. Additional metadata requests were outstanding at the time this report was prepared. Data sets were excluded from QC activities and from subsequent analysis when metadata were insufficient to determine a location for the observations in the data set.

3.3 Data Quality Control

Data were assessed for QC activities using similar yet distinct procedures for different types of data. Data types were:

- Continuous water temperature measurements;
- Water quality sonde deployments; and
- Analysis of water grab samples.

A thermistor chain is a set of continuous temperature sensors arranged vertically along a rope or cable that is held in a constant geographical location during deployment. In this report, this term is used distinctly from "vertical profile," which denotes data collected by lowering or raising a water quality sonde at a location at a discrete, singular time.

Several standard operating procedure (SOP) documents written by King County or Washington State Department of Ecology (Ecology) were reviewed and applied to data sets when sufficient metadata and related information were available (Table 3.3-1). The SOPs were used as a starting point for QC activities, but they were not regarded as the only path to determining useability of data due to separate QC activities performed by the agencies that reported the data. Data that did not meet quality standards in these SOPs were noted with qualifiers in the internal database (see Section 3.4 below) and used in interpretation.

Table 3.3-1. Standard operating procedures considered for data quality control.

SOP	Topic	Citation	Applicable Data
King County Thermistor Chain Quality Assurance Project Plan	Thermistor Chain Quality	King County 2018	Thermistor Chains
Ecology EAP080[1]	Continuous Temperature Monitoring of Freshwater Rivers and Streams	Ecology 2018	Individual Thermistors Deployed in Lakes or Streams
Ecology EAP129	Field Deployment of Water Quality Sondes	Ecology 2019a	Vertical Profiles or Continuous Data from Water Quality Sondes
Ecology EAP130	Interpretation of Data from Water Quality Sondes	Ecology 2019b	

1 EAP documents are SOPs created by the Ecology Environmental Analysis Program.

3.3.1 Continuous Water Temperature Measurements

Continuous temperature data were assessed for quality separately for sensors deployed in thermistor chains and individually. Each is described in the following paragraphs.

For thermistor chains, King County (2018) recommends that the accuracy of a thermistor chain be checked occasionally by comparing its results to temperature measured by a recently calibrated water quality sonde. This is meant to detect instrument drift that could occur in the thermistors while they are deployed for a long time. However, this was not possible for the data collected in the Project reservoirs, either because vertical profiles were not co-located with thermistor chains or because, when vertical profiles were measured with a water quality sonde, this occurred next to thermistor chains in which the depth of the thermistors was not reported (NCCN is still investigating refining qualitative depth estimates). Therefore, no quantitative QC activities were performed for thermistor chains. The presence of obvious errors in the temperature time series that were collected by the thermistor chain was assessed visually in contour plots (Appendix 5).

For individual sensors placed in creeks or in reservoirs, metadata do not provide information regarding whether field activities followed Ecology SOP EAP080, "Continuous Temperature Monitoring of Freshwater Rivers and Streams" (Ecology 2018). Therefore, data were examined visually for temporal inconsistencies. Data were qualified and removed from analysis when outliers suggested that sensors were temporarily out of water or buried in sediment or when NPS Stream Sensor Reports indicated these or other problems (NPS 2015; 2016; 2017; 2018; 2019; 2020). After this QC activity, remaining data were used in analysis and interpretation.

3.3.2 Water Quality Sonde Deployments

Vertical profiles collected with a multiparameter sonde were measured in Ross and Diablo Lakes by NCCN (Archambault 2019a; 2019b). When Project Data Certification Forms were available for these data, they described the model name and number of the sonde, the calibration activities for the sonde, and the quality assessment of the data (Archambault 2019a; Archambault 2019b). These activities and quality assessments constitute meaningful QC activities that do not conform to Ecology SOP EAP129 "Short-term Continuous Data Collection with a Multiparameter Sonde, Part 1: Field Procedures" (Ecology 2019a). Notably, the use of reference standards to check sonde readings does not exist in Project Data Certification Forms (Archambault 2019a; Archambault 2019b). These data were qualified in the internal database (see Section 3.4 below) and used in this analysis.

A water quality sonde collects a time series of depth and other variables. Often, these data are collected while the sonde is moving vertically through the water column and the data are organized to relate the other variables to specific depths. However, the raw time series can be examined as a way of checking sonde data for quality. Ecology SOP EAP130 "Short-term Continuous Data Collection with a Multiparameter Sonde, Part 2: Data Processing" (Ecology 2019b) suggests plotting depth measurements against time to verify that the sonde was allowed to equilibrate at certain depths while being lowered or raised through the water column. Approximately 25 percent of sonde casts were selected at random and plotted in this manner. Additionally, Ecology EAP130 suggests plotting the other variables measured by a sonde against depth and examining the plot for noise in the data. This was done in a random selection of greater than 50 percent of sonde casts.

3.3.3 Grab Samples

Grab samples collected from Ross and Diablo lakes were analyzed by Water Analysis Laboratory of the College of Forestry Cooperative Chemical Analytical Laboratory at Oregon State University (Archambault 2019a; Archambault 2019b), which uses an established Quality Assurance Plan (Motter et al 2018). These data were accepted without further evaluation for quality.

3.4 Qualifiers Added to the Database

Quality control activities of metadata and data resulted in the addition of qualifiers to the database (Table 3.4-1). When locations were unknown or when depths in a thermistor chain were unknown, data were qualified (Qualifier "L") and archived without analysis or interpretation because the lack of location information prevents all but general observations. Data sets without metadata describing the method of data collection (e.g., the instrument used), the measurement methodology, or the calibration of instrumentation were qualified (Qualifier "E") and used because they were collected by reputable entities. Data collected by the NPS, USGS, and City Light as well as some data collected by NCCN fall into this category. Data sets collected by the NCCN with a water quality sonde were described by documentation that reported QC activities that differed from Ecology SOP EAP129, so these were also qualified (Qualifier "C") and used for analysis and interpretation.

When erroneous data were identified either through examination of NPS documentation (NPS 2015; 2016; 2017; 2018; 2019; 2020) or visual inspection of obvious outliers, these were qualified (Qualifier "A") and omitted from analyses. Data duplicated in two files with different file names were qualified (Qualifier "D"), and one observation from a duplicate pair was used in analysis. This frequently occurred when identical data were saved in files whose filenames suggested different locations, usually "Log Boom" and "Forebay." When this occurred, "Log Boom" data were used in the analysis because this location corresponds to location metadata from thermistor deployment records and the "Forebay" location was understood to be redundant. Forebay data were archived and excluded from analyses. Data from City Light thermistors with a depth specified as "surface" were qualified (Qualifier "S") and assigned a depth of 2 feet (ft) before inclusion in inventories, analyses, and interpretation.

Table 3.4-1. Qualifiers added to the database.

Qualifier	Description	Significance	Data Treatment	Data Included in Inventories?[1]
L	Location unknown or in a thermistor chain, depth unknown	Cannot interpret or analyze without known location or, in a thermistor chain, known depth	Qualified, archived, and omitted from inventories, analyses, and interpretation	No
E	No information about instrumentation or measurement methods	Cannot verify quality of data	Qualified, assumed to be reliable, and included in interpretation because data are from reputable entities[2]	Yes
C	QC activities documented for vertical profiles, but they do not conform to Ecology SOP EAP129	Data not consistent with Ecology standards but likely reliable	Qualified, assumed to be reliable, and included in interpretation because data are from the NCCN	Yes
A	Erroneous data based on visual inspection or NPS Stream Sensor Reports[3]	Erroneous measurements (frequently due to low water level in streams leaving sensors out of water)	Qualified, archived, and omitted from inventories, analyses, and interpretation	No
D	Data are duplicated in two files with different file names (usually containing different location names)	Duplicate data and location names suggest that additional locations exist beyond those actually measured	Qualified with data from the more certain location (i.e., Log Boom) used in inventories, analyses, and interpretation and the less certain location (i.e., Forebay) omitted from inventories, analyses, and interpretation.	Half included, half omitted
S	City Light thermistors specified at a depth of “surface”	Cannot analyze or plot data quantitatively without a depth value	Qualified, assigned a depth value of 2 ft, and used in inventories, analyses, and interpretation	Yes

1 See Section 4 and Appendix 3.
2 Reputable entities are the NPS, USGS, the NCCN, and City Light.
3 NPS 2015; 2016; 2017; 2018; 2019; 2020.

4.0 DATA OVERVIEW

Data sets were identified from 60 unique locations associated with either the lacustrine portions of reservoirs, the mainstem of the Skagit River, or tributaries to reservoirs or the river. Locations are specified in Appendix 1 and mapped in Appendix 2.

Data inventories were created for continuous temperature measurements,[3] water quality sonde deployments, and grab samples (Appendix 3). Continuous temperature data collected between 2000 and 2020 constitute the vast majority of data inventoried. Nearly all data were included in the inventory for assessment of quality and potential inclusion in analysis. Data rejected due to insufficient metadata pertaining to location consisted of 1,800 days of data from the Skagit River above Ross Lake collected between July 17, 2003 and July 24, 2018. Although these data could be located generally, no additional information was available about their location and thus they could not be used for analysis or interpretation. An assessment of the quality of the available data is provided in Appendix 4.

Data were collected by the NPS, NCCN, USGS, and City Light. In this report for the ISR, City Light is relying upon the established QC and calibration protocols practiced within these organizations. The effort to continue to collate QC procedures is continuing. This will be reported in the Update Study Report (USR). A few continuous temperature data sets were archived without analysis when their durations were short or their records had large gaps. Specific observations within data sets were qualified and removed from analysis when they did not conform to QC protocols described in Section 3.0.

[3] When water quality sonde data measured temperature at a location where a thermistor chain was also deployed, these were combined in data inventories to represent the extent of temperature data available at a reservoir location.

5.0 DATA INTERPRETATION

5.1 Thermistor Chains

Data from thermistor chains in Ross Lake are available at the Hozomeen, Little Beaver, Skymo, and Pumpkin Mountain locations in 2017 and 2018 and at the Log Boom location from 2001 through 2018. Concise summaries of these sensor deployments were created by averaging data collected in a given month across available times, days, and years.

At the Hozomeen location, measurements were made at depths identified as "Bottom" (i.e., 3.28 ft from the bottom of the water column) and "Surface" (i.e., 3.28 ft below the water surface) between June and October. Monthly average surface temperatures ranged from approximately 14 degrees Celsius (°C) in October to approximately 22 °C in August (Figure 5.1-1). Bottom temperatures were 4-6 °C cooler than surface temperatures.

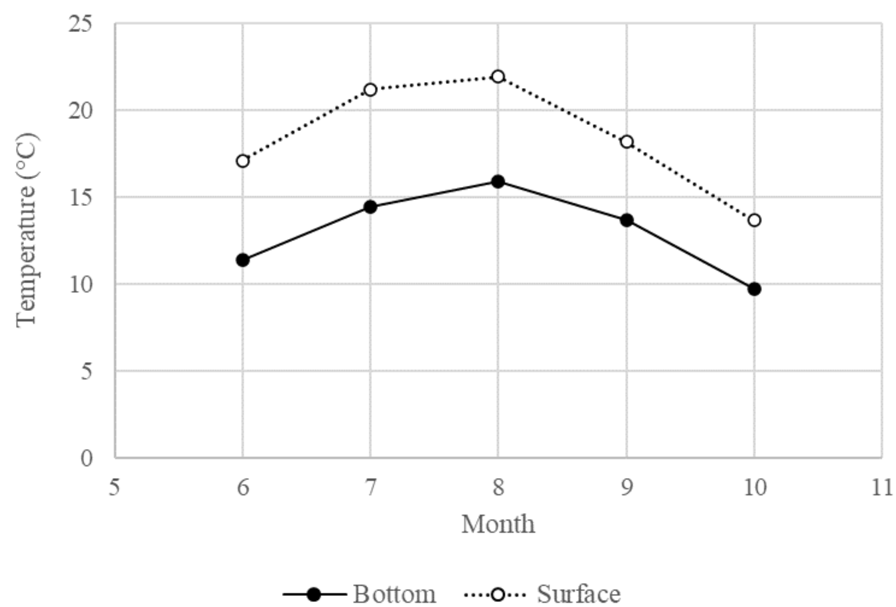

Figure 5.1-1. Monthly average water temperature at Surface and Bottom depths at the Hozomeen monitoring location in Ross Lake. Data were collected by the NCCN in 2017 and 2018.

At the Little Beaver location, surface water increased from a temperature of 15 °C in May to maximum of 22 °C in August and then decreased to 7 °C in December (Figure 5.1-2). A difference in temperature between the "Surface" and "Middle" depths existed in spring but disappeared by September, indicating that summer stratification changed to vertically mixed conditions through much, but not all, of the water column in the early autumn. During summer, surface water temperatures were up to 11 °C warmer than bottom water temperatures; during and after autumn overturn, this difference was 1 °C.

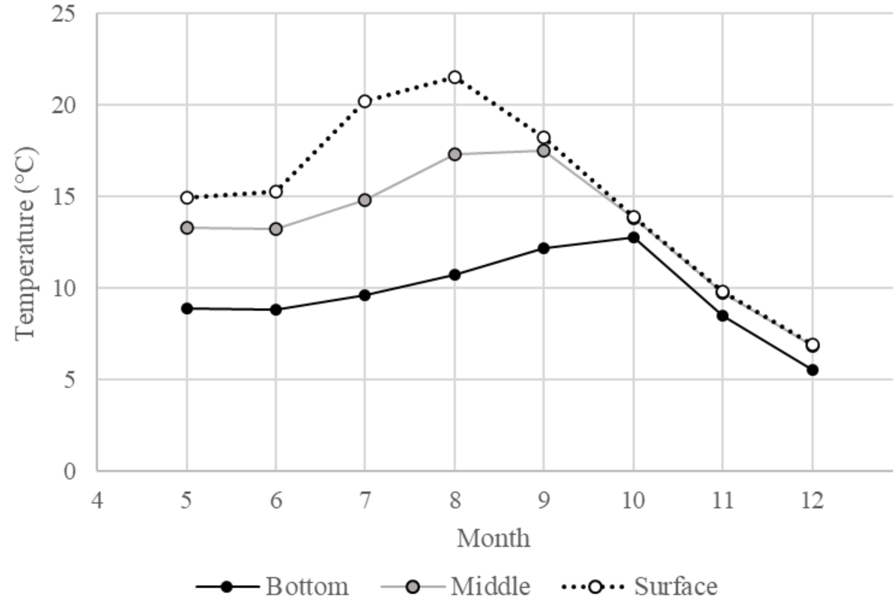

Figure 5.1-2. Monthly average water temperature at Surface, Middle, and Bottom depths at the Little Beaver monitoring location in Ross Lake. Data were collected by the NCCN in 2017 and 2018.

The Skymo location resembled the temporal pattern of the Little Beaver location, though its temperatures were slightly cooler at all depths between May and September with a maximum surface water temperature of 21 °C (Figure 5.1-3). Temperatures in October-December were close to those at the Little Beaver location.

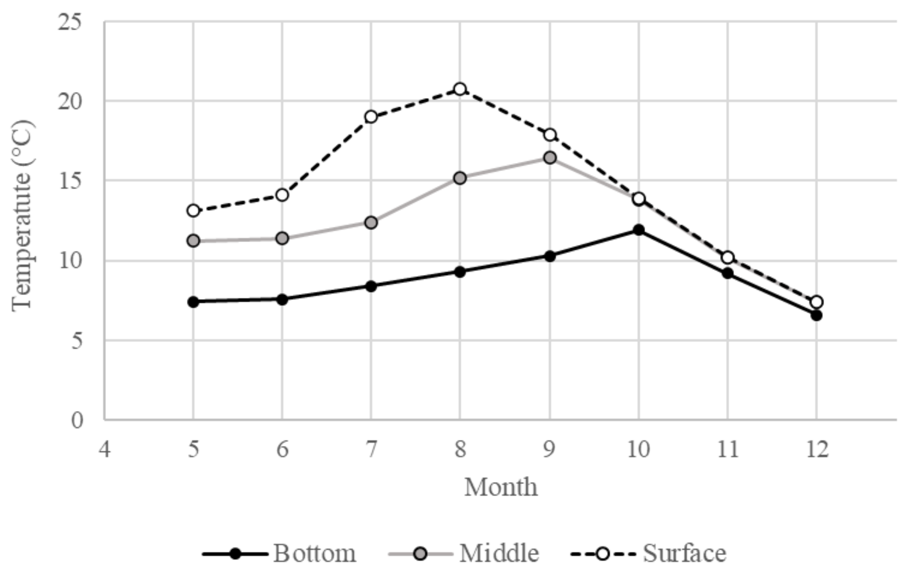

Figure 5.1-3. Monthly average water temperature at Surface, Middle, and Bottom depths at the Skymo monitoring location in Ross Lake. Data were collected by the NCCN in 2017 and 2018.

Monitoring occurred at the Pumpkin Mountain location between May and February. At this location, the monthly pattern of surface water temperatures was similar to and slightly cooler than that of Little Beaver upstream (Figure 5-1.4). Middle depth temperatures were slower to rise during the summer, but this may be because the “Middle” depth at Pumpkin Mountain is likely deeper than the “Middle” depth at the Skymo location because the reservoir is deeper at Pumpkin Mountain, although neither depth is known. The greater depth at the Pumpkin Mountain location also likely explains the nearly constant bottom water temperatures throughout the year.

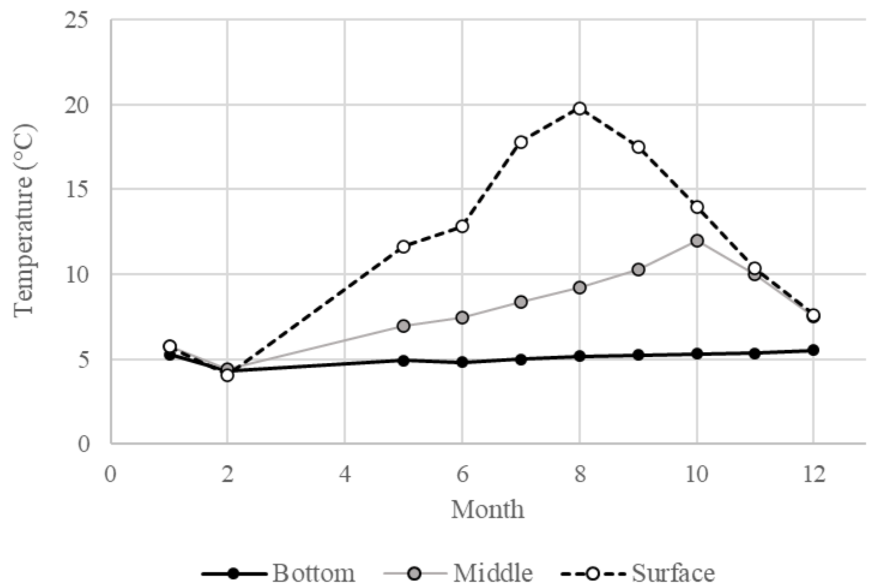

Figure 5.1-4. Monthly average water temperature at Surface, Middle, and Bottom depths at the Pumpkin Mountain monitoring location in Ross Lake. Data were collected by the NCCN in 2017 and 2018.

At the Log Boom location, where monitoring occurred at more depths and over more years, monthly average surface temperatures ranged from slightly below 4 °C to 18.5 °C (Figure 5.1-5). Water at a depth of 200 ft increased from the same minimum to a maximum of 8 °C by November. At Ross Dam, water depths can exceed 500 ft and water level fluctuates by approximately 100 ft each year, indicating that, even at low water level, measurements at 200 ft deep represent an intermediate depth in the water column. Monthly average temperatures at the Log Boom location indicate that stratification begins in April and persists through August. The equal temperature of the 2-ft and 12-ft sensors in September indicate the beginning of vertical mixing of the water column in autumn, which continues through the fall and early winter until the water column is isothermal to a depth of 200 ft by January. Limited additional data from as deep at 330 ft recorded monthly average temperatures of 5.6 °C and 5.7 °C in September through December of some years (not shown).

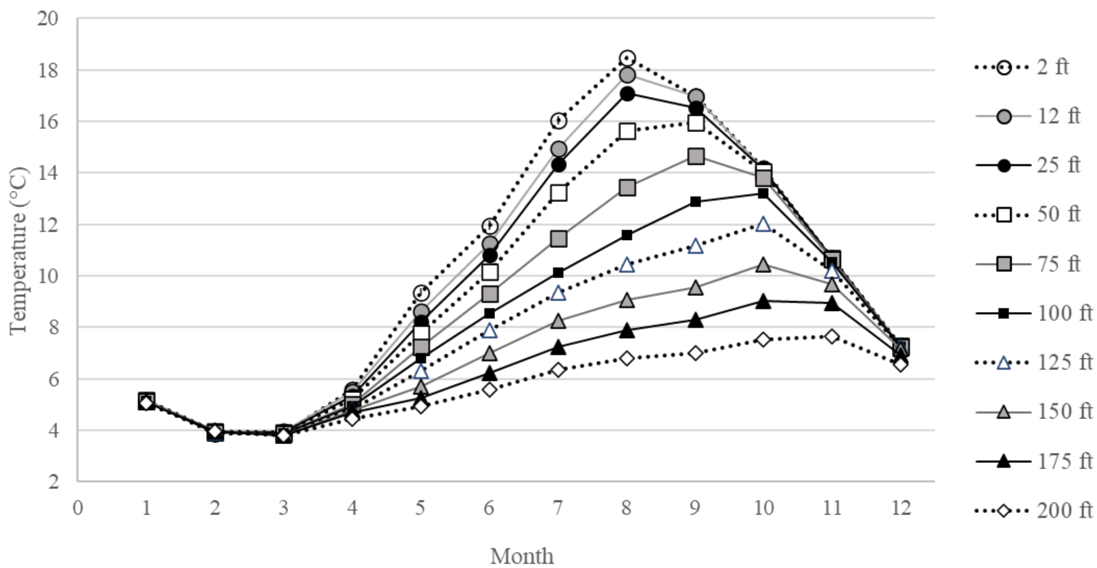

Figure 5.1-5. Monthly average water temperature at 10 depths at the Log Boom monitoring location in Ross Lake. Data were collected by City Light from 2001 through 2019.

In Diablo Lake at the Log Boom location, monthly average surface water temperatures ranged from slightly below 4 °C to slightly above 14 °C (Figure 5.1-6). Stratification began in April and overturn began in September. Diablo Lake is usually >300 ft deep, so the deepest temperature data recorded (i.e., 85 ft) were at an intermediate depth. Thermistor chains at other locations near Diablo Dam showed similar results.

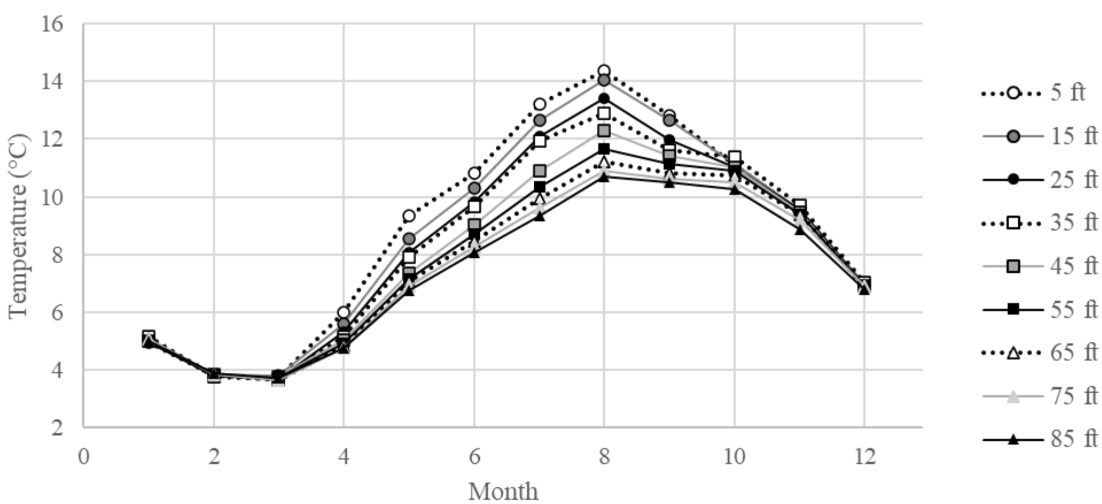

Figure 5.1-6. Monthly average water temperature at 9 depths at the Log Boom monitoring location in Diablo Lake. Data were collected by City Light from 2014 through 2019.

Gorge Lake was colder than Diablo Lake upstream with similar minimum temperatures and summer maximum temperatures slightly above 12 °C (Figure 5.1-7). The water column of Gorge Lake was nearly isothermal to a depth of 80 ft during most of the year, with the peak difference between surface water and water at 80 ft approximately 1 °C.

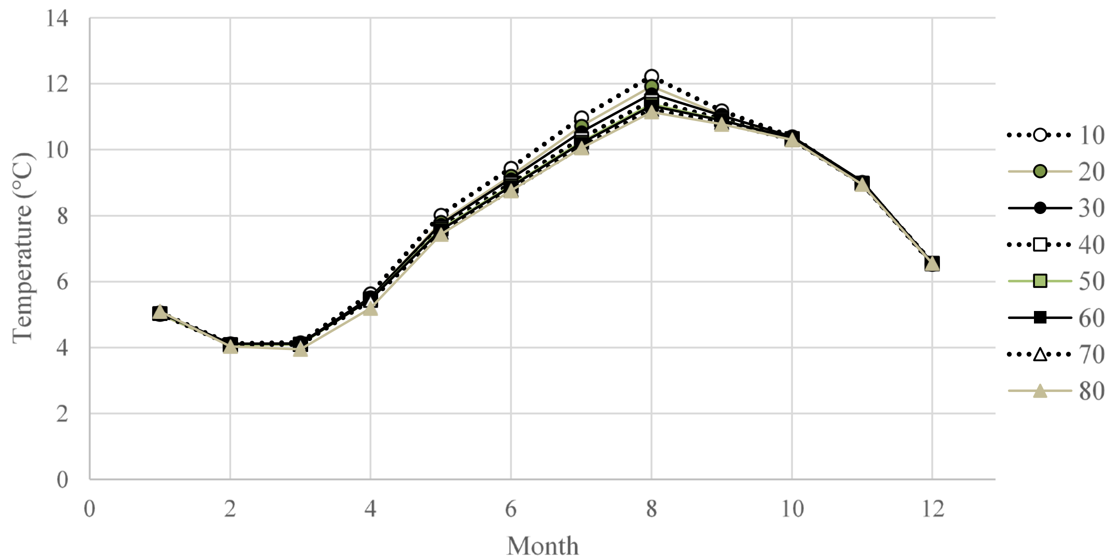

Figure 5.1-7. Monthly average water temperature at 8 depths at the Log Boom monitoring location in Diablo Lake. Data were collected by City Light from 2014 through 2019.

The data of the multiple sensors that comprise a thermistor chain can also be organized as a time series of vertical profiles with values recorded at high frequency (e.g., every 20 minutes at the Ross Lake Log Boom in 2018). Specific times of interest can be easily extracted from the database and plotted. However, the high-frequency data of a thermistor chain is most efficiently displayed as a contour plot with time and depth as the horizontal and vertical axes, respectively, and the temperature indicated by color contours (Appendix 5).

5.2 Continuous Temperature Measurements in Shallow Water

5.2.1 Skagit River Inflow to Ross Lake

Data were available for temperature (T), specific conductance (SC), pH, dissolved oxygen (DO), turbidity, and fluorescent dissolved organic matter (fDOM) in the Skagit River inflow to Ross Lake from August 2019 through November 2020 (T, pH, and turbidity), through June 2020 (SC and DO), or through May 2020 (fDOM; Figure 5.2-1).[4] The reasons for discontinuation of data collection for some but not all sensors is not known because documentation or metadata were not available at the time of report generation.

Temperature followed a predictable seasonal cycle between 0 °C and 15 °C, and SC ranged between 40 and 170 microsiemens per centimeter (µS/cm). Local minima of SC were sometimes associated with minima in T, which may suggest concomitant dilution and lower temperatures

4 Collection of these data is ongoing as of spring 2022.

brought by significant rainstorms and associated cold fronts. The notable decrease in SC between April and June 2020 is consistent with dilution of river water by snowmelt. Local minima in SC were often associated with maxima in turbidity and fDOM, potentially indicating large inflows. Turbidity generally ranged from 0-200 formazin nephelometric unit (FNU), although one large event in late January 2020, which produced a maximum fDOM of 12 quinine sulfate equivalents (QSE), also produced a maximum turbidity of >900 FNU. Otherwise, fDOM ranged from 0-8 QSE with one other local maximum >10 QSE. Unsurprisingly, these patterns suggest that large inflows introduce both particles and organic matter to Ross Lake.

DO was usually >8 milligrams per liter (mg/L) and within 90 percent of saturation, but it was <8 mg/L for six days in September 2019, reaching a minimum of 2.9 mg/L. The cause for this low reading is unknown, but it is associated with a local minimum in pH and a sharp increase in fDOM, and so it does not appear to be due to a faulty sensor. It may be the result of physical or biological processes not captured with existing data. Measurements of pH ranged from 6.9 to 8.4 with most values near 7.

Measurements in the Skagit River upstream of Ross Lake prior to summer 2019 (see next section), when the water quality sonde was deployed in the Ross Lake inflow, indicated that the 2019-2020 sonde deployment measured a representative year relative to the several years preceding it.

5.2.2 Tributary Monitoring

NPS, City Light, and City Light contractors have collected continuous temperature data in many tributaries over the past 20 years. River temperatures varied from near 0 °C in winter to close to 15 °C in summer.

In the Skagit River upstream of Ross Lake, the Klesilkwa River had monthly average temperatures slightly below 2 °C and up to 12 °C. These were slightly more extreme than the Sumallo River and the Skagit River at 26-Mile Bridge and Swing Bridge (Figure 5.2-2). Monthly averages calculated for individual years at the Swing Bridge location varied over a range of approximately 2 °C (not shown), suggesting moderate interannual variability in Skagit River temperatures entering Ross Lake.

Select other tributaries to Ross Lake had monthly average temperatures ranging from less than 2 °C (Devil’s Creek in February) to nearly 12 °C (Ruby Creek in August; Figure 5.2-3). These two creeks had the coldest winter monthly average temperatures, whereas Big Beaver Creek, Lightning Creek, and Hozomeen Creek had slightly warmer temperatures in winter months. Little Beaver Creek, Hozomeen Creek, and Big Beaver Creek had the coolest summer temperatures, peaking at less than 10 °C in August.

Tributaries to Diablo Lake varied, with West Fork Creek and Fisher Creek showing similar annual patterns that were more extreme than McAllister Creek (Figure 5.2-4). Insufficient temperature data were available to evaluate annual temperature variation in Thunder Creek. Stetattle Creek was the only Gorge Lake tributary monitored, and it had a minimum monthly average temperature of 3 °C in February and a maximum monthly average temperature of nearly 12 °C in August (Figure 5.2-5).

Downstream of Gorge Dam, the Skagit River at Newhalem had a smaller range of water temperature variation than did the Skagit River at Swing Bridge upstream of Ross Lake (Figure 5.2-6). Minimum temperatures were approximately 4 °C and maximum monthly average temperatures were near 11 °C at Newhalem. Compared to other Skagit River tributaries downstream from Gorge Dam, the Illabot River, Bacon Creek, and Boulder Creek had higher summer maximum temperatures and comparable temperatures during spring. The Skagit River was 1-2 °C warmer than these tributaries during autumn.

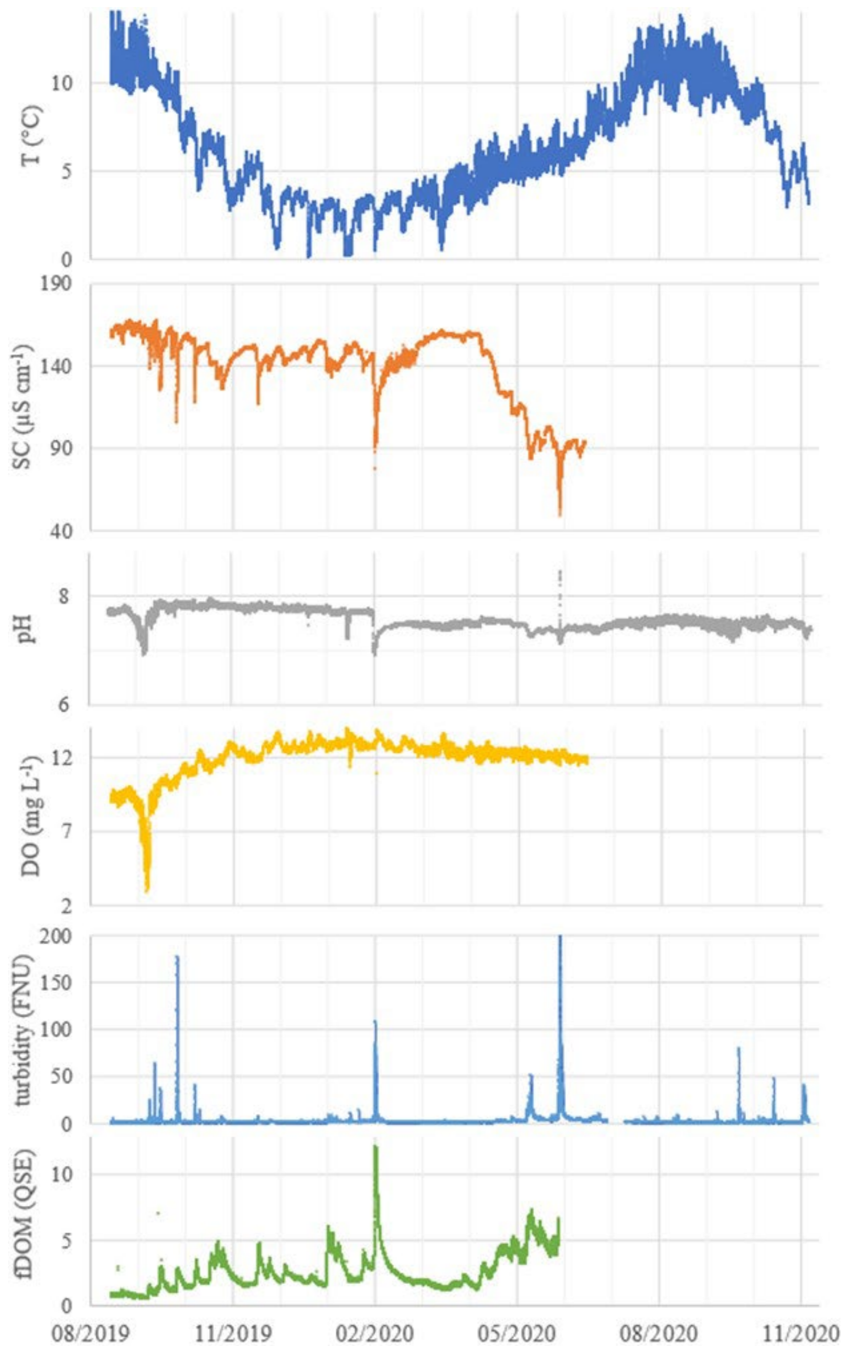

Figure 5.2-1. Continuous data measured by USGS in the Skagit River inflow to Ross Lake.

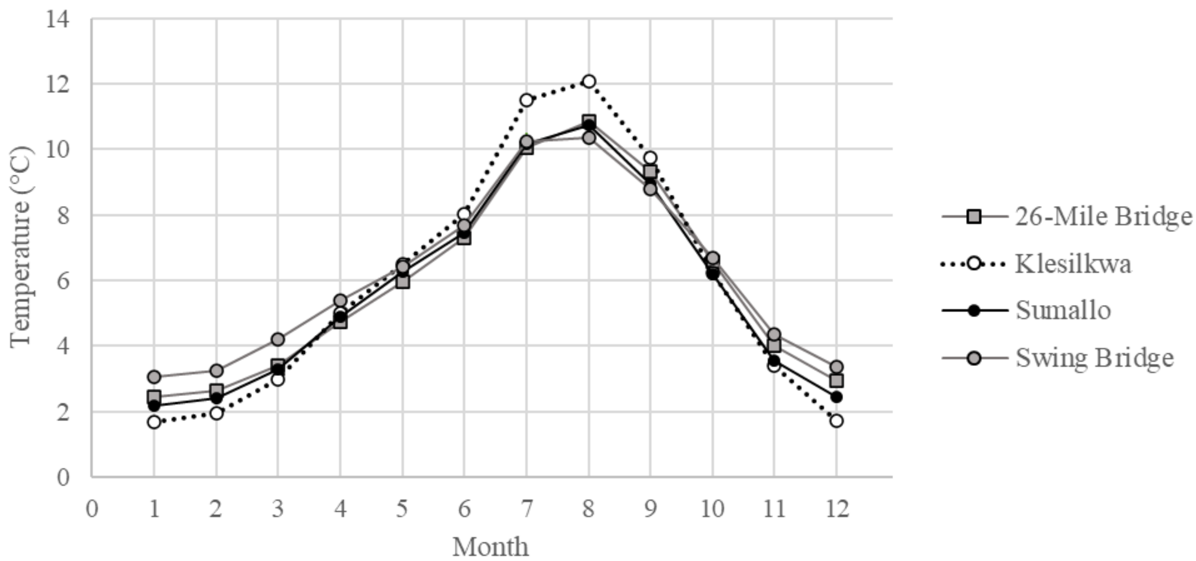

Figure 5.2-2. **Monthly averages of continuous temperature data measured at select Skagit River locations (26-Mile Bridge [2001-2019] and Swing Bridge [2002-2019]) and tributaries (the Klesilkwa [2001-2019] and Sumallo Rivers [2003-2018]) upstream of Ross Lake. Data from City Light.**

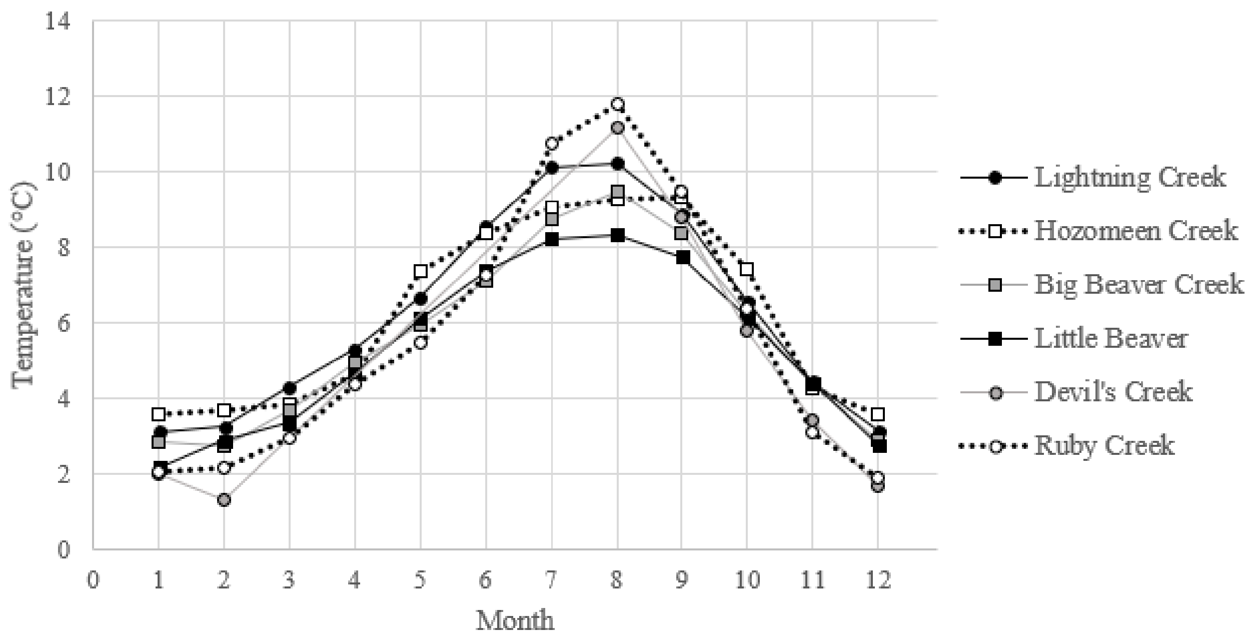

Figure 5.2-3. **Monthly averages of continuous temperature data measured in select tributaries to Ross Lake: Lightning Creek (2000-2017), Hozomeen Creek (2019-2020), Big Beaver Creek (2000-2020), Little Beaver Creek (2001-2019), Devil's Creek (2000-2002), and Ruby Creek (2000-2018). Data from City Light.**

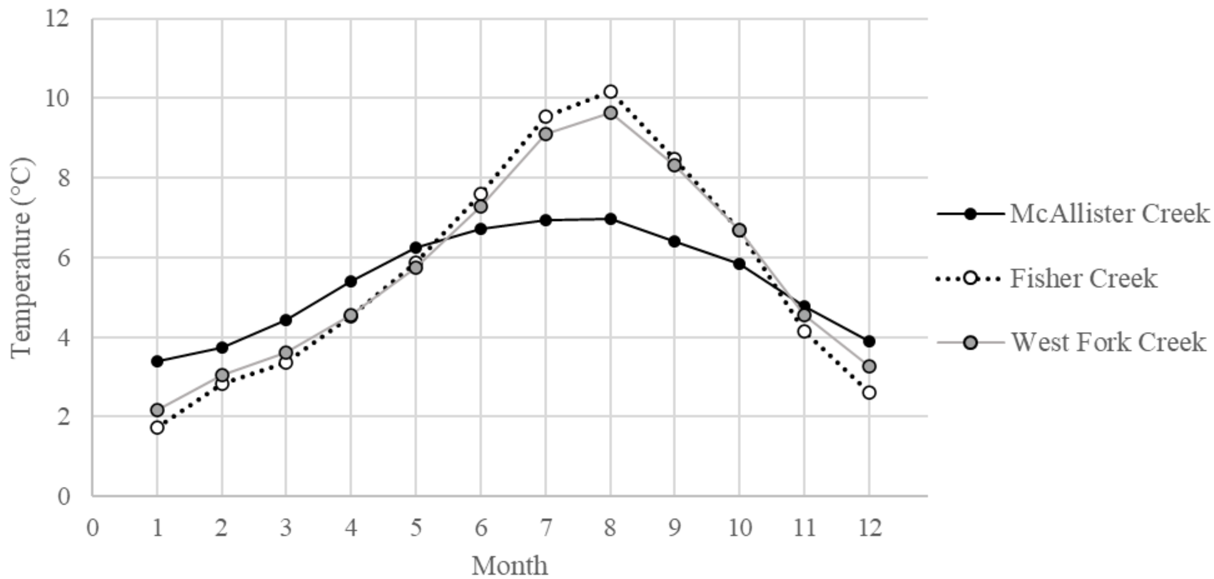

Figure 5.2-4. Monthly averages of continuous temperature data measured in select tributaries to Diablo Lake: McAllister Creek (2014-2017), Fisher Creek (2014-2017), and West Fork Creek (2014-2017). Data from City Light.

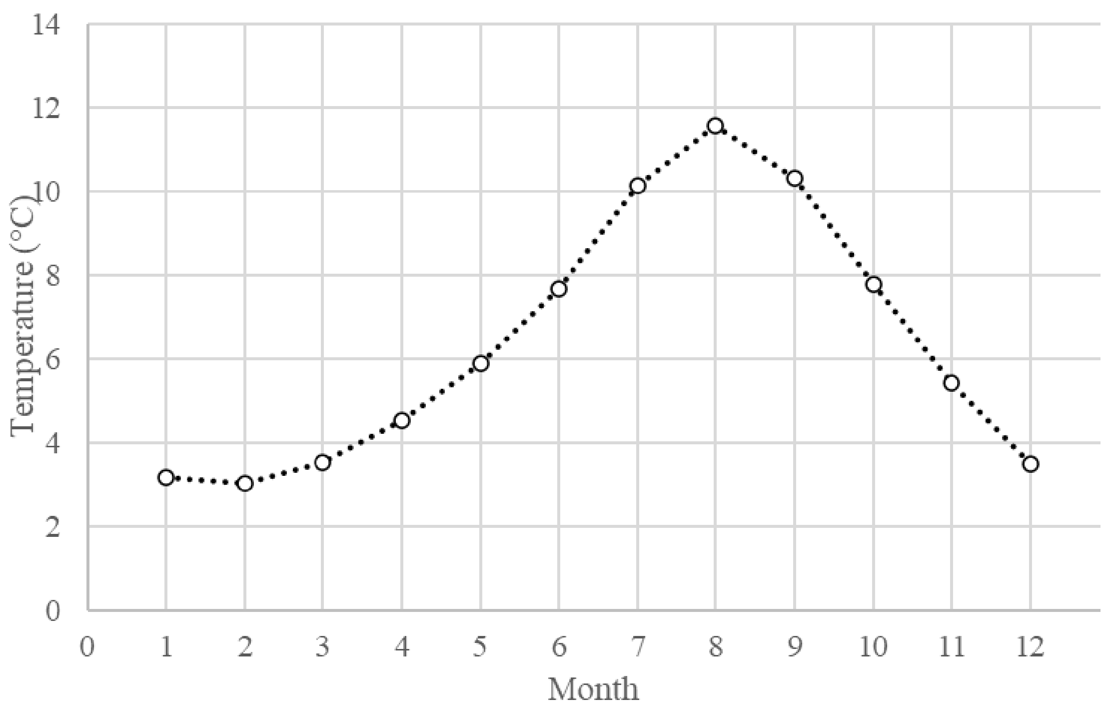

Figure 5.2-5. Monthly average of continuous temperature data measured in Stetattle Creek (2005-2019). Data from City Light.

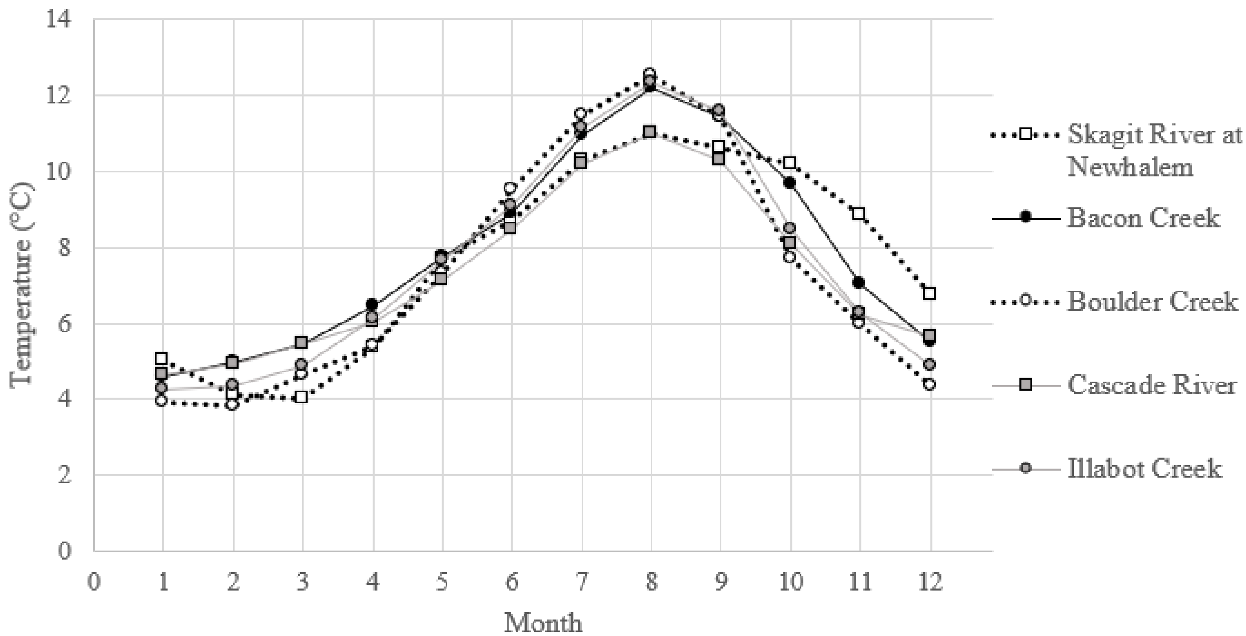

Figure 5.2-6. **Monthly average of continuous temperature data measured in the Skagit River at Newhalem (2013-2019) and select tributaries downstream of Gorge Dam: Bacon Creek (2015-2020), Boulder Creek (2014-2020), the Cascade River (2014-2020), and Illabot Creek (2014-2021). Data from City Light.**

5.3 Vertical Profiles

5.3.1 Ross Lake

From 2015 to 2018, 73 vertical profiles of T, SC, pH, and DO were collected from the Little Beaver, Skymo, and Pumpkin Mountain locations in Ross Lake. These are shown in their entirety in Appendix 6; observations and interpretations are summarized here. Surface water temperatures ranged from near 4 °C in early spring to above 20 °C in late summer.

Vertical profiles were collected between May and November, and, during each of these times, the surface water of Ross Lake was warmer than the water temperature measured in the Skagit River at the Swing Bridge location, which is a short distance upstream of Ross Lake (Figure 5.2-2). Surface water temperatures were slightly warmer at the upstream Little Beaver than the Skymo and downstream Pumpkin Mountain locations during June, July, August, and September of each year. Maximum reservoir temperatures exceeded 20 °C, whereas maximum river temperatures reached only about 12 °C, so the warming of Ross Lake is due to solar radiation, not river inflows.

The warm surface waters of Ross Lake could lead the Skagit River inflow to form a density-driven underflow current as the cooler river water plunged to a depth in the water column where the density of the lake water matched the density of the inflowing river water. Profile data suggests this because of the match of the Skagit River temperature with the lake temperature at 60-100 ft deep at the Little Beaver and Skymo locations. At these depths in spring and summer, notable excursions in SC and DO occur in several vertical profiles, with the most abrupt variations occurring at the Little Beaver location, where the underflow current in the inflow region had likely become an interflow current further down the lake. This current appears to persist into autumn because the river cools more rapidly than the lake, which is likely to exhibit notable thermal inertia and lose its heat to convective cooling more slowly than the river does.

Temperature stratification was evident by May of each year and was pronounced in June and July. When the reservoir was stratified in summer, the surface mixed layer was 40-60 ft thick, suggesting significant mechanical mixing due to wind at these up-lake locations that does not occur near Ross Dam, where a surface mixed layer was not observed (Figure 5.1-2 and relative thermal resistance to mixing [RTRM] plots in Appendix 5). Convective cooling and vertical overturn had begun by the September sampling that occurred in each year, but by mid-November surface waters had not cooled sufficiently to turn over completely with 200-ft-deep bottom water at Pumpkin Mountain, which was 5 °C throughout the year.

These vertical circulation patterns affect DO concentrations differently during different months of the year. In spring, DO in the Skagit River underflow appeared to be higher than DO in the surface water of Ross Lake. However, during the late summer and autumn, this pattern reversed, with notably lower DO concentrations in the deepest water measured at Little Beaver and Skymo relative to surface waters. This is consistent with a notable decrease in Skagit River DO in autumn 2019 (Figure 5.2-1). If this pattern occurs each year, e.g., perhaps due to productivity increasing carbonaceous biochemical oxygen demand in the Skagit River, or perhaps due only to higher water temperatures decreasing DO concentrations at saturation, then this may explain decreased DO concentrations during autumn in deep water in Ross Lake. By November, this low-DO inflow had disappeared, and the DO profiles in the upper two monitoring locations were nearly invariant with depth. These variations were not significant enough to induce low DO concentrations in Ross Lake; the minimum DO concentration measured in any location and at any depth was above 7 mg/L and thus well above the threshold for impairment of fish health. Variation in pH was minor and consistent with the range observed in the Skagit River inflow.

5.3.2 Diablo Lake

Vertical profiles of T, SC, pH, and DO were collected in Diablo Lake in July, August, and September 2018 and in June, August, and October of 2019 (Appendix 6). Even during mid-summer, surface waters of Diablo Lake were notably colder than those of Ross Lake; Diablo Lake temperatures peaked barely above 15 °C due to inflows originating from the middle of the water column in Ross Lake via the Ross Dam intakes.

In each year, stratification of the water column was pronounced by the early summer (June), and convective cooling appeared to have begun by mid-September. Wind-driven circulation appeared to mix the water column to a depth of 20 ft at the sampling location near Diablo Dam in August 2018, but obvious surface mixed layers were not otherwise observed.

DO ranged from 10 mg/L to over 12 mg/L with a median of 10.7 mg/L, and pH varied in a similarly narrow range, 6.78 to 7.84 with a median of 7.26.

5.4 Grab Samples

Grab samples were collected at the Little Beaver, Skymo, and Pumpkin Mountain locations from May through November in 2015 through 2018. Some replicates were collected; this implies that a total of about 80 grab samples were analyzed. These are considered separately for the following groups of analytes:

- Total dissolved solids (TDS);
- Acid neutralizing capacity (ANC) and dissolved organic carbon (DOC);
- Nutrients;
- Anions;
- Cations;
- Chlorophyll *a;* and
- Zooplankton.

No depth information for grab samples was provided, so observations and discussion that follow are discussed without considering variation within the water column.

5.4.1 Total Dissolved Solids

TDS ranged from 26 mg/L to 58 mg/L with an interquartile range of 39-51 mg/L and a median of 44 mg/L (Table 5.4-1). Concentrations were higher in 2015 and 2018; no trend over time was observed. The Little Beaver, Skymo, and Pumpkin Mountain locations had nearly identical distribution statistics for TDS.

Table 5.4-1. Distribution statistics of total dissolved solids (mg/L) in Ross Lake.

Percentile	2015	2016	2017	2018
Maximum	58	42	52	57
75th Percentile	55	41	43	53
Median	50	39	39	51
25th Percentile	46	38	36	49
Minimum	39	35	26	40

5.4.2 Acid Neutralizing Capacity and Dissolved Organic Carbon

ANC samples showed minimal variation between the Little Beaver, Skymo, and Pumpkin Mountain locations, with the 75th percentiles, median, and 25th percentiles of the data at each location differing by no more than 13 microequivalents per liter (µeq/L). Data showed a slight decreasing trend with time (Table 5.4-2).

Table 5.4-2. Distribution statistics of acid neutralizing capacity (mg/L) in Ross Lake.

Percentile	2015	2016	2017	2018
Maximum	640	600	640	560
75th Percentile	570	550	515	520
Median	520	500	490	485
25th Percentile	455	450	440	443
Minimum	370	360	280	360

DOC ranged from 0.2 milligrams of carbon per liter ([mg C]/L) to 9.5 (mg C)/L with a median of 1.4 (mg C)/L. The median and the 75th percentile were higher in 2016 than in other years; the maximum was much lower in 2018 than in other years (Table 5.4-3). Compared to the magnitude of the higher of the two blank samples, which was 0.75 (mg C)/L, distribution statistics of the three Ross Lake locations were indistinguishable.

Table 5.4-3. Distribution statistics of dissolved organic carbon ([mg C]/L).

Percentile	2015	2016	2017	2018
Maximum	9.3	8.9	9.5	3.9
75th Percentile	2.3	3.7	1.8	2.1
Median	1.1	2.4	1.5	1.3
25th Percentile	1.0	1.1	1.2	1.0
Minimum	0.8	0.9	0.8	0.2

5.4.3 Nutrients

Nitrogen concentrations were low in Ross Lake (Table 5.4-4). The maximum total dissolved nitrogen (TDN) concentration was 0.11 milligrams of nitrogen per liter ([mg N]/L); most samples were a fraction of this value. The maximum nitrate+nitrite concentration was 0.08 (mg N)/L, and the maximum nitrate concentration was 0.03 (mg N)/L. No clear seasonal trends were discernable. Nearly all ammonia concentrations were negligible.

When phosphate (PO_4) and uridine-5'-triphosphate (UTP) were measurable, they each ranged from 0.002 milligrams of phosphorus per liter ([mg P]/L) to 0.004 (mg P)/L. Given the caveats discussed in Section 3.3.3 of this report, conclusions beyond the universally low concentration of phosphorus in Ross Lake would be tenuous.

Sulfate concentrations ranged from 1.45 milligrams of sulfur per liter ([mg S]/L) to 1.82 (mg S)/L with a median of 1.62 (mg S)/L. No trends across years, seasons, or locations were observed.

Detection limits (DL) for analytes were not included in available metadata.

Table 5.4-4. Nutrient concentration ranges in Ross Lake (mg/L), from NCCN grab samples.

Cation	Number of Samples	Number of Samples above Detection Limit	Maximum Concentration (mg/L)
Total Dissolved Nitrogen	106	104	0.11
Nitrate + Nitrite	64	42	0.08
Nitrate	24	10	0.03
Ammonia	99	2	0.003
Phosphate	89	37	0.004
Uridine-5’-Triphosphate	95	25	0.004
Sulfate	88	88	1.82

5.4.4 Anions

Chloride ranged from 0.48 mg/L to 0.92 mg/L with a median of 0.55 mg/L. No clear trends could be determined with regard to year or sampling location.

5.4.5 Cations

Cations in Ross Lake were dominated by calcium; whose concentrations were roughly an order of magnitude higher than those of sodium, magnesium, and potassium (Table 5.4-5).

Table 5.4-5. Cation concentrations in Ross Lake (mg/L), from NCCN grab samples.

Cation	Minimum	Median	Maximum
Sodium	1.0	1.2	1.4
Magnesium	1.2	1.3	1.6
Potassium	0.3	0.4	0.4
Calcium	8.6	11.0	12.6

5.4.6 Chlorophyll *a* and Zooplankton

Chlorophyll *a* data were available from 2015 through 2017. They ranged from 0.1 µg/L to 1.1 µg/L with a median of 0.4 µg/L. Maxima during each year and at each of the Little Beaver, Skymo, and Pumpkin Mountain sampling locations were considerably higher than the 75th percentiles at these locations; the 75th percentile of the samples available was 0.5 µg/L. No trend was observed relative to year or location (Table 5.4-6). Seasonally, maxima occurred in June, July, and August, although July and August had distribution statistics comparable to other months (Table 5.4-7). Medians were highest in June and October, which may indicate increases in primary productivity due to relatively nutrient-rich inflows in June and the onset of autumn overturn in October. However, these increased medians were only marginally higher than those of August and September, suggesting that any seasonal increases in productivity are small.

Table 5.4-6. Distribution statistics of chlorophyll *a* by year and location (µg/L) for all months in a given year or location, from NCCN grab samples.

Percentile	2015	2016	2017	Little Beaver	Skymo	Pumpkin
Maximum	0.89	1.07	0.73	0.89	0.73	1.07
75th Percentile	0.59	0.41	0.48	0.59	0.48	0.41
Median	0.40	0.33	0.40	0.40	0.40	0.33
25th Percentile	0.34	0.28	0.32	0.33	0.32	0.29
Minimum	0.20	0.07	0.21	0.20	0.21	0.07

Table 5.4-7. Distribution statistics of chlorophyll *a* by month (µg/L) for all locations and years, from NCCN grab samples.

Percentile	May	June	July	August	September	October	November
Maximum	0.47	0.83	0.89	1.07	0.56	0.68	0.65
75th Percentile	0.38	0.62	0.49	0.45	0.46	0.45	0.38
Median	0.28	0.42	0.32	0.39	0.38	0.40	0.33
25th Percentile	0.25	0.31	0.29	0.34	0.32	0.35	0.28
Minimum	0.07	0.17	0.16	0.30	0.21	0.25	0.22

Zooplankton data were available from 2015 through 2018 in water samples collected from Ross Lake. Samples were collected monthly between May and November at Little Beaver, Skymo, and Pumpkin Mountain, with one sample taken at the Log Boom in July 2015. A typical sample consisted of two replicates. In total, 148 samples were analyzed. Additional data exist for 2019, 2020, and 2021, but they have yet to be processed.

The organism density, expressed in organisms per cubic meter, was calculated for each species within each sample. Mean densities for each species were calculated between replicates. Dominance of specific species varied with time, with overall zooplankton density typically peaking in the early summer (Figure 5.4 1). Maximum organism densities were considerably higher than other samples within the same year (Table 5.4-8).

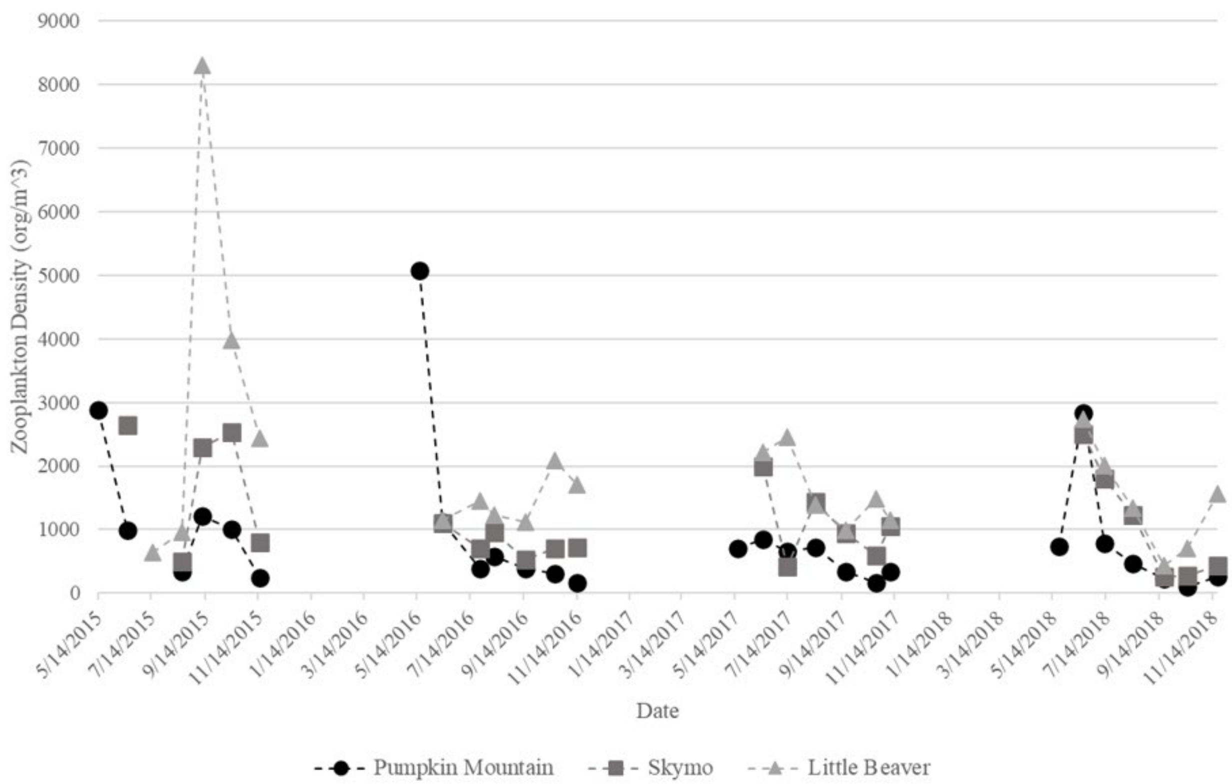

Figure 5.4-1. Total zooplankton density in Ross Lake. Data from NCCN.

Table 5.4-8. Distribution statistics of zooplankton by year (org/m^3) for all locations, from NCCN grab samples.

Percentile	2015	2016	2017	2018
Maximum	8290	5070	2447	2839
75th Percentile	2650	1234	1477	2002
Median	1004	963	939	737
25th Percentile	637	574	658	429
Minimum	103	160	163	100

Samples were analyzed for 196 species of zooplankton. Of these 196 species, 57 species were observed at least once in the samples collected (Figure 5.4-2). Among all organisms sampled, ten species made up 87 percent of organisms present, and four of these ten species made up over 60 percent of organisms present. These were:

- *Kellicottia longispina*, accounting for 19 percent of sampled organisms.
- *Polyarthra vulgaris*, accounting for 18 percent of sampled organisms.
- *Conochilus unicornis*, accounting for 13 percent of sampled organisms.
- *Synchaeta sp.,* accounting for 13 percent of sampled organisms.

All four of these species are rotifers, which are small in size and have large populations in Ross Lake. Though relative dominance of each species varied seasonally, these four species were consistently the most dominant species observed.

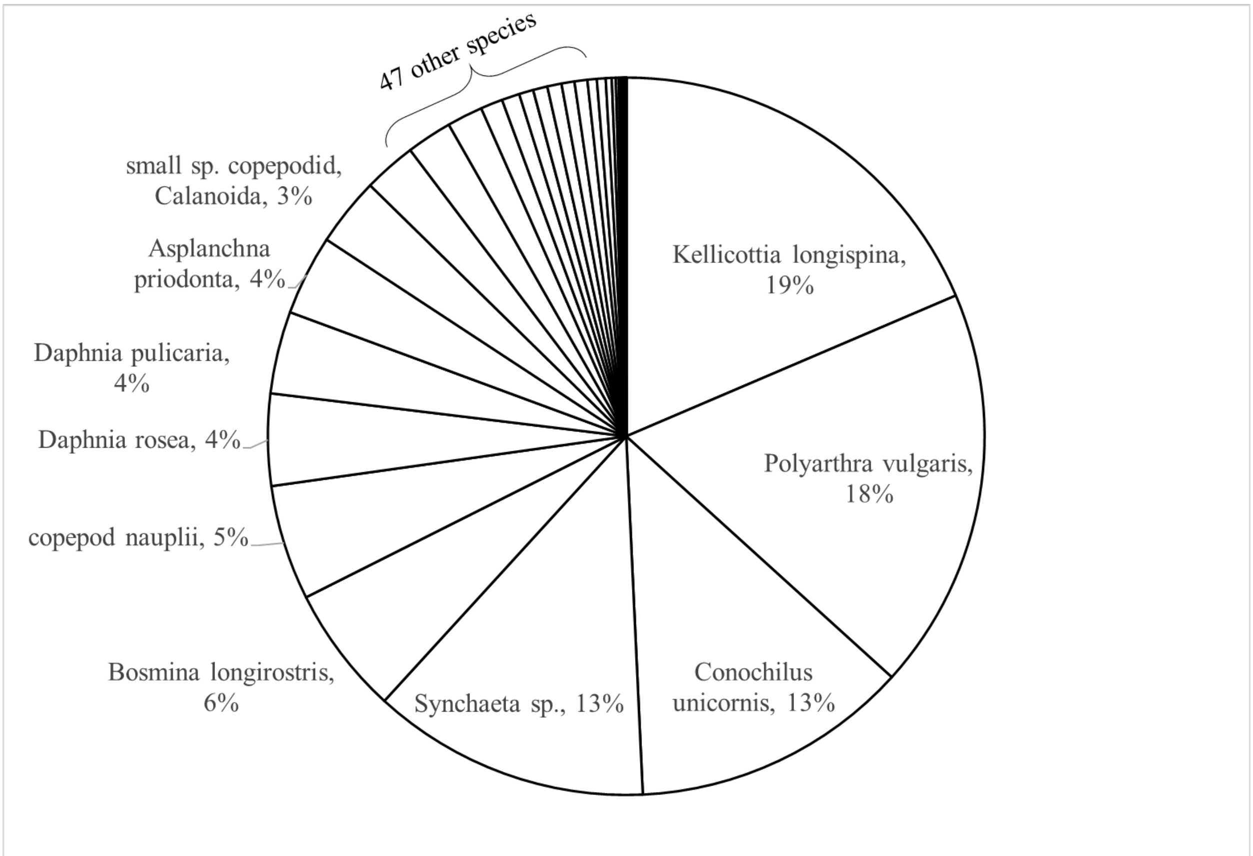

Figure 5.4-2. Percent of total organisms sampled.

The relative dominance of these three species is observed to vary with time but no spatial patterns were observed. The percentage of sampled organisms identified as *Kellicottia longispina* at Little Beaver, Skymo, and Pumpkin Mountain locations in all samples were 24.2 percent, 23.4 percent, and 16.4 percent, respectively. The percentage of sampled organisms identified as *Kellicottia longispina* at all locations over time typically peaks in the late summer (Figure 5.4-3).

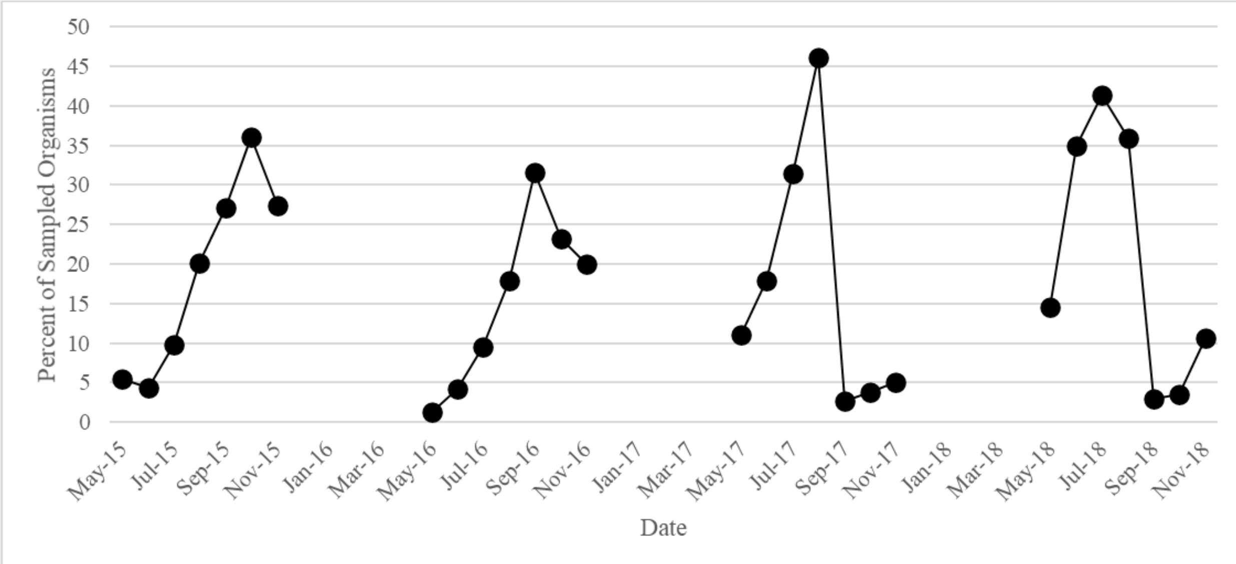

Figure 5.4-3. Relative dominance of *Kellicottia longispina* over time.

Similarly, the relative dominance of *Polyarthra vulgaris* did not vary significantly between locations. The percentage of sampled organisms identified as *Polyarthra vulgaris* at Little Beaver, Skymo, and Pumpkin Mountain were 19.9 percent, 20.1 percent, and 17.4 percent, respectively. The percentage of sampled organisms identified as *Polyarthra vulgaris* at all locations over time typically reaches a minimum in the summer (Figure 5.4-4).

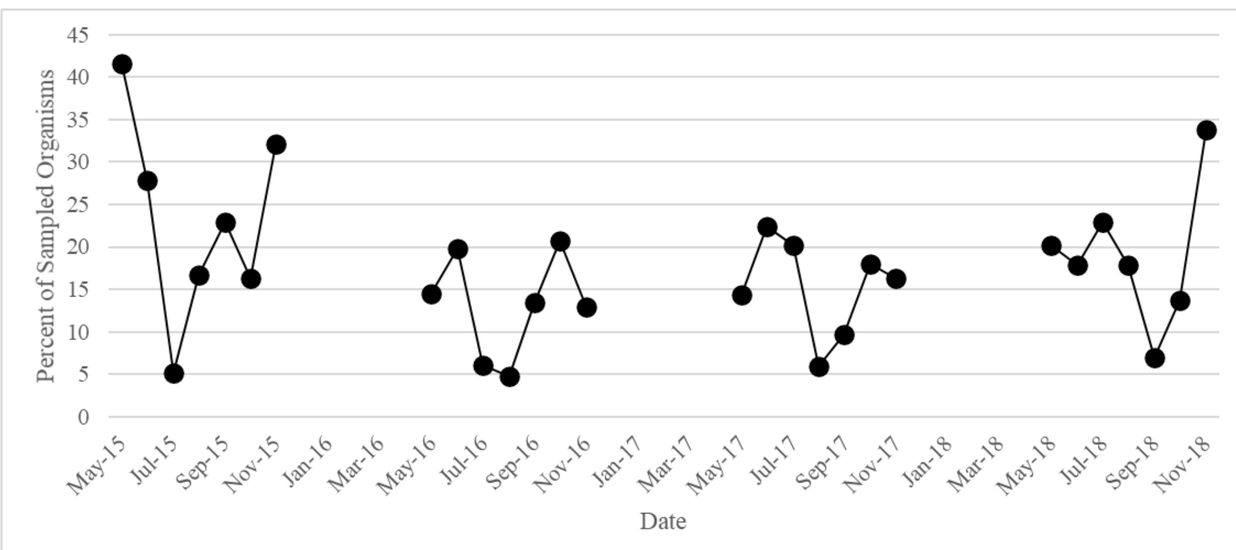

Figure 5.4-4. Relative dominance of *Polyarthra vulgaris* over time.

Conochilus unicornis had slight variations in relative dominance between locations. The percentage of organisms identified as *Conochilus unicornis* at Little Beaver, Skymo, and Pumpkin Mountain were 5.4 percent, 9.8 percent, and 14.6 percent, respectively. The percentage of sampled organisms identified as *Conochilus unicornis* over time typically peaks in the spring (Figure 5.4-5).

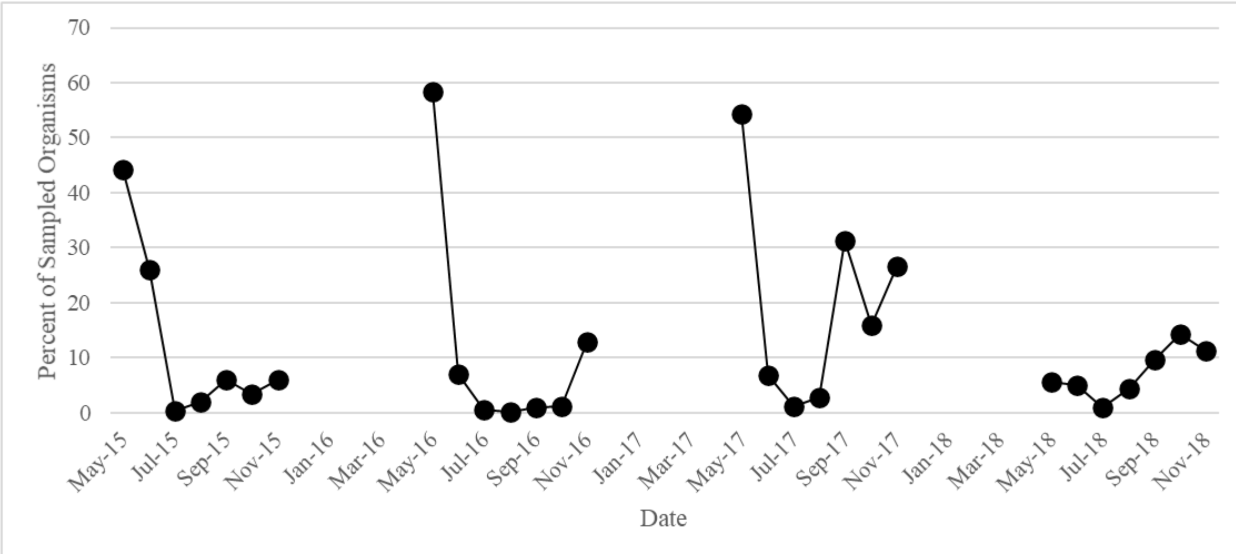

Figure 5.4-5. Relative dominance of *Conochilus unicornis* over time.

Synchaeta sp. also had slight variations in relative dominance between locations. The percentage of organisms identified as *Synchaeta sp.* at Little Beaver, Skymo, and Pumpkin Mountain were 4.1 percent, 7.0 percent, and 15.4 percent, respectively. The percentage of sampled organisms over time at all locations identified as *Synchaeta sp.* typically peaks in the early summer (Figure 5.4-6).

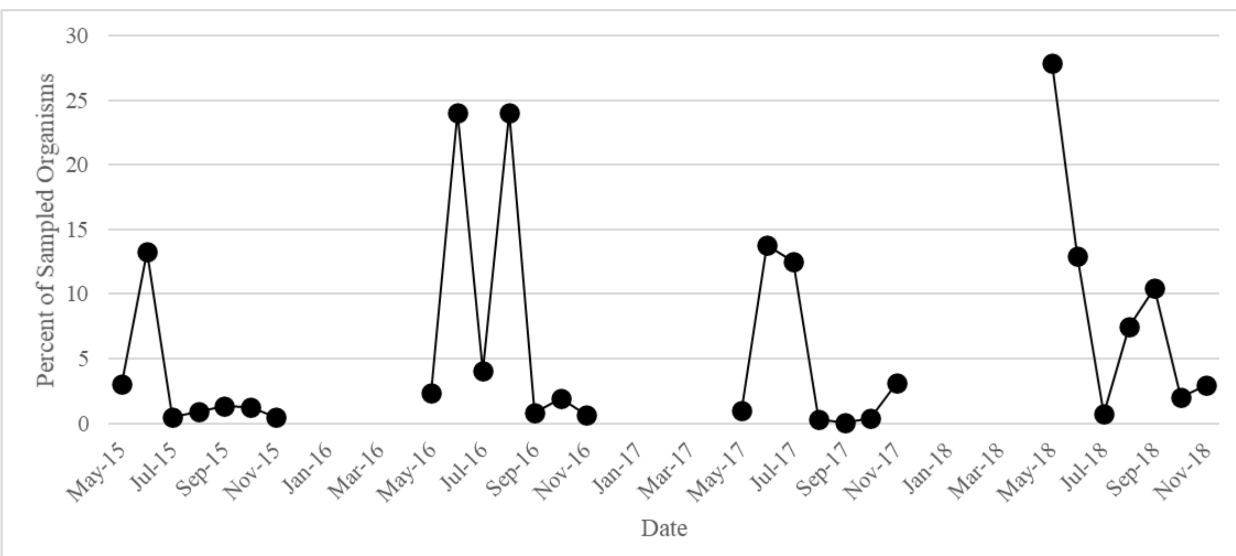

Figure 5.4-6. Relative dominance of *Synchaeta sp.* over time.

5.5 Limnological Summary

The water temperature of the Skagit River at Newhalem is less variable and exhibits lower summer maxima and higher winter minima than the Skagit River at Swing Bridge (the upstream measurement location nearest to Ross Lake). This implies that, despite significant solar heating in Ross Lake during summer, as well as significant variations in the water temperature of the Skagit River tributaries downstream of Gorge Dam, the overall effect of the Project is to dampen the variation of water temperature in the Skagit River downstream.

Within the Project reaches, Ross Lake exhibits yearly vertical circulation patterns typical of a deep, clear, temperate-latitude lake, with pronounced thermal stratification in summer and vertical overturn in autumn. Winter stratification appears to occur in some but not all years near Ross Dam, where wind-induced mixing of surface waters is significantly less than at other monitoring locations further upstream in the reservoir. In summer, solar heating increases the temperature of surface water above that of the Skagit River from May through November of each year, thus leading the Skagit River to enter Ross Lake as a density-driven underflow current. This changes to an interflow current that persists through most, if not all, the length of the reservoir.

This circulation pattern supports the hypothesis that the increase in residence time due to the damming of the Skagit River to form Ross Lake contributes to the oligotrophic nature of this reach of the Skagit River (i.e., the reach impounded by Ross Dam). If the Skagit River moves as an underflow or an interflow current through the length of Ross Lake, then its nutrient load will move through the reservoir at depths where light penetration through the water column is far less than in surface water. If these nutrients reach the dam and exit via the penstocks, then this implies that they can pass through the reservoir without supporting primary productivity that would have otherwise occurred if they had flowed in a shallower reservoir. In turn under this hypothesis, these nutrients would be available to support biological productivity downstream of the Project dams and the impoundments. This effect was documented in a similar long, deep, mountain reservoir, Arrow Lakes Reservoir, British Columbia, and was cited in a modeling study as the explanation for the decline in Kokanee populations following construction of a dam at the outflow of the two natural lakes in order to deepen the lakes, prevent flooding downstream, and produce hydropower (Matzinger et al. 2007). Such a phenomenon should be considered only as a hypothesis at this stage of analysis and is being further investigated as this study proceeds.

Although summer stratification occurs in Diablo Lake near the dam, summertime maximum temperatures are much lower than those in Ross Lake. This is likely a result of both a shorter residence time and somewhat consistent temperatures leaving Ross Dam. In Gorge Lake, stratification does not occur due to a residence time of less than one day.

Analysis of several water quality variables in Ross Lake between May and November indicated that concentrations of total dissolved solids, dissolved organic carbon, and chlorophyll *a* were low and largely invariant at four separate locations. Nutrient concentrations were either undetectable or just slightly above instrument detection limits, and they were also invariant over time and space.

6.0 REFERENCES

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MANAGEMENT AND EVALUATION OF EXISTING WATER QUALITY DATA DRAFT REPORT

APPENDIX 1

MONITORING AND SAMPLING LOCATIONS OF EXISTING WQ DATA

Sampling and monitoring locations were sorted first by water body and then classified as type "Lake," "Tributary," "Skagit Upstream," or "Skagit Downstream" according to the maximum water surface elevation extent of the reservoirs (e.g., upstream locations in Ross Lake were classified as "Lake" sites despite drawdown in this region leading these sites to experience flowing conditions annually Tables A1-1 through A1-5). Accuracies of geographical coordinates are understood to be within 10 meters and coordinates not noted as having high confidence will differ from actual sampling locations due to uncertainty in the coordinates themselves. Confidence is high for several locations following consultation with City Light and examination of metadata files provided.

Table A1-1. Ross Lake sampling locations.

Name	Type	Agency[1]	Page[2]	Latitude	Longitude	Confidence	Confidence Notes
USGS Border Station	Lake	USGS	7	48.99865	-121.0779	High	Location provided by Bob Black of USGS
Hozomeen (Lake)	Lake	NCCN	7	48.997	-121.083111	High	City Light and STS Study Temp Logger Metadata
Little Beaver (Lake)	Lake	NCCN	9	48.936547	-121.07666	High	City Light and STS Study Temp Logger Metadata
Skymo	Lake	NCCN	13	48.86725	-121.033389	High	City Light and STS Study Temp Logger Metadata
Pumpkin Mountain[3]	Lake	NCCN	18	48.787917	-121.051278	High	City Light and STS Study Temp Logger Metadata
Log Boom	Lake	City Light	19	48.737218	-121.054392	High	City Light and STS Study Temp Logger Metadata
Big Beaver Creek Upstream	Trib	NPS	15	48.835506	-121.203726	High	2019-20 stream sensor report, Site NOCA-14-14
Big Beaver Creek Downstream	Trib	NPS	16	48.808299	-121.161291	High	2019-20 stream sensor report, Site NOCA-14-15
Big Beaver Creek	Trib	City Light	18	48.775	-121.06703	High	City Light and STS Study Temp Logger Metadata
Canyon Creek	Trib	NPS	21	48.70708	-120.917626	High	2019-20 stream sensor report, Site NOCA-19-02
Devil's Creek	Trib	City Light	17	48.820562	-121.021332	High	City Light and STS Study Temp Logger Metadata
Granite Creek	Trib	NPS	22	48.589928	-120.805734	High	2019-20 stream sensor report, Site NOCA-14-16
Granite Creek	Trib	City Light		48.70621	-120.9575	High	City Light and STS Study Temp Logger Metadata
Hozomeen Creek	Trib	NPS	7	48.985709	-121.0692	High	2019-20 stream sensor report, Site NOCA-19-01
Lightning Creek	Trib	NPS	12	48.900525	-120.981365	High	2019-20 stream sensor report, Site NOCA-14-20
Lightning Creek	Trib	City Light	13	48.87557	-121.00912	High	City Light and STS Study Temp Logger Metadata
Little Beaver Creek	Trib	NPS	14	48.895031	-121.255671	High	2019-20 stream sensor report, Sites NOCA-14-12, 14-13
Little Beaver Creek	Trib	City Light	10	48.916524	-121.097653	High	City Light and STS Study Temp Logger Metadata
Panther Creek	Trib	NPS	20	48.70426	-120.976737	High	2019-20 stream sensor report, Sites NOCA-14-05, 14-10
Perry Creek	Trib	NPS	11	48.924946	-121.145348	High	2019-20 stream sensor report, Sites NOCA-14-10, 14-11
Ruby Creek	Trib	City Light	20	48.71126	-120.985292	High	City Light and STS Study Temp Logger Metadata
Silver Creek	Trib	NPS	8	48.966201	-121.107015	High	2019-20 stream sensor report, Site NOCA-14-09

1 Data Source Reporting Agency: USGS; NCCN; City Light; NPS.
2 Page in the mapbook provided in Appendix 2.
3 On the map, Pumpkin Mountain is referred to as "Pump."

Table A1-2. Diablo Lake sampling locations.

Name	Type	Agency[1]	Page[2]	Latitude	Longitude	Confidence	Confidence Notes
Ross Powerhouse	Lake	City Light	19	48.729881	-121.071952	High	Powerhouse visible on Google Earth
Buster Brown Bay	Lake	City Light	23	48.7167	-121.10093	High	City Light thermistor deployment metadata
Continuous Temp Station	Lake	NCCN	25	48.716389	-121.130556	High	NCCN Project Data Certification Form
Thunder Arm Nav. Buoy	Lake	NCCN	23	48.70262	-121.09936	High	NCCN Project Data Certification Form
Thunder Arm Bridge	Lake	City Light	24	48.6911	-121.09548	High	City Light thermistor deployment metadata
Diablo Dam or Dam Face	Lake	City Light	25	48.713611	-121.131111	High	Dam face visible on Google Earth
Log Boom	Lake	City Light	25	48.715134	-121.131338	High	City Light thermistor deployment metadata
Thunder Creek (Mouth)	Trib	City Light	24	48.677639	-121.077111	High	Using mouth of creek visible on Google Earth
Thunder Creek (Lower)	Trib	NPS	24	48.668108	-121.069253	High	2019-20 stream sensor report, Site NOCA-19-05
McAllister Creek	Trib	NPS	24	48.666248	-121.069569	High	2019-20 stream sensor report, Site NOCA-14-16
Fisher Creek	Trib	NPS	30	48.603853	-121.047463	High	2019-20 stream sensor report, Site NOCA-14-17
West Fork Thunder Creek	Trib	NPS	31	48.562401	-121.026866	High	2019-20 stream sensor report, Site NOCA-14-18

1 Data Source Reporting Agency: USGS; NCCN; City Light; NPS.
2 Page in the mapbook provided in Appendix 2.

Table A1-3. Gorge Lake sampling locations.

Name	Type	Agency[1]	Page[2]	Latitude	Longitude	Confidence	Confidence Notes
Reflector Bar	Lake	City Light	25	48.713644	-121.143566	High	Inventory of 2020 thermistor replacements
Diablo Powerhouse	Lake	City Light	25	48.715352	-121.142506	High	City Light and STS Study Temp Logger Metadata
Upstream of Stetattle Creek[3]	Lake	City Light	25	48.716763	-121.148274	High	Inventory of 2020 thermistor replacements
Powerline	Lake	City Light	26	48.7085	-121.16502	High	Inventory of 2020 thermistor replacements
Midway	Lake	City Light	26	48.7036	-121.1824	High	Inventory of 2020 thermistor replacements
Log Boom	Lake	City Light	27	48.69913	-121.20081	High	Inventory of 2020 thermistor replacements
Boat Launch	Lake	City Light	25	48.7133	-121.15244	High	From inventory of present thermistor deployments
Stetattle Creek	Trib	City Light	25	48.716966	-121.14819	Med	City Light and STS Study Temp Logger Metadata

1 Data Source Reporting Agency: USGS; NCCN; City Light; NPS.
2 Page in the mapbook provided in Appendix 2.
3 Location is also referred to as “Dolly Hole.”

Table A1-4. Skagit River sampling locations—upstream of Project.

Name	Type	Agency[1]	Page[2]	Latitude	Longitude	Confidence	Confidence Notes
Near Sumallo Confluence	Skagit Upstream	City Light	1	49.209463	-121.080724	High	Confluence visible on Google Earth
Foot Bridge	Skagit Upstream	City Light	1	49.20738	-121.07794	High	City Light and STS Study Temp Logger Metadata
Right Dry Channel	Skagit Upstream	City Light	1	49.20737	-121.074459	High	City Light and STS Study Temp Logger Metadata
Left Wet Channel	Skagit Upstream	City Light	1	49.20737	-121.074459	Med	Assuming co-located with Right Dry Channel
Sumallo River	Trib	City Light	1	49.209119	-121.080789	High	City Light and STS Study Temp Logger Metadata
Klesilkwa River	Trib	City Light	2	49.126498	-121.211069	High	City Light and STS Study Temp Logger Metadata
26_Mile_Bridge	Skagit Upstream	City Light	3	49.11806	-121.16667	High	City Light and STS Study Temp Logger Metadata
Brown Sign	Skagit Upstream	City Light	4	49.0801	-121.11283	High	City Light and STS Study Temp Logger Metadata
Nepopekum	Skagit Upstream	City Light	5	49.04549	-121.09411	High	City Light and STS Study Temp Logger Metadata
Swing Bridge	Skagit Upstream	City Light	6	49.018789	-121.060742	High	City Light and STS Study Temp Logger Metadata

1 Data Source Reporting Agency: USGS; NCCN; City Light; NPS.
2 Page in the map book provided in Appendix 2.

Table A1-5. Skagit River sampling locations—downstream of Project.

Name	Type	Agency[1]	Page[2]	Latitude	Longitude	Confidence	Confidence Notes
Newhalem	Skagit Downstream	City Light	29	48.671306	-121.256	High	City Light and STS Study Temp Logger Metadata
Bacon Creek	Tributary	NPS	32	48.587642	-121.394994	High	2019-20 stream sensor report, Site NOCA-19-09
Cascade River	Tributary	NPS	33	48.527911	-121.270785	High	2019-20 stream sensor report, Site NOCA-14-03
Boulder Creek	Tributary	NPS	34	48.514726	-121.364024	High	2019-20 stream sensor report, Site NOCA-14-08
Rocky Creek	Tributary	NPS	35	48.50602	-121.497104	High	2019-20 stream sensor report, Site NOCA-19-04
Illabot Creek	Tributary	NPS	36	48.482083	-121.500719	High	2019-20 stream sensor report, Site NOCA-14-07
Baker River	Tributary	NPS	28	48.755703	-121.547637	High	2019-20 stream sensor report, Site NOCA-14-04
Hidden Creek	Tributary	NPS	28	48.738231	-121.553197	High	2019-20 stream sensor report, Site NOCA-15-01

1 Data Source Reporting Agency: USGS; NCCN; City Light; NPS.
2 Page in the mapbook provided in Appendix 2.

MANAGEMENT AND EVALUATION OF EXISTING WATER QUALITY DATA DRAFT REPORT

APPENDIX 2

MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA MAPBOOK

Note: the sample location label convention includes different colors to represent the different watersheds and different symbol shapes to represent the sample location types.

MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

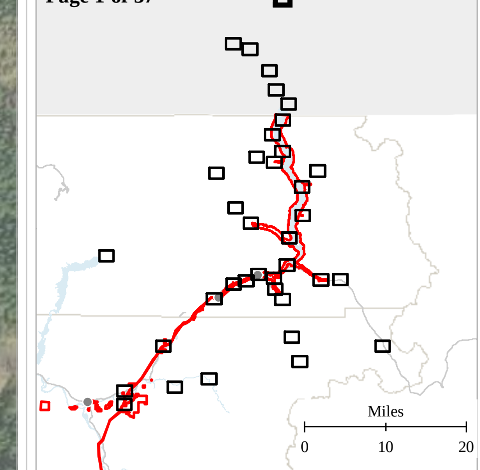
FERC Project Boundary

Watershed
- Diablo
- Gorge
- Ross
- Skagit

Site Type
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies
- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

0 390 780 Feet



Seattle City Light

SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)

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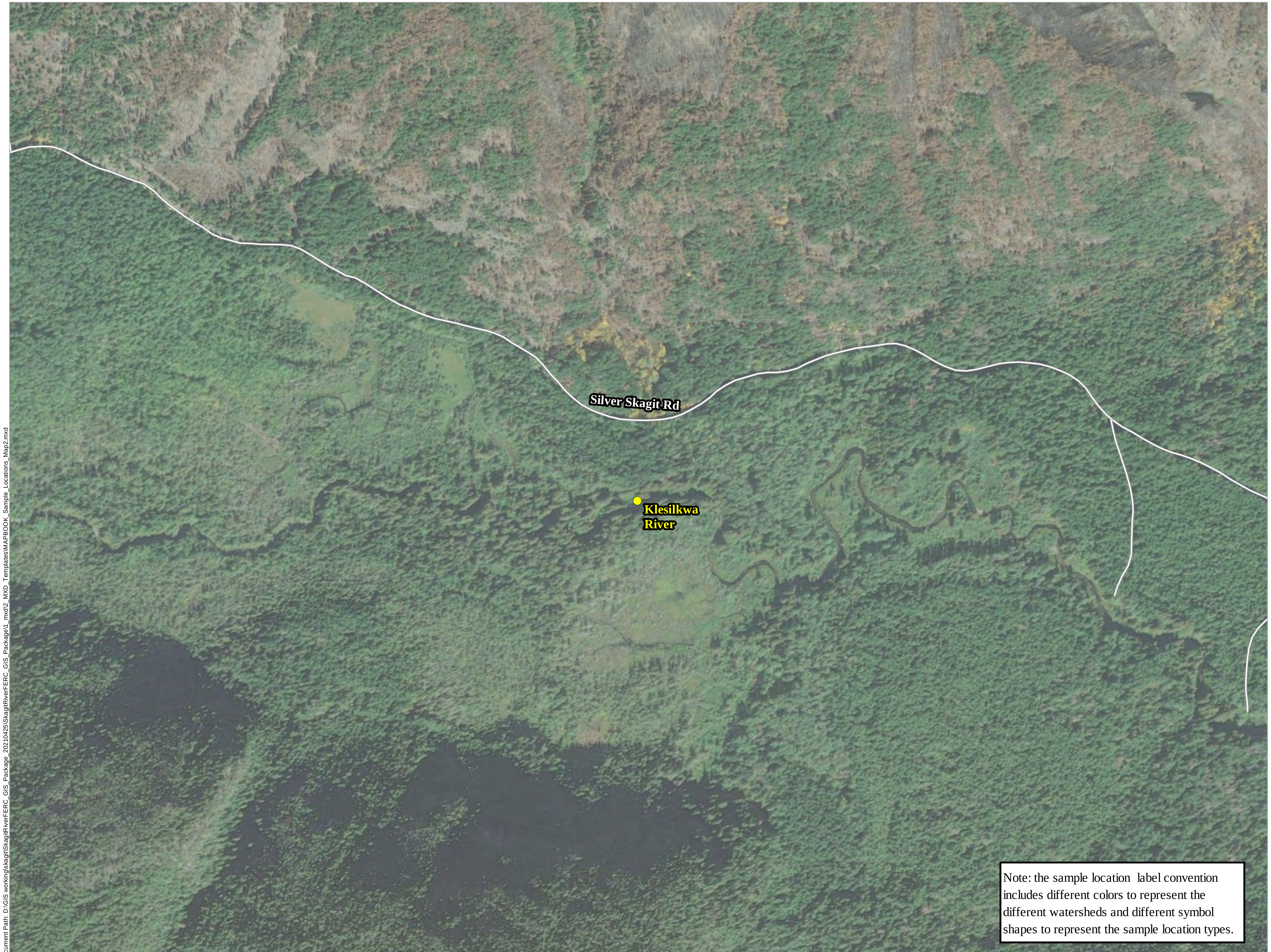


MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

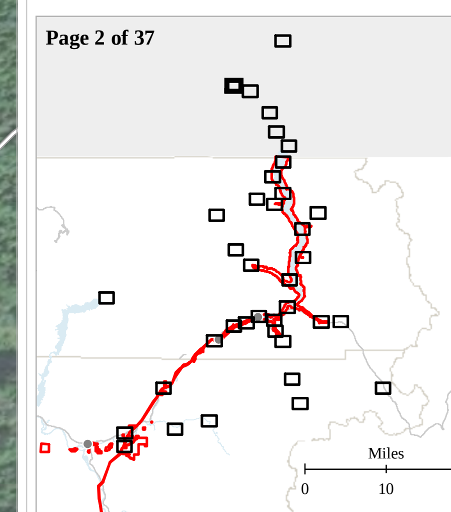
FERC Project Boundary

Watershed
- Diablo
- Gorge
- Ross
- Skagit

Site Type
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies
- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N
0 360 720 Feet



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MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

- Diablo
- Gorge
- Ross
- Skagit

Site Type

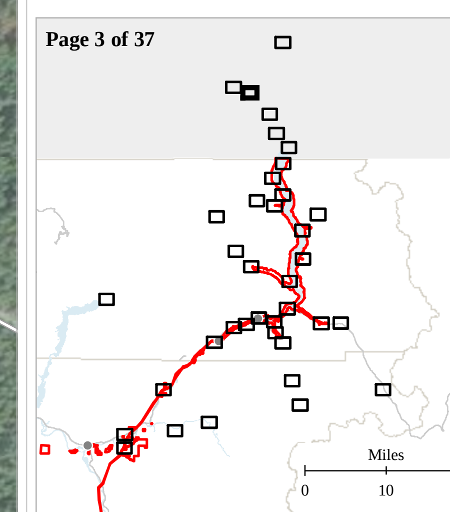
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



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Note: the sample location label convention includes different colors to represent the different watersheds and different symbol shapes to represent the sample location types.

MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

- Diablo
- Gorge
- Ross
- Skagit

Site Type

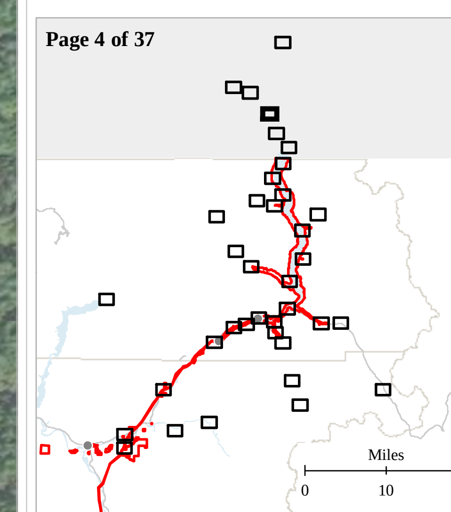
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



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Note: the sample location label convention includes different colors to represent the different watersheds and different symbol shapes to represent the sample location types.

MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

- Diablo
- Gorge
- Ross
- Skagit

Site Type

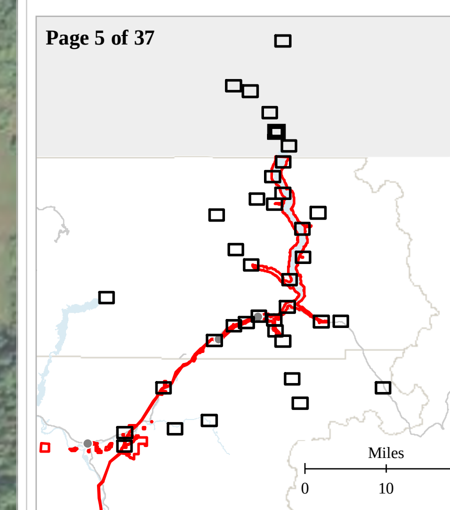
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



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MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

- Diablo
- Gorge
- Ross
- Skagit

Site Type

- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

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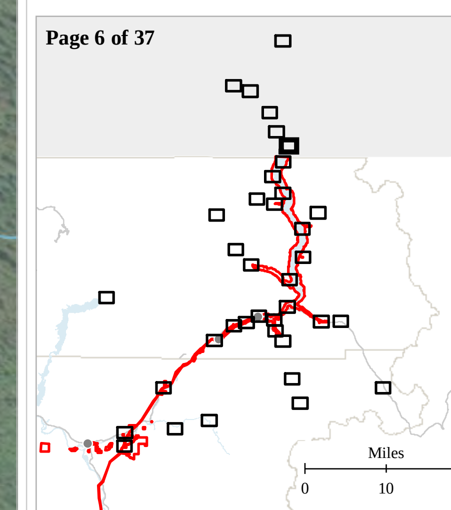

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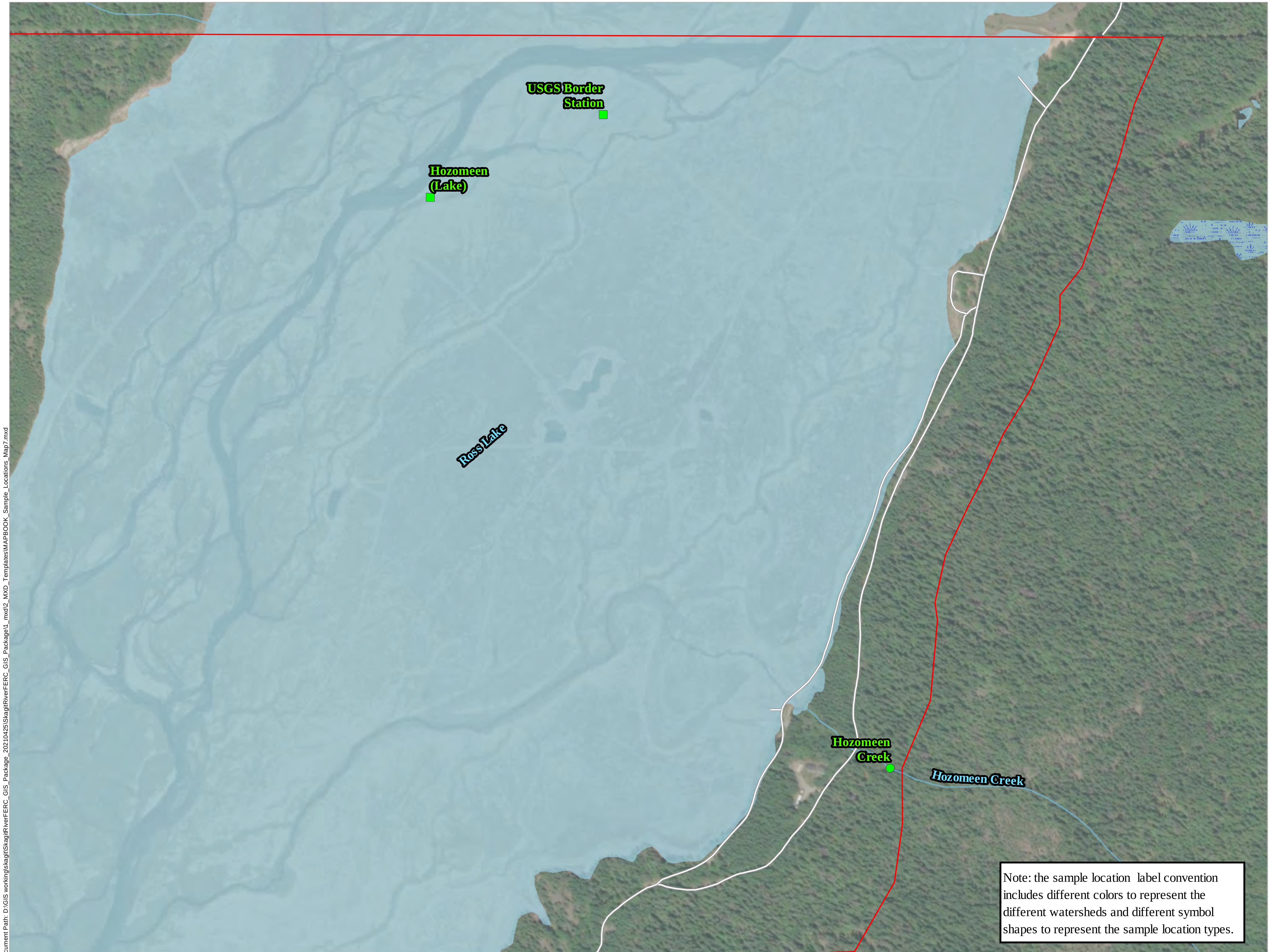
MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA



FERC Project Boundary

Watershed

Diablo

Gorge

Ross

Skagit

Site Type

Lake

Tributary

Downstream

Upstream

Waterbodies

Estuary

Ice Mass

Lake/Pond

Reservoir

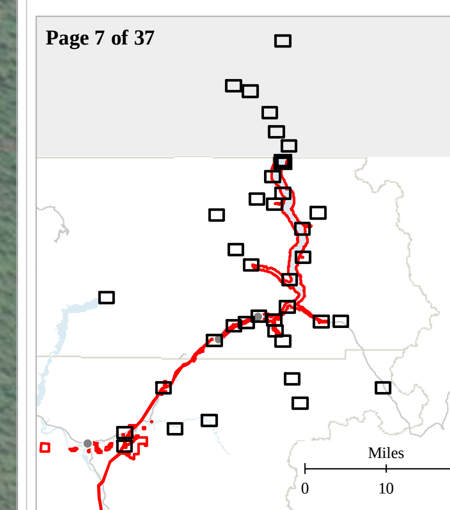
Swamp/Marsh

Stream/River

Streams

N

0 360 720 Feet



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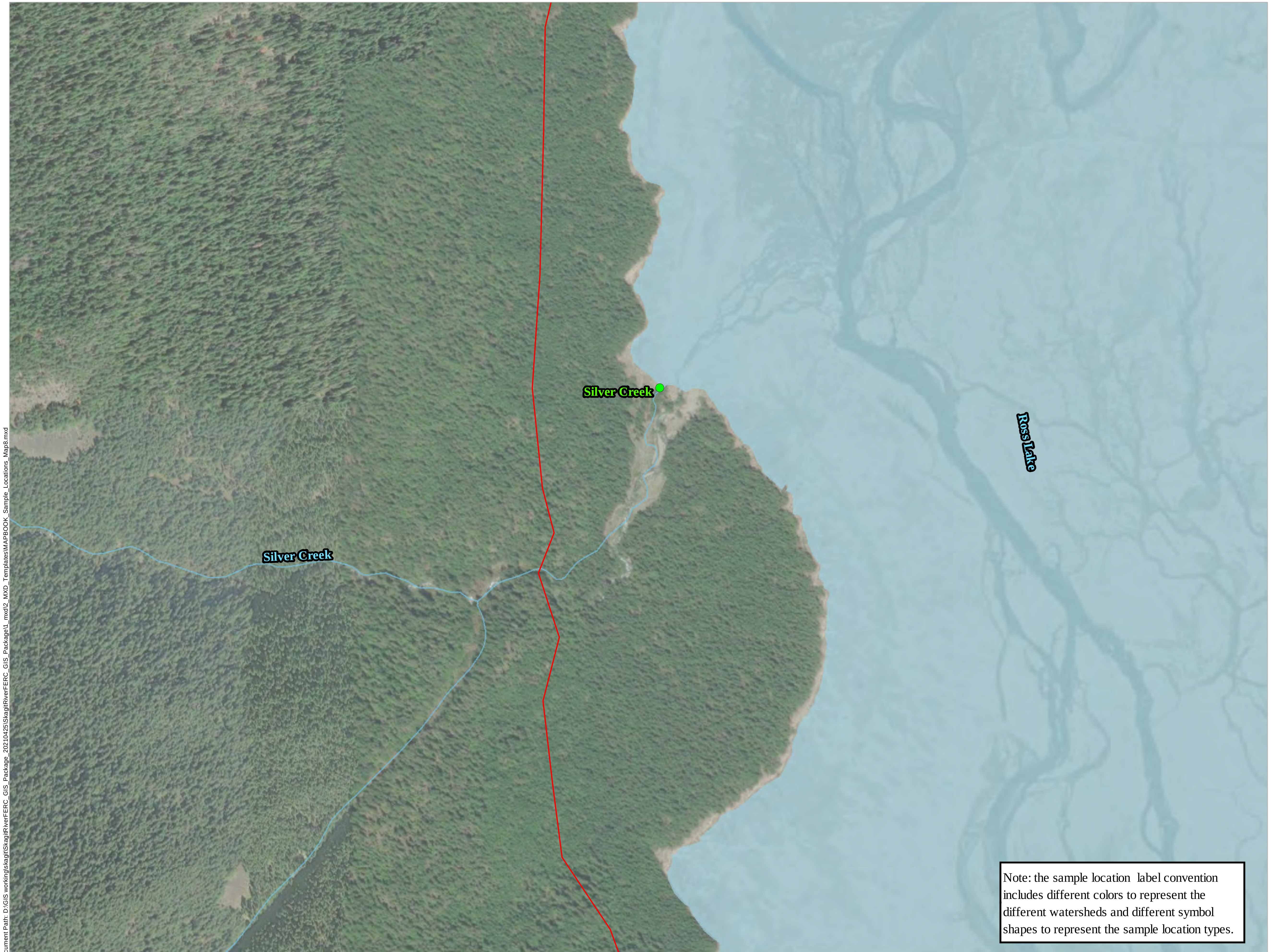
MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA



FERC Project Boundary

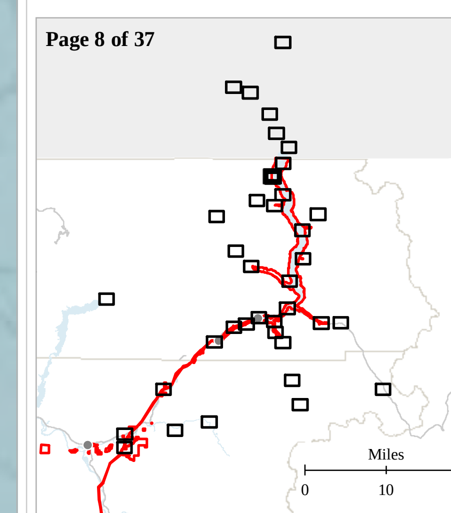
Watershed
- Diablo
- Gorge
- Ross
- Skagit

Site Type
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies
- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



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MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

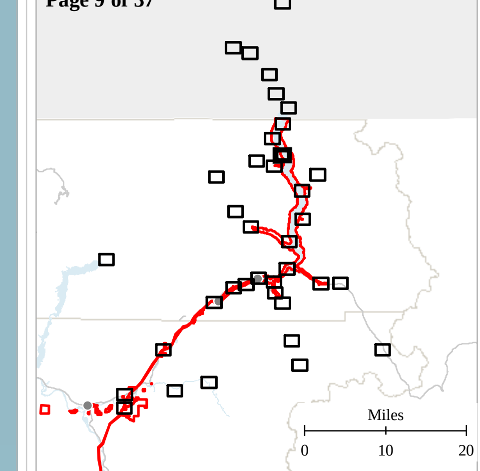
FERC Project Boundary

Watershed
- Diablo
- Gorge
- Ross
- Skagit

Site Type
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies
- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

0 360 720 Feet



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MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

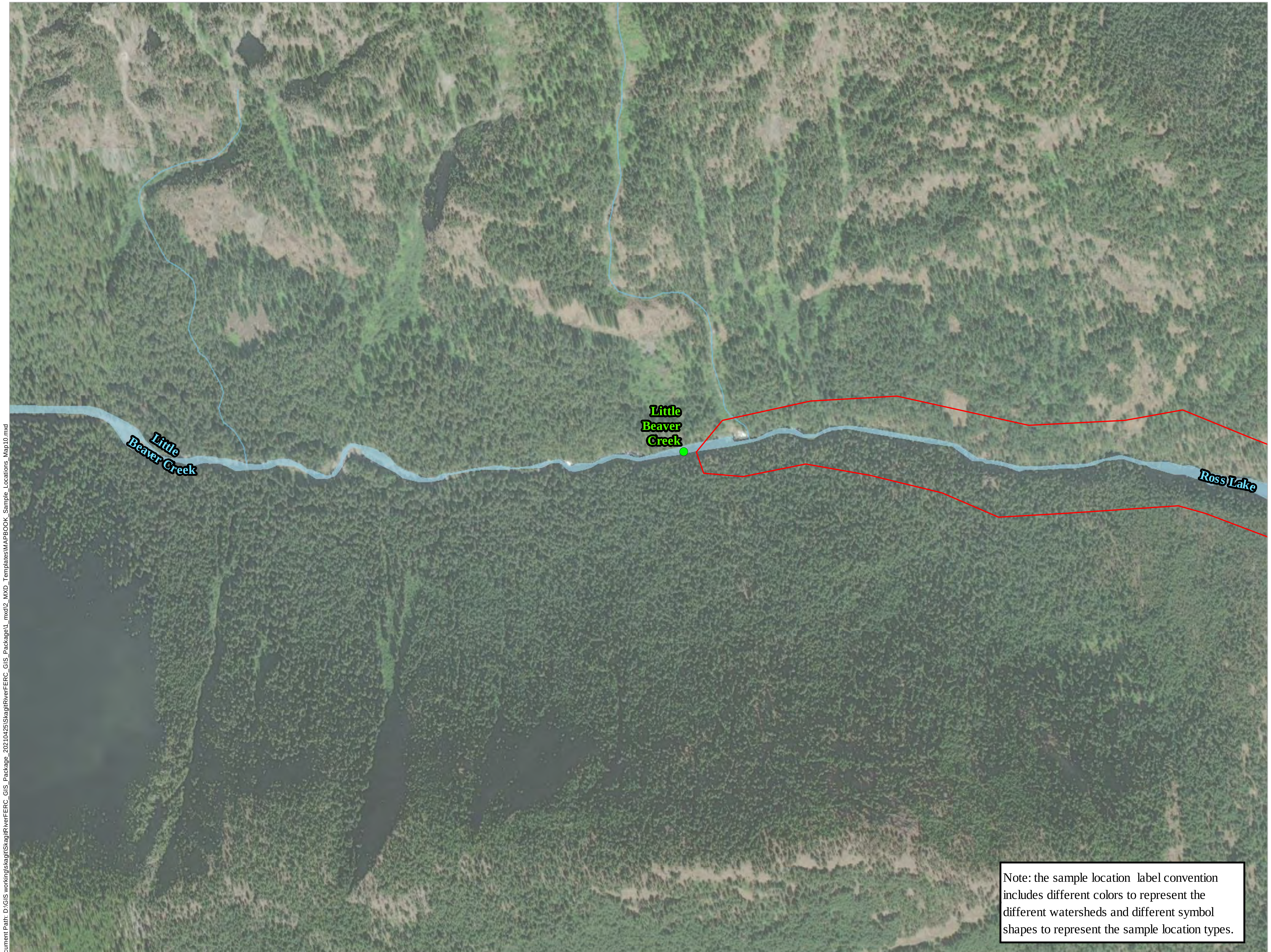
- Diablo
- Gorge
- Ross
- Skagit

Site Type

- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams



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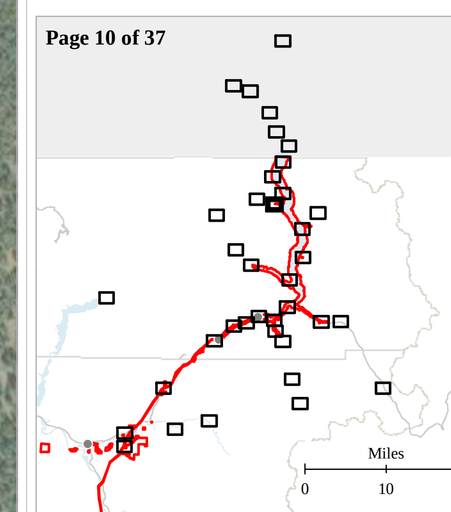

Seattle City Light

SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)

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Document Path: D:\GIS working\Skagit\SkagitRiverFERC_GIS_Package_20210425\SkagitRiverFERC_GIS_Package1_mxd\2_MXD_Templates\MAPBOOK_Sample_Locations_Map10.mxd

Note: the sample location label convention includes different colors to represent the different watersheds and different symbol shapes to represent the sample location types.

MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

- Diablo
- Gorge
- Ross
- Skagit

Site Type

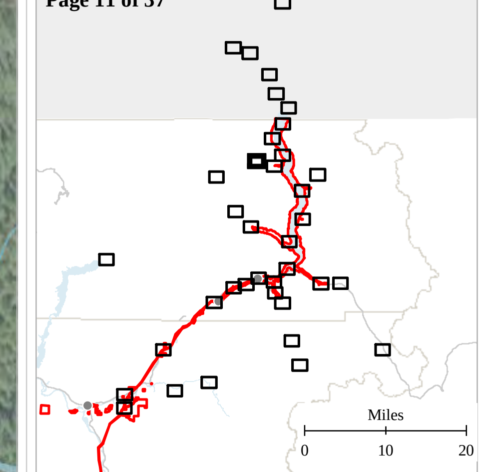
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



Seattle City Light

SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)

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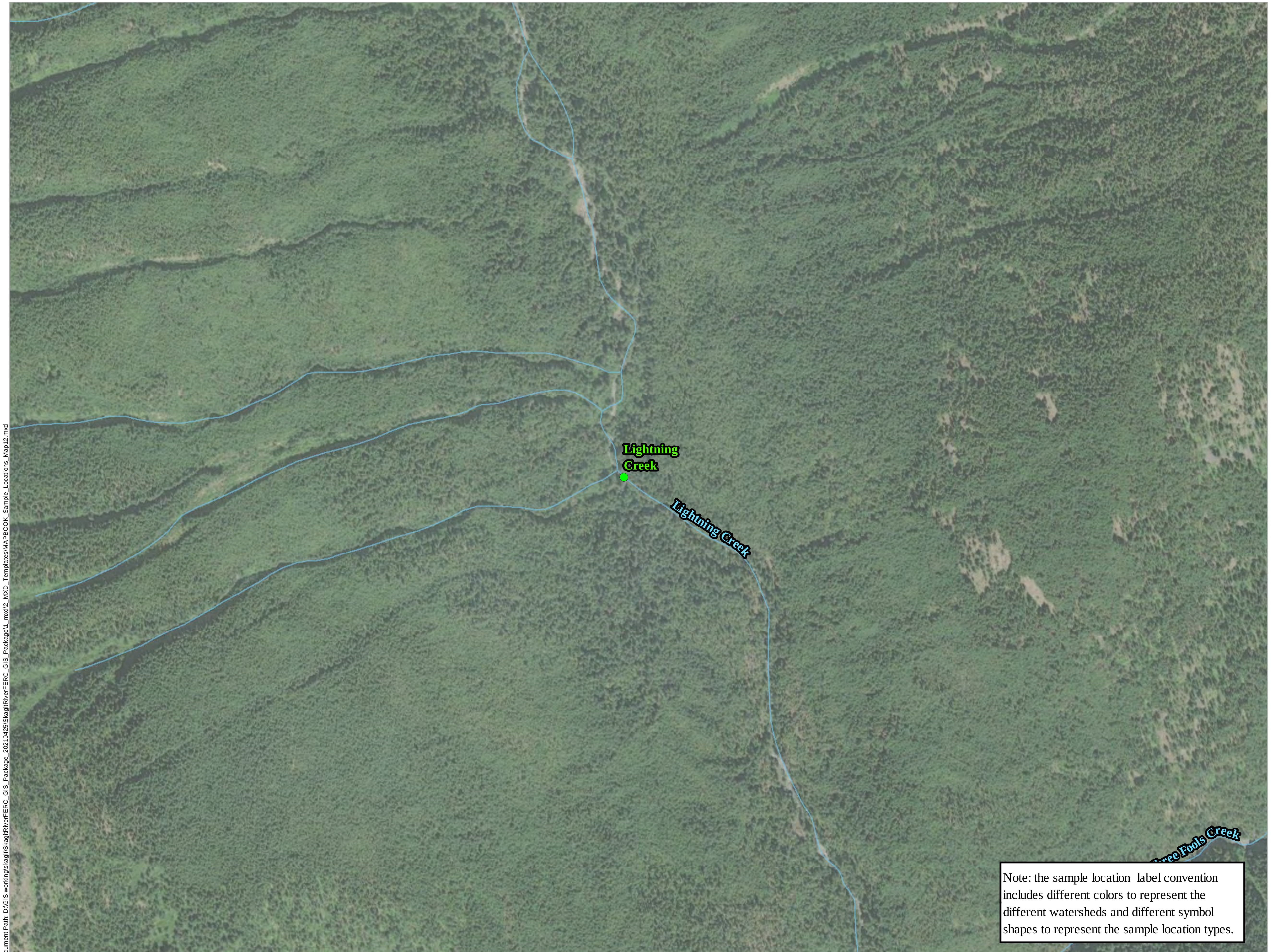
Data Source: NPS, SCL, Four Peaks, City Light, Jeff Fisher, and Geosyntec.



MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

Diablo

Gorge

Ross

Skagit

Site Type

Lake

Tributary

Downstream

Upstream

Waterbodies

Estuary

Ice Mass

Lake/Pond

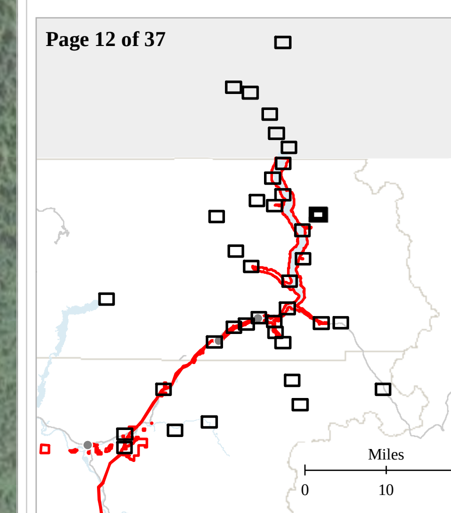
Reservoir

Swamp/Marsh

Stream/River

Streams

0 360 720 Feet



Seattle City Light

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MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

- Diablo
- Gorge
- Ross
- Skagit

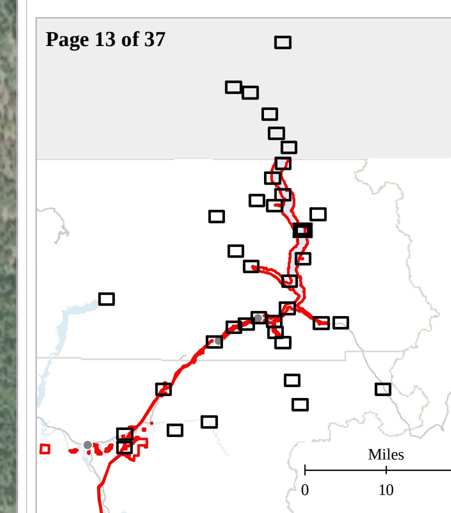
Site Type

- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

0 360 720 Feet



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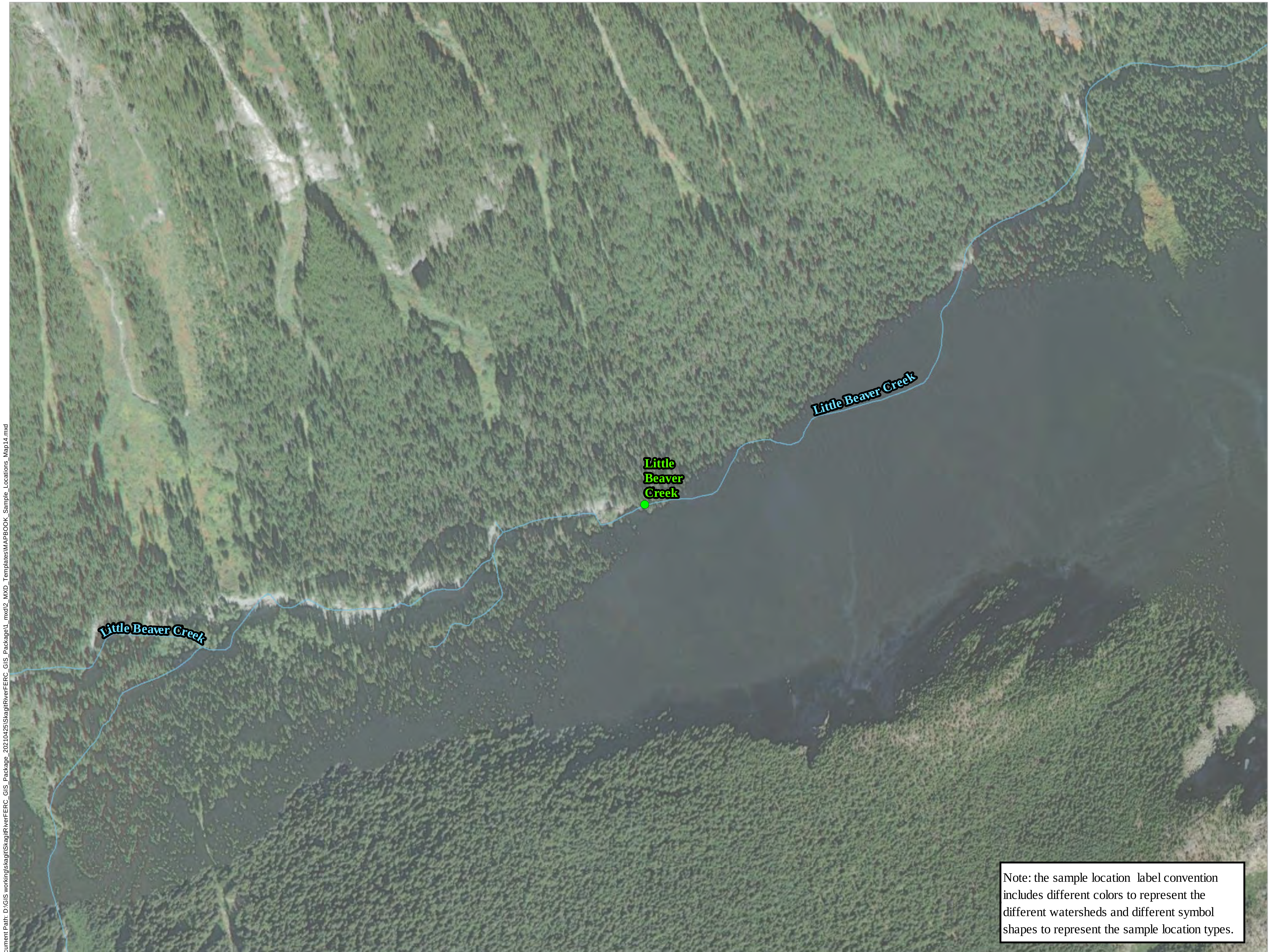


Note: the sample location label convention includes different colors to represent the different watersheds and different symbol shapes to represent the sample location types.

MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

- Diablo
- Gorge
- Ross
- Skagit

Site Type

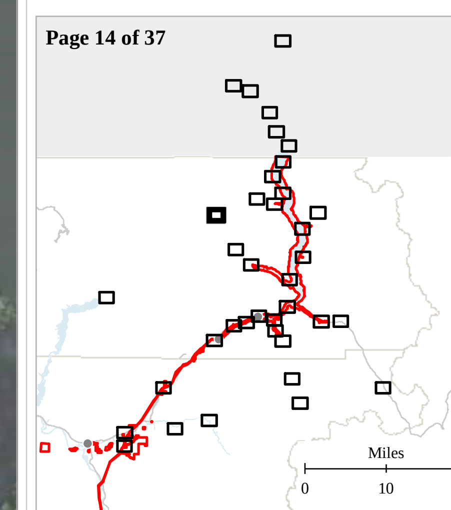
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



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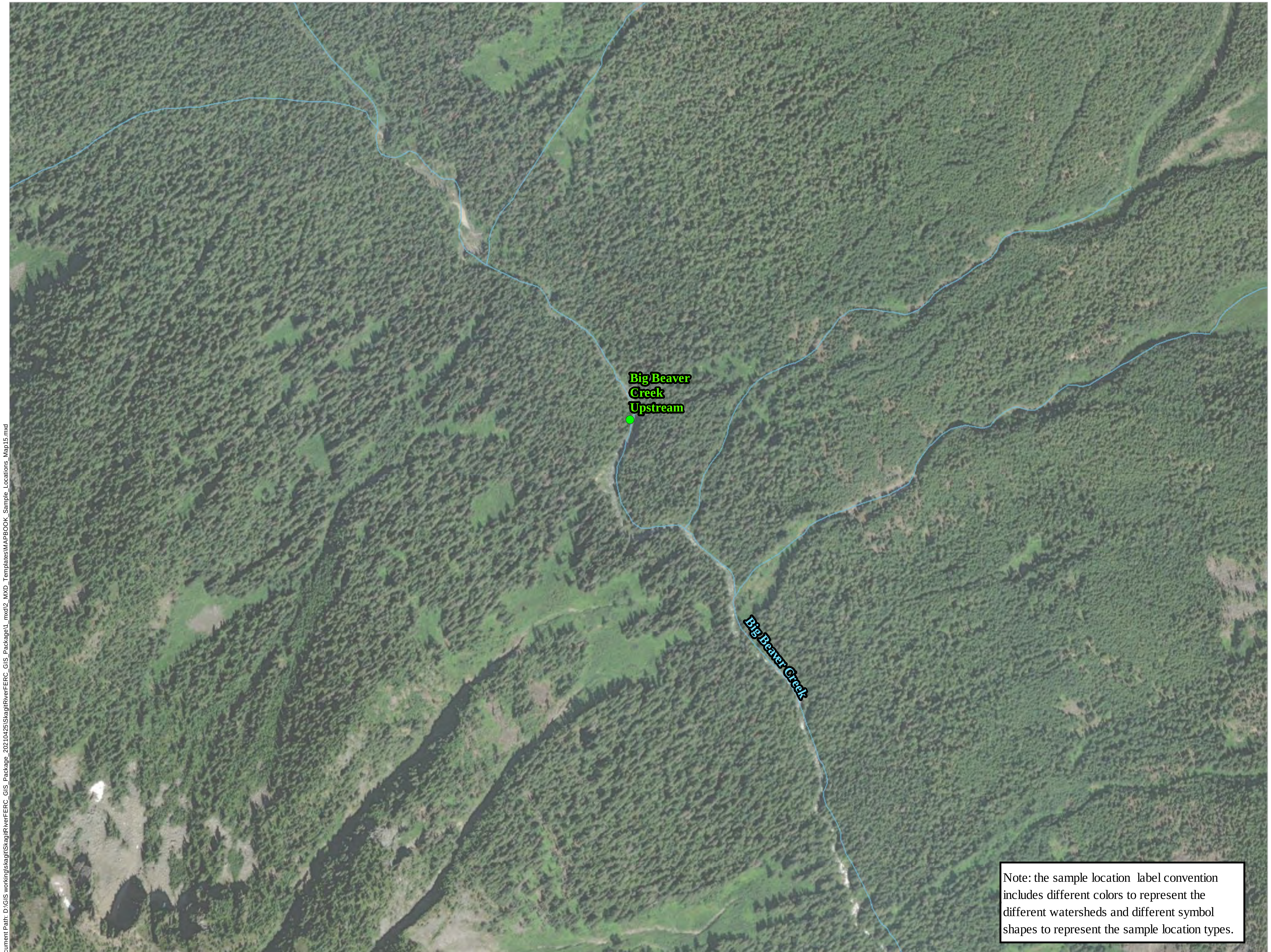
Document Path: D:\GIS working\skagit\SkagitRiverFERC_GIS_Package\SkagitRiverFERC_GIS_Package_20210425\SkagitRiverFERC_GIS_Package\1_mxd\2_MXD_Templates\MAPBOOK_Sample_Locations_Map14.mxd



MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

Diablo

Gorge

Ross

Skagit

Site Type

Lake

Tributary

Downstream

Upstream

Waterbodies

Estuary

Ice Mass

Lake/Pond

Reservoir

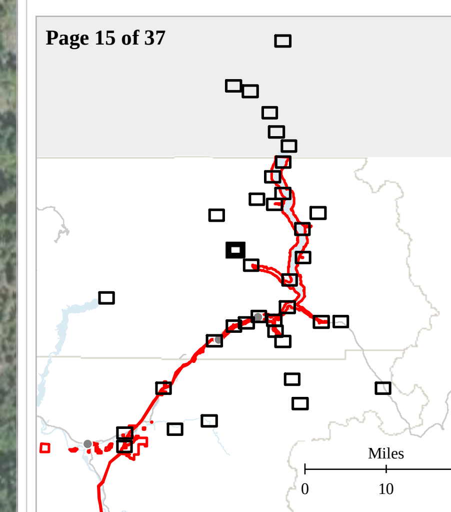
Swamp/Marsh

Stream/River

Streams

N

0 360 720 Feet



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SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)

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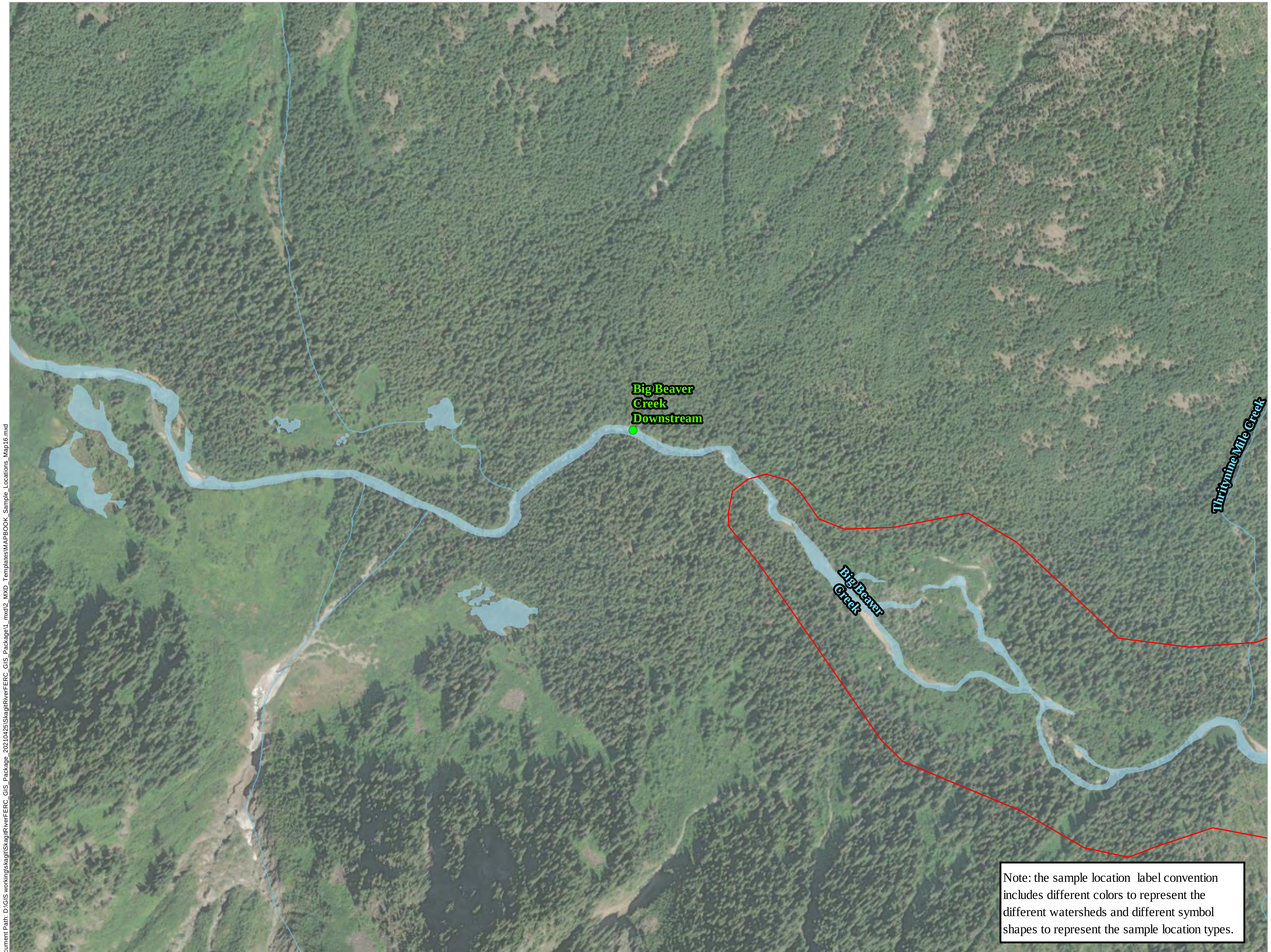
Document Path: D:\GIS working\Skagit\SkagitRiverFERC_GIS_Package_20210425\SkagitRiverFERC_GIS_Package1_mxd\2_MXD_Templates\MAPBOOK_Sample_Locations_Map15.mxd



MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

- Diablo
- Gorge
- Ross
- Skagit

Site Type

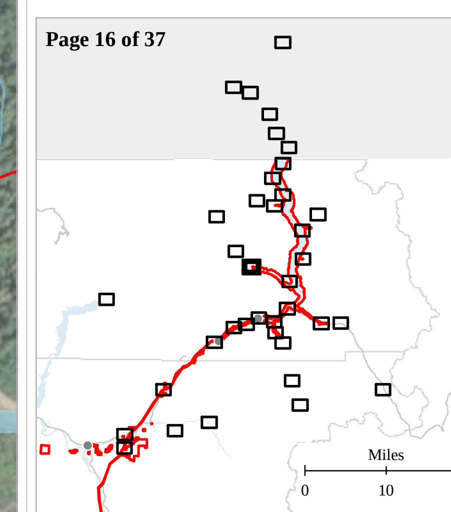
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



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Document Path: D:\GIS working\skagit\SkagitRiverFERC_GIS_Package\SkagitRiverFERC_GIS_Package_20210425\SkagitRiverFERC_GIS_Package\1_mxd\2_MXD_Templates\MAPBOOK_Sample_Locations_Map16.mxd

Note: the sample location label convention includes different colors to represent the different watersheds and different symbol shapes to represent the sample location types.

MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

- Diablo
- Gorge
- Ross
- Skagit

Site Type

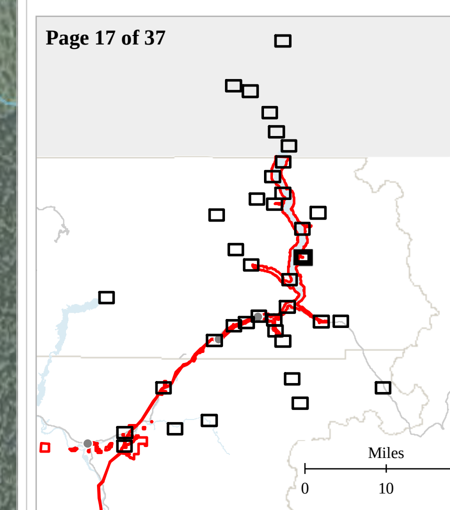
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



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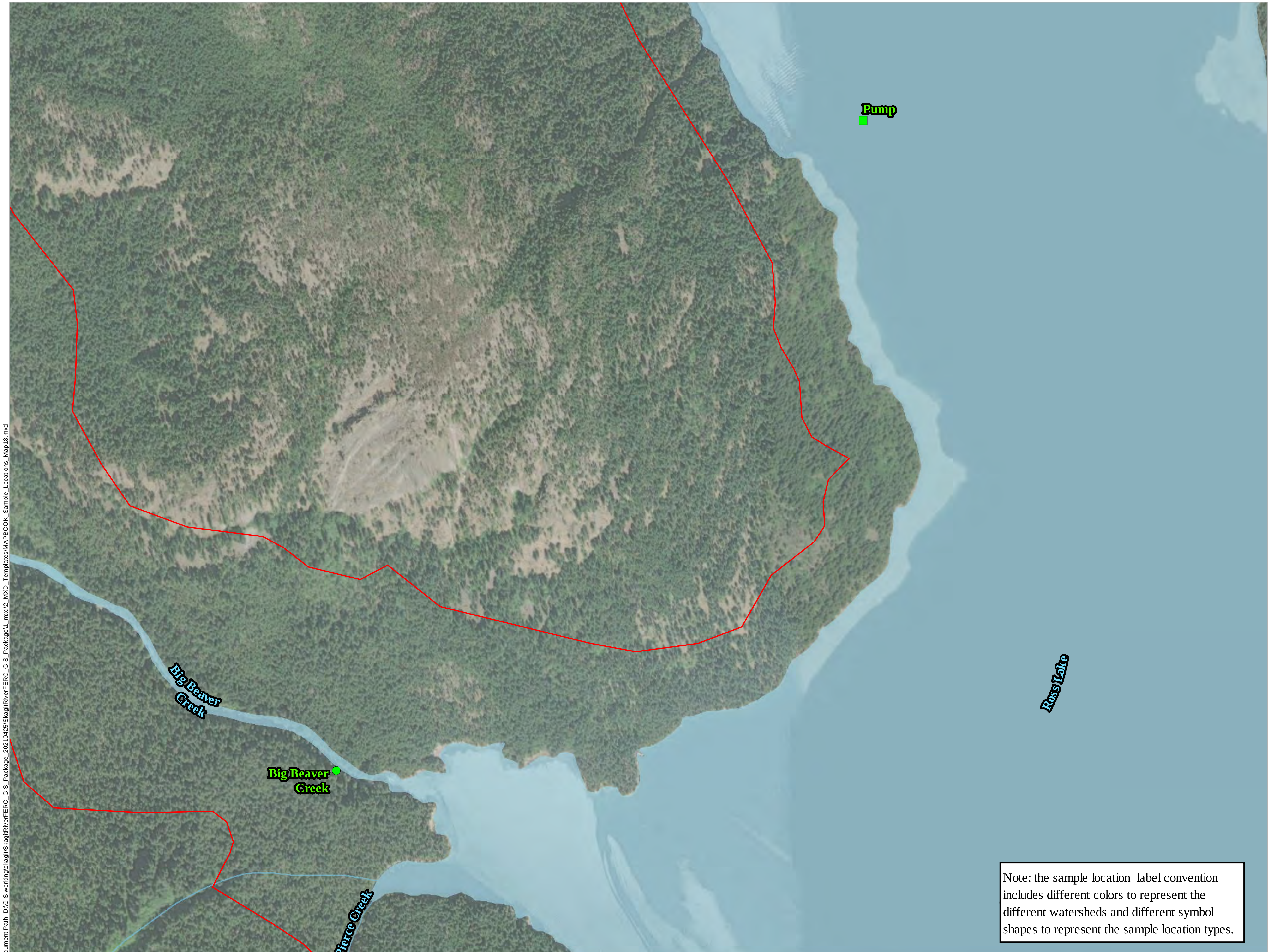
Document Path: D:\GIS working\Skagit\SkagitRiverFERC_GIS_Package\SkagitRiverFERC_GIS_Package_20210425\SkagitRiverFERC_GIS_Package1_mxd\2_MXD_Templates\MAPBOOK_Sample_Locations_Map17.mxd

MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA



FERC Project Boundary

Watershed

- Diablo
- Gorge
- Ross
- Skagit

Site Type

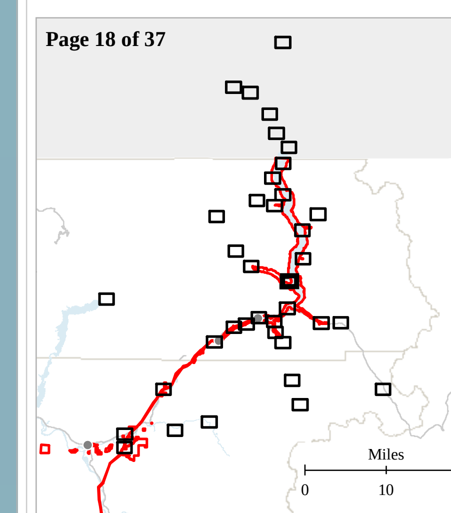
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



Seattle City Light

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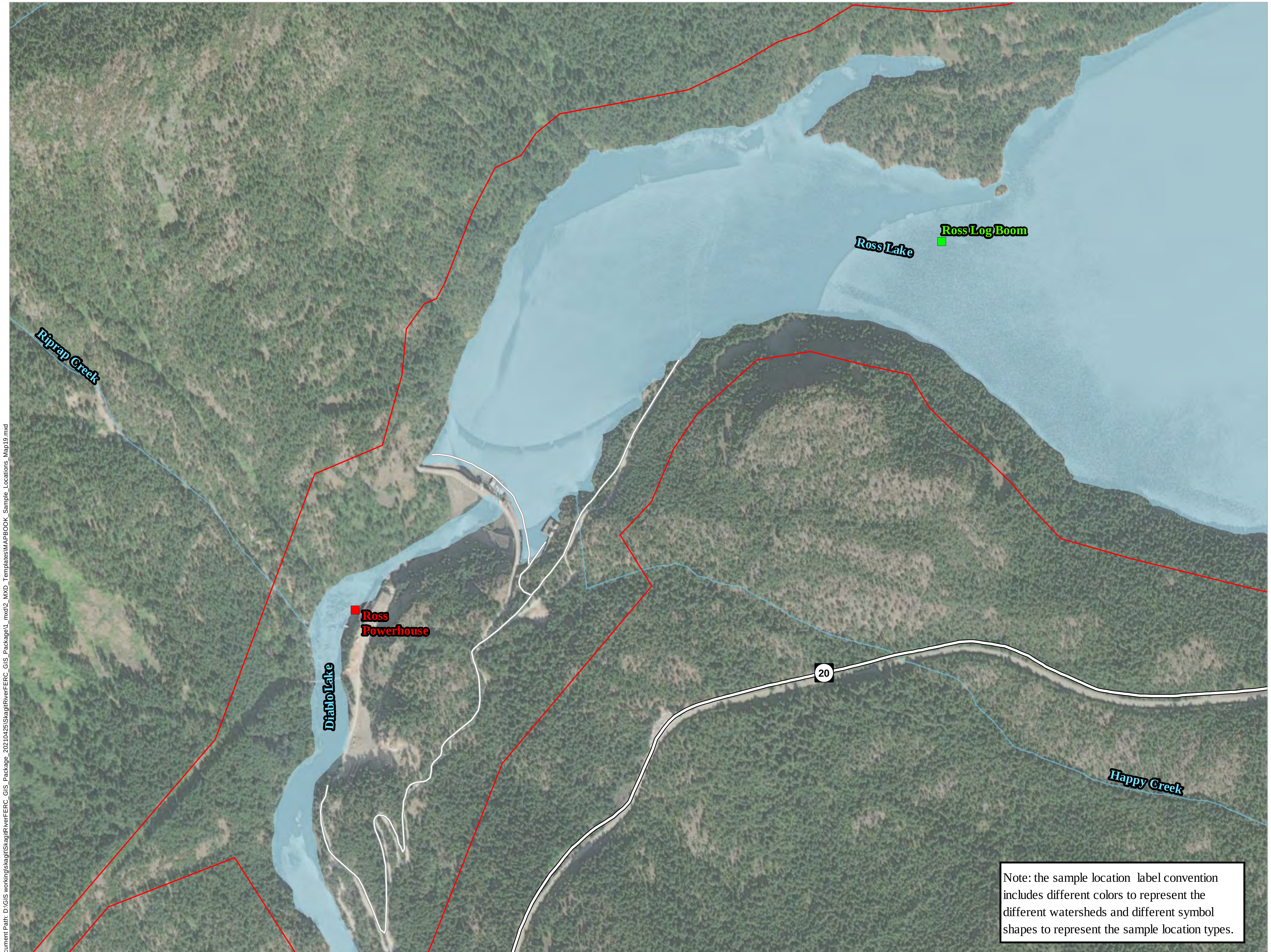
Document Path: D:\GIS working\skagit\SkagitRiverFERC_GIS_Package_20210425\SkagitRiverFERC_GIS_Package\1_mxd\2_MXD_Templates\MAPBOOK_Sample_Locations_Map18.mxd



MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

Diablo

Gorge

Ross

Skagit

Site Type

Lake

Tributary

Downstream

Upstream

Waterbodies

Estuary

Ice Mass

Lake/Pond

Reservoir

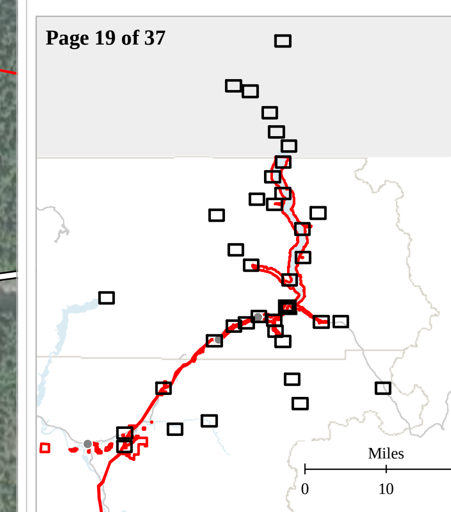
Swamp/Marsh

Stream/River

Streams

N

0 360 720 Feet



Seattle City Light

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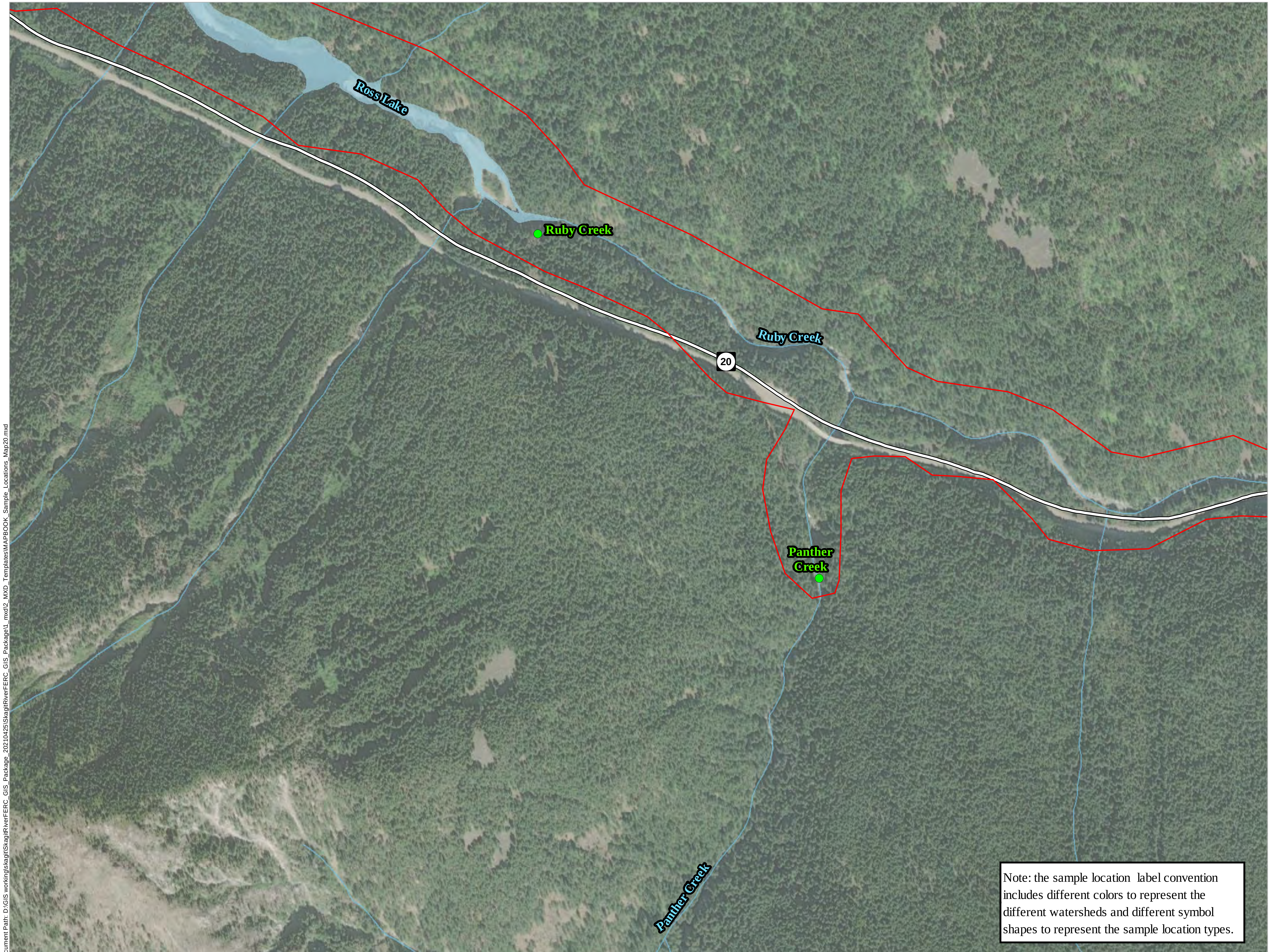
Document Path: D:\GIS working\Skagit\SkagitRiverFERC_GIS_Package_20210425\SkagitRiverFERC_GIS_Package1_mxd\2_MXD_Templates\MAPBOOK_Sample_Locations_Map19.mxd

MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA



Note: the sample location label convention includes different colors to represent the different watersheds and different symbol shapes to represent the sample location types.

FERC Project Boundary

Watershed

- Diablo
- Gorge
- Ross
- Skagit

Site Type

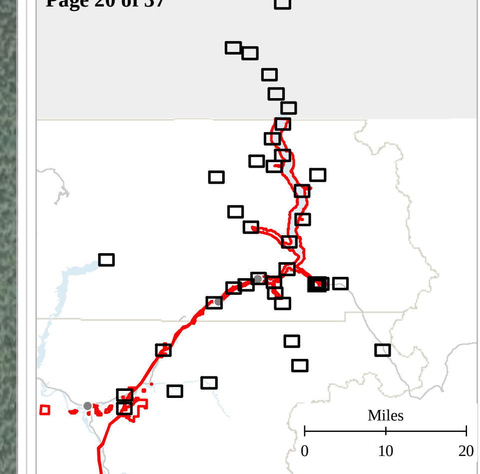
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

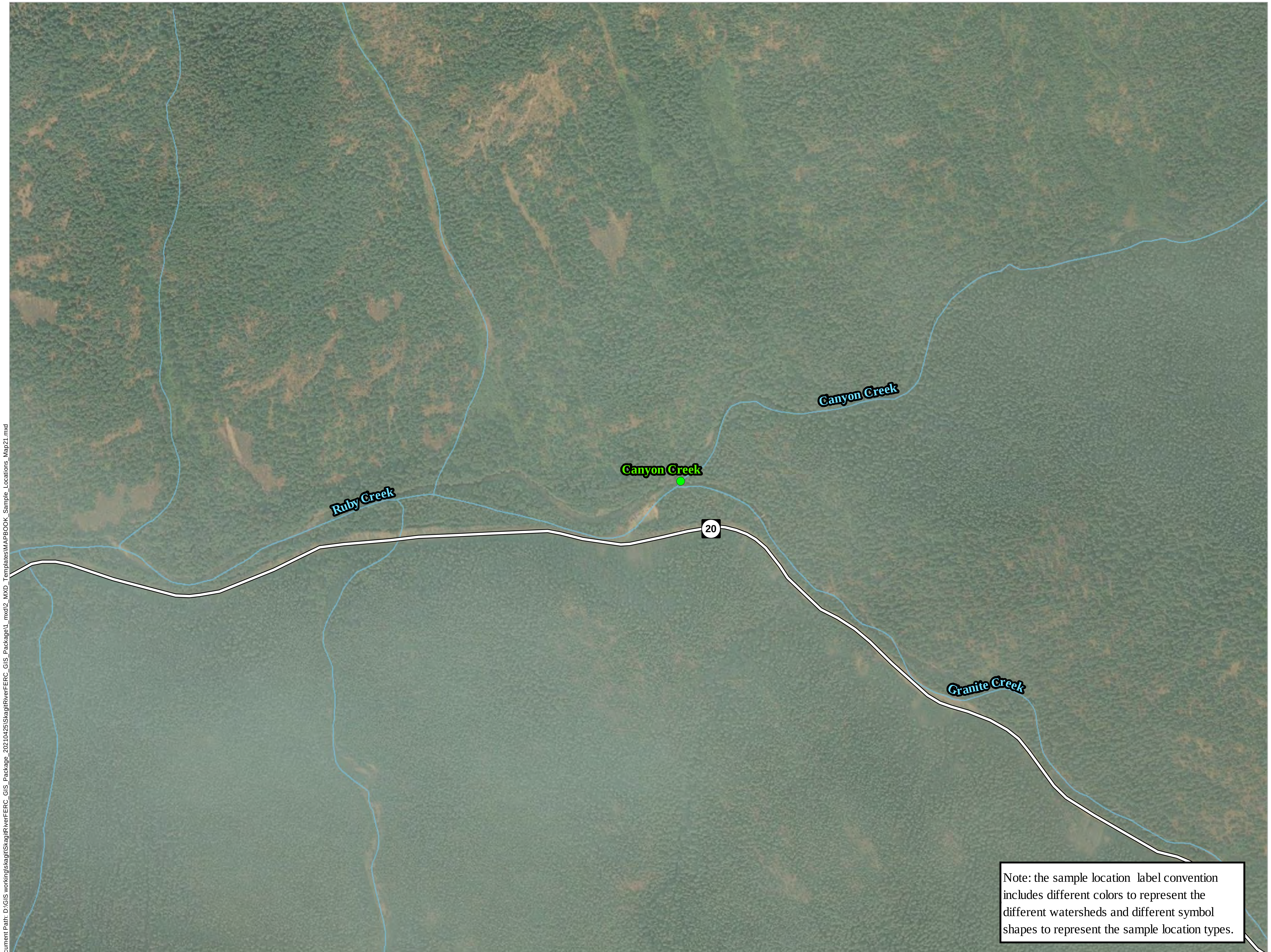
N

0 360 720 Feet



Seattle City Light

SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)



MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

- Diablo
- Gorge
- Ross
- Skagit

Site Type

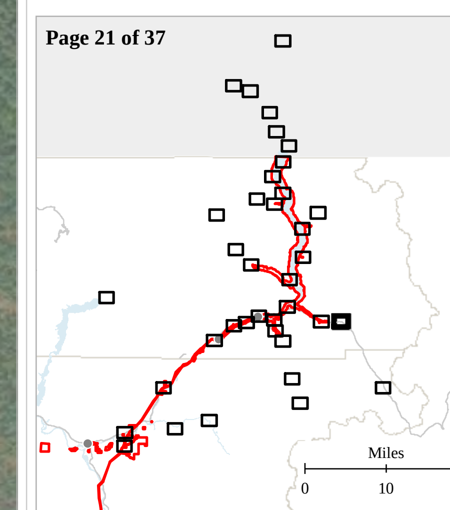
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



Seattle City Light

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Document Path: D:\GIS working\skagit\SkagitRiverFERC_GIS_Package_20210425\SkagitRiverFERC_GIS_Package\1_mxd\2_MXD_Templates\MAPBOOK_Sample_Locations_Map21.mxd

MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

Note: the sample location label convention includes different colors to represent the different watersheds and different symbol shapes to represent the sample location types.

FERC Project Boundary

Watershed

- Diablo
- Gorge
- Ross
- Skagit

Site Type

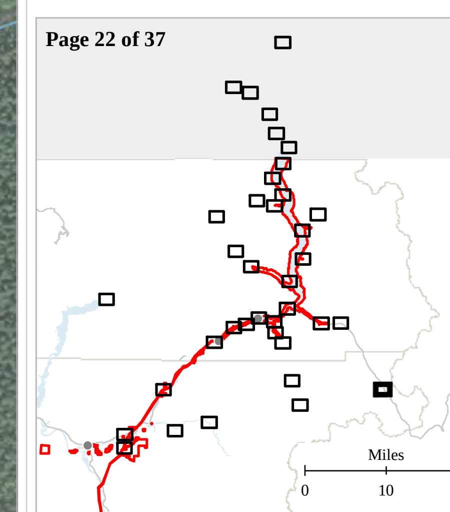
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



Seattle City Light

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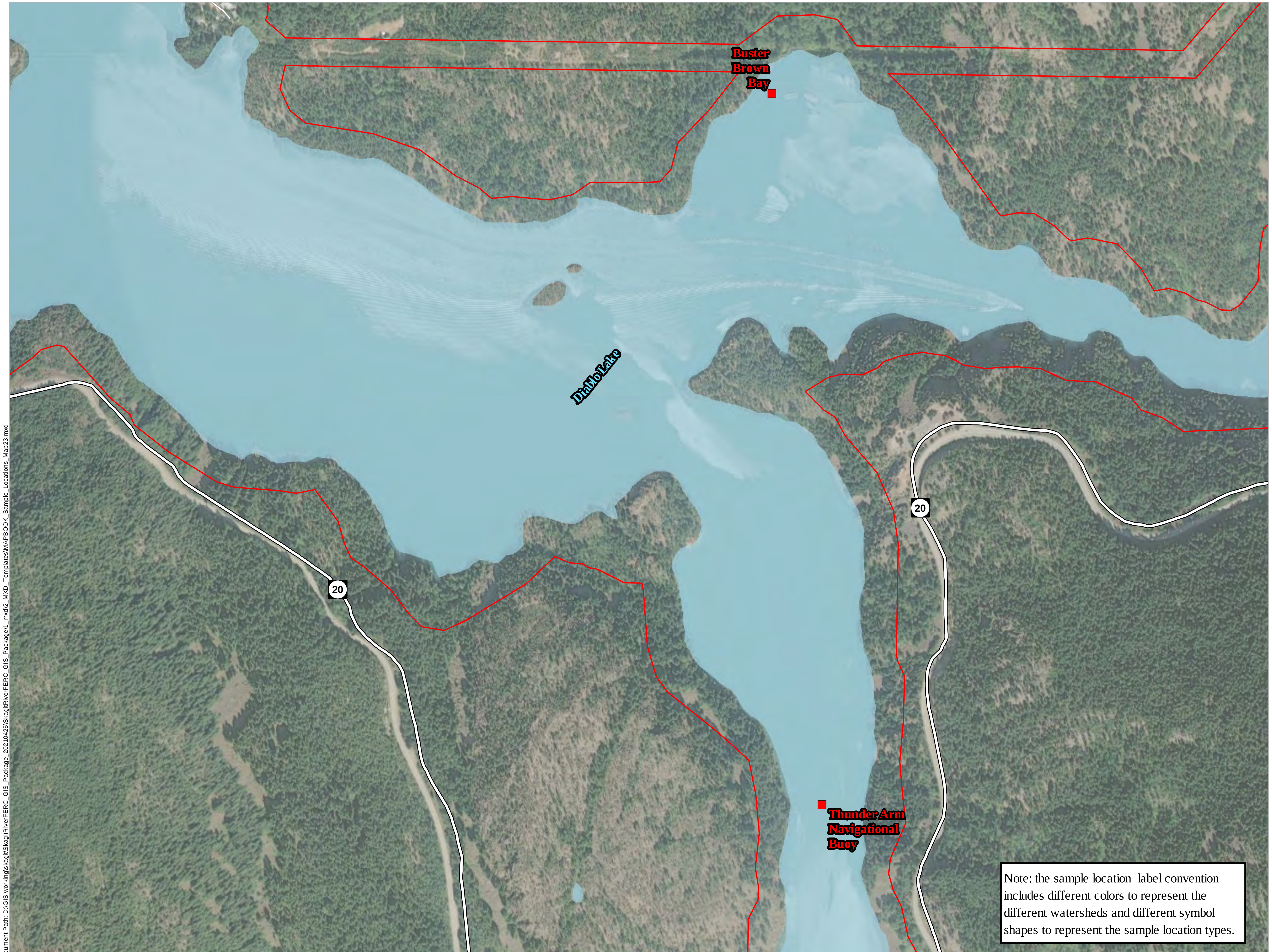
Document Path: D:\GIS working\skagit\SkagitRiverFERC_GIS_Package_20210425\SkagitRiverFERC_GIS_Package1_mxd\2_MXD_Templates\MAPBOOK_Sample_Locations_Map22.mxd

MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA



Note: the sample location label convention includes different colors to represent the different watersheds and different symbol shapes to represent the sample location types.

FERC Project Boundary

Watershed

- Diablo
- Gorge
- Ross
- Skagit

Site Type

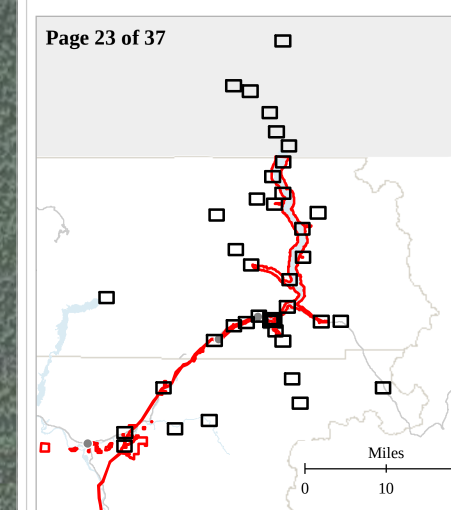
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



Seattle City Light

SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)

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Note: the sample location label convention includes different colors to represent the different watersheds and different symbol shapes to represent the sample location types.

MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

Diablo

Gorge

Ross

Skagit

Site Type

Lake

Tributary

Downstream

Upstream

Waterbodies

Estuary

Ice Mass

Lake/Pond

Reservoir

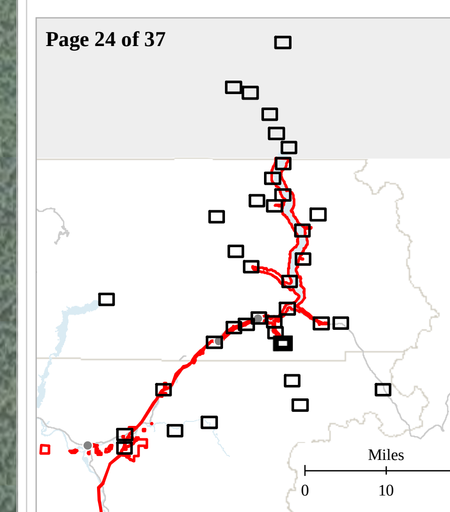
Swamp/Marsh

Stream/River

Streams

N

0 360 720 Feet



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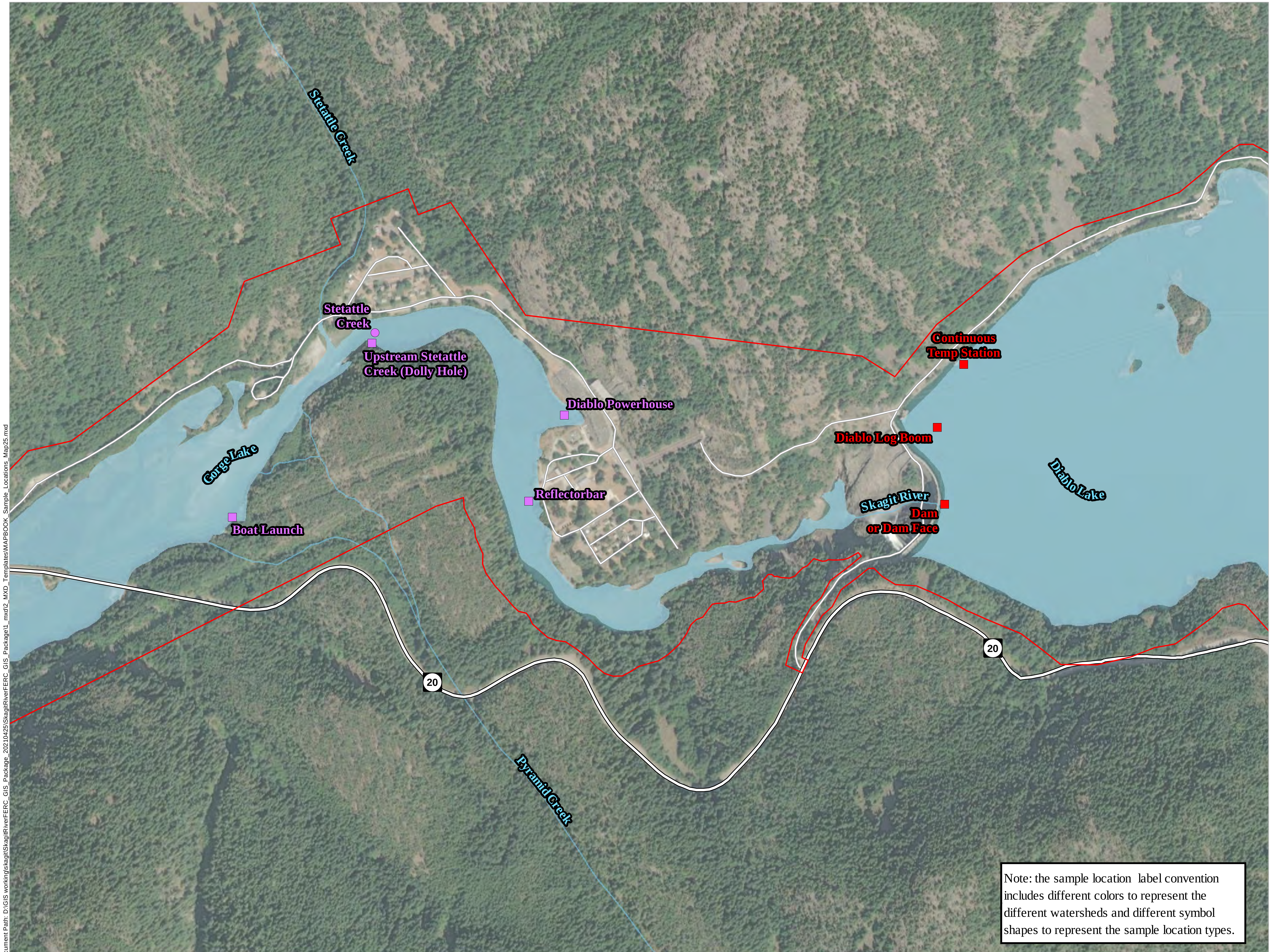


MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

- Diablo
- Gorge
- Ross
- Skagit

Site Type

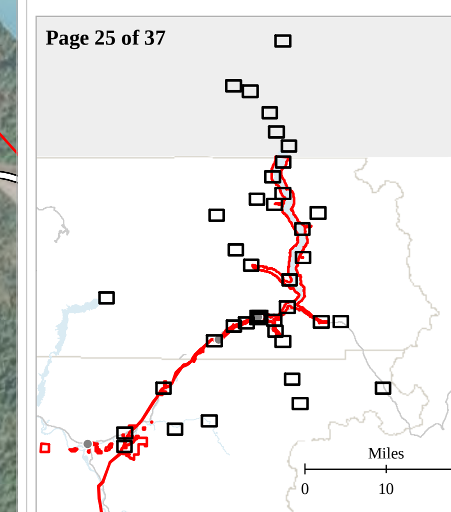
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



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Document Path: D:\GIS working\skagit\SkagitRiverFERC_GIS_Package_20210425\SkagitRiverFERC_GIS_Package\1_mxd\2_MXD_Templates\MAPBOOK_Sample_Locations_Map25.mxd

MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

- Diablo
- Gorge
- Ross
- Skagit

Site Type

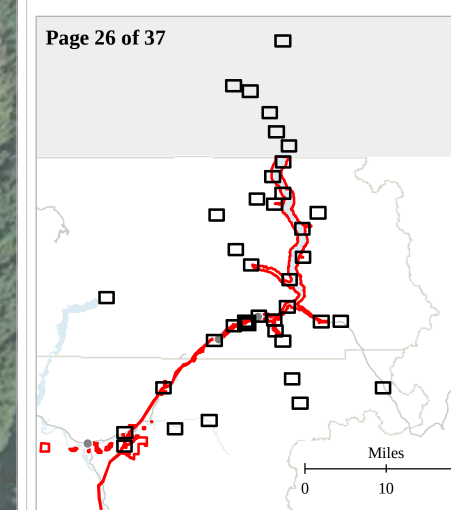
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



Seattle City Light

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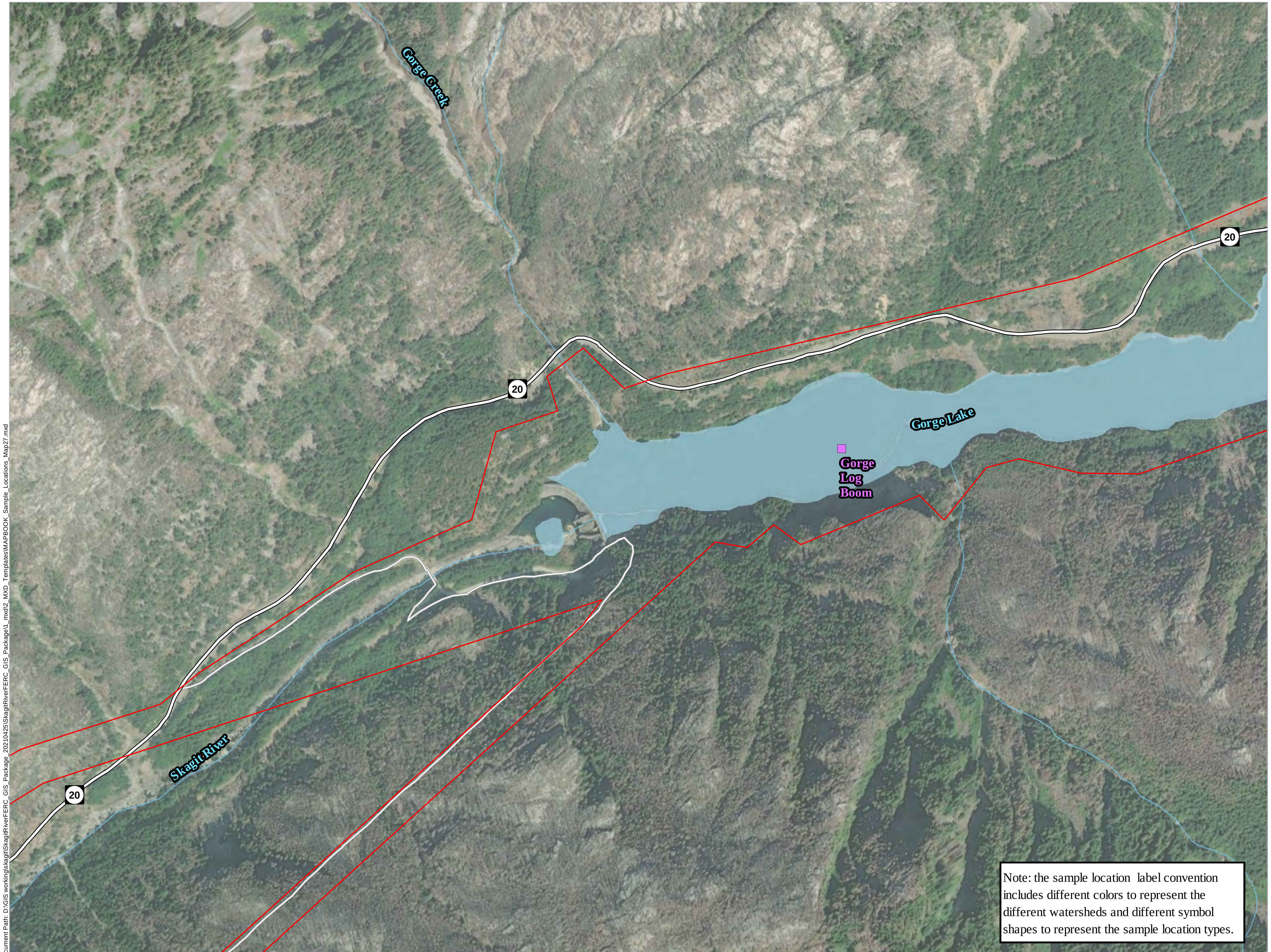
Document Path: D:\GIS working\Skagit\SkagitRiverFERC_GIS_Package_20210425\SkagitRiverFERC_GIS_Package1_mxd\2_MXD_Templates\MAPBOOK_Sample_Locations_Map26.mxd



MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

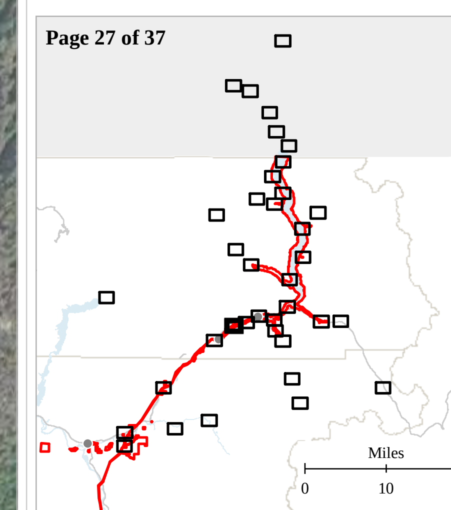
Watershed
- Diablo
- Gorge
- Ross
- Skagit

Site Type
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies
- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



Seattle City Light

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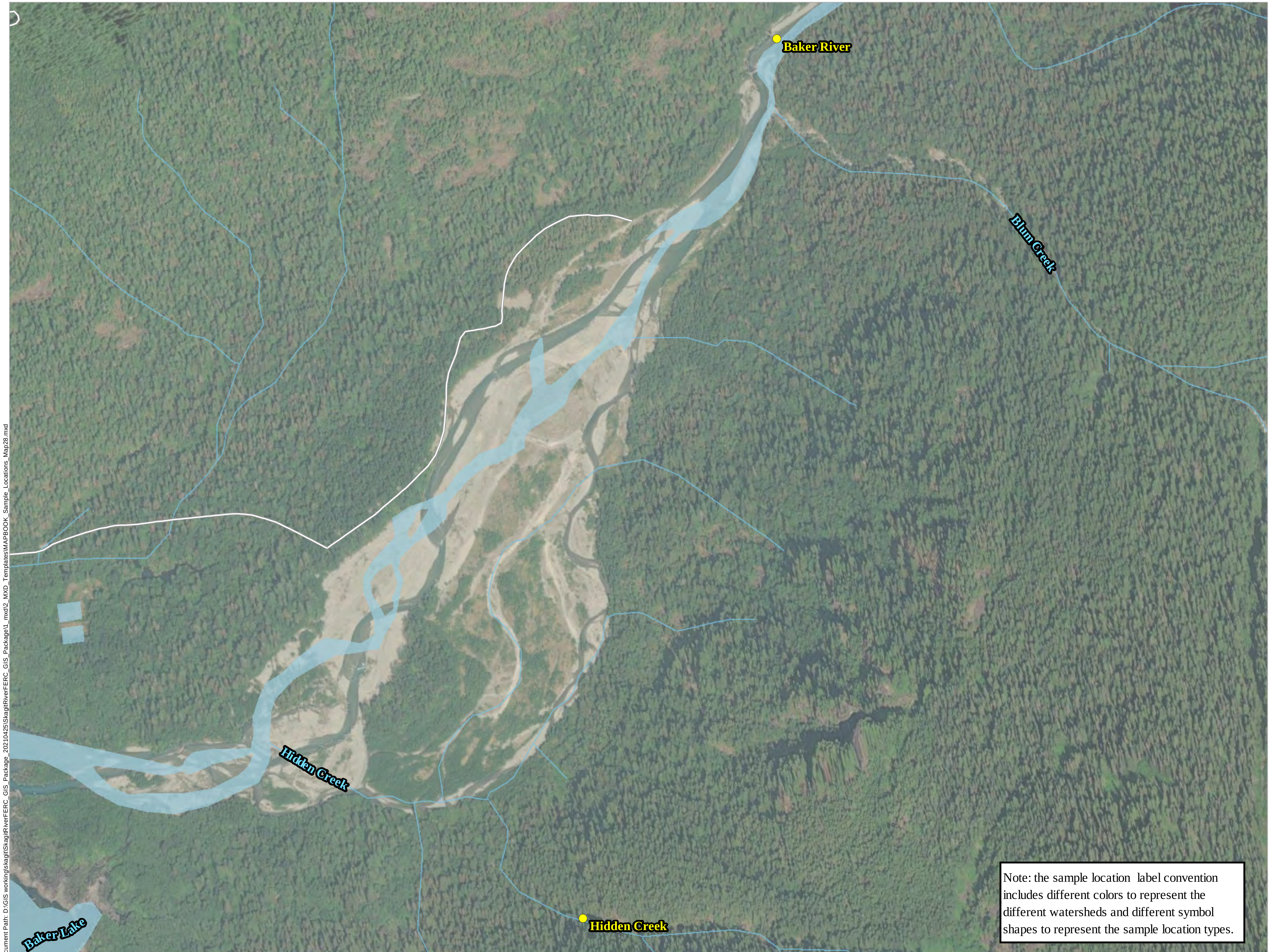


MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

Diablo

Gorge

Ross

Skagit

Site Type

Lake

Tributary

Downstream

Upstream

Waterbodies

Estuary

Ice Mass

Lake/Pond

Reservoir

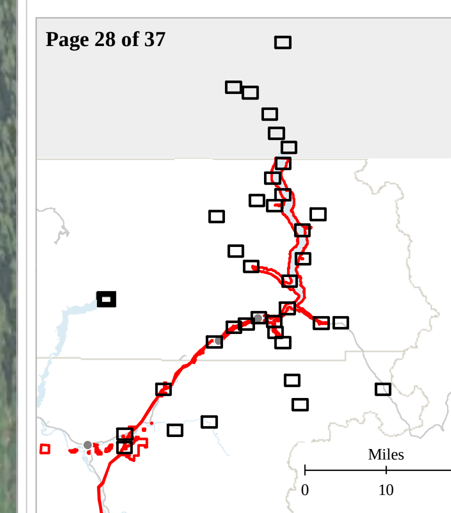
Swamp/Marsh

Stream/River

Streams

N

0 360 720 Feet



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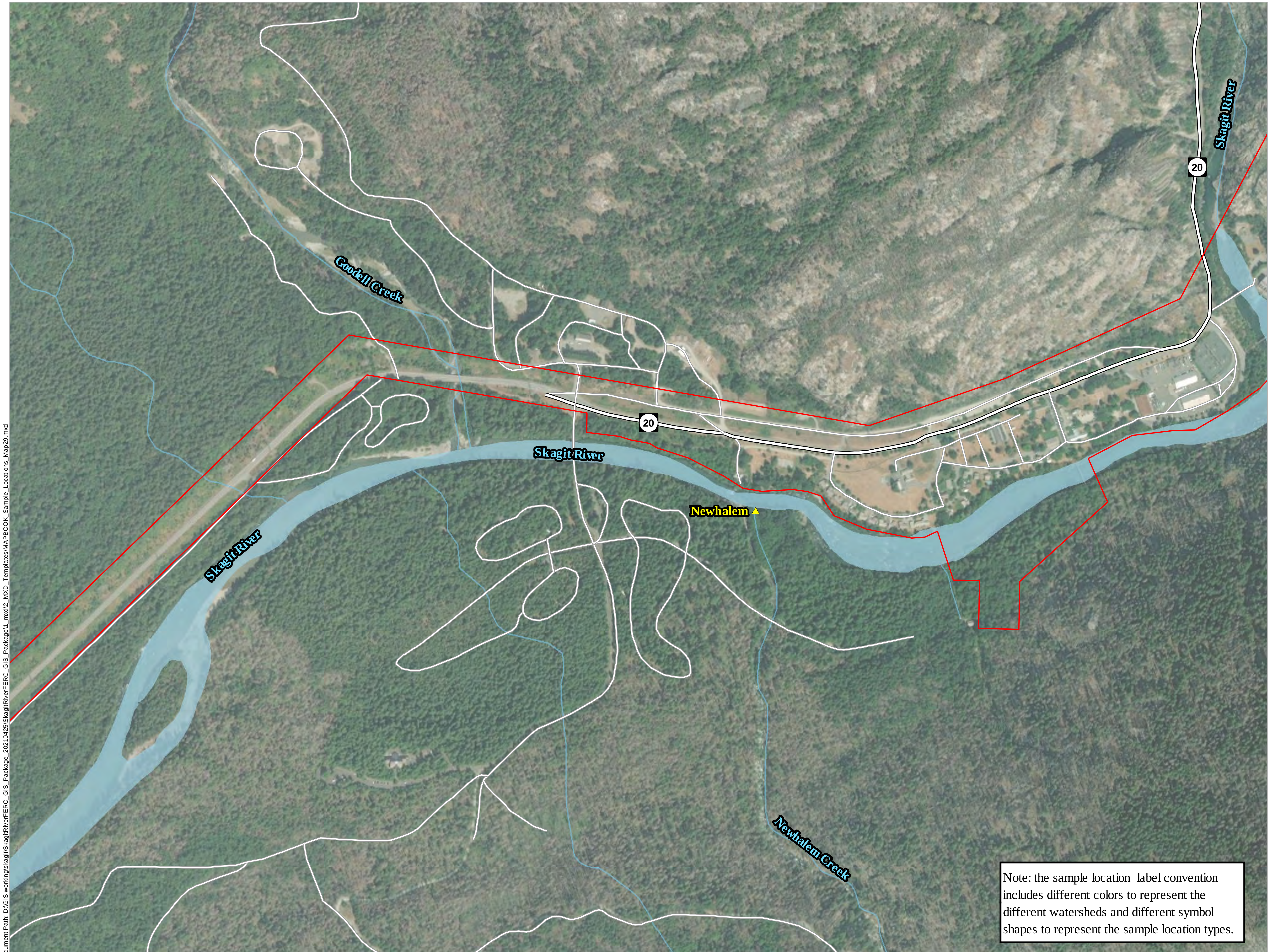


MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

Diablo

Gorge

Ross

Skagit

Site Type

Lake

Tributary

Downstream

Upstream

Waterbodies

Estuary

Ice Mass

Lake/Pond

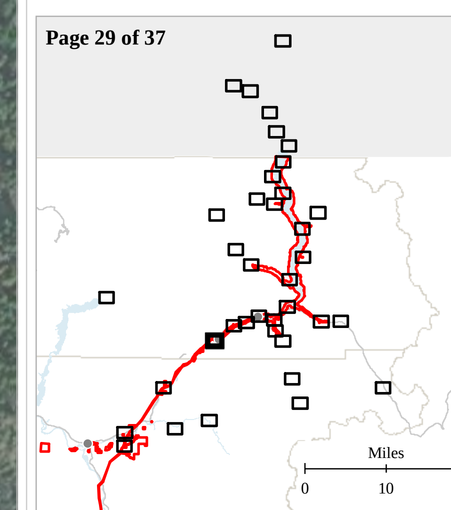
Reservoir

Swamp/Marsh

Stream/River

Streams

0 360 720 Feet



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MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

- Diablo
- Gorge
- Ross
- Skagit

Site Type

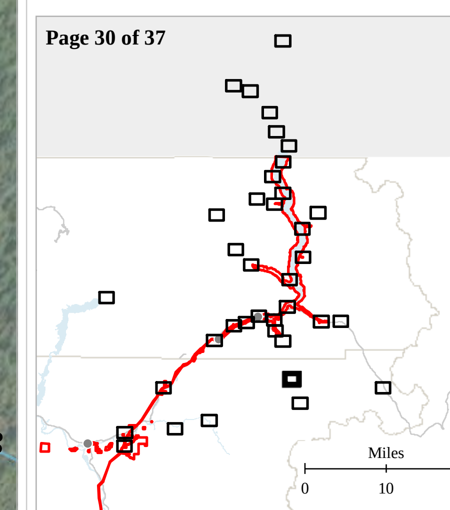
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies

- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



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MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

Note: the sample location label convention includes different colors to represent the different watersheds and different symbol shapes to represent the sample location types.

FERC Project Boundary

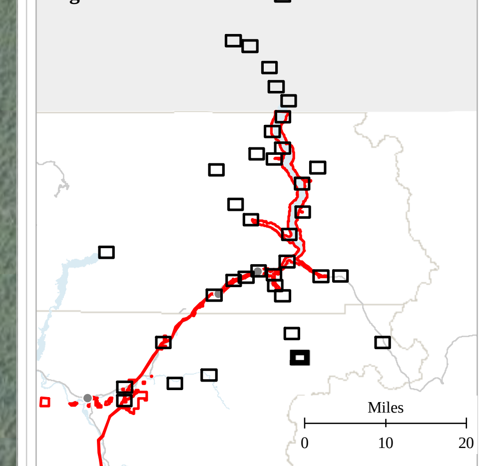
Watershed
- Diablo
- Gorge
- Ross
- Skagit

Site Type
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies
- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



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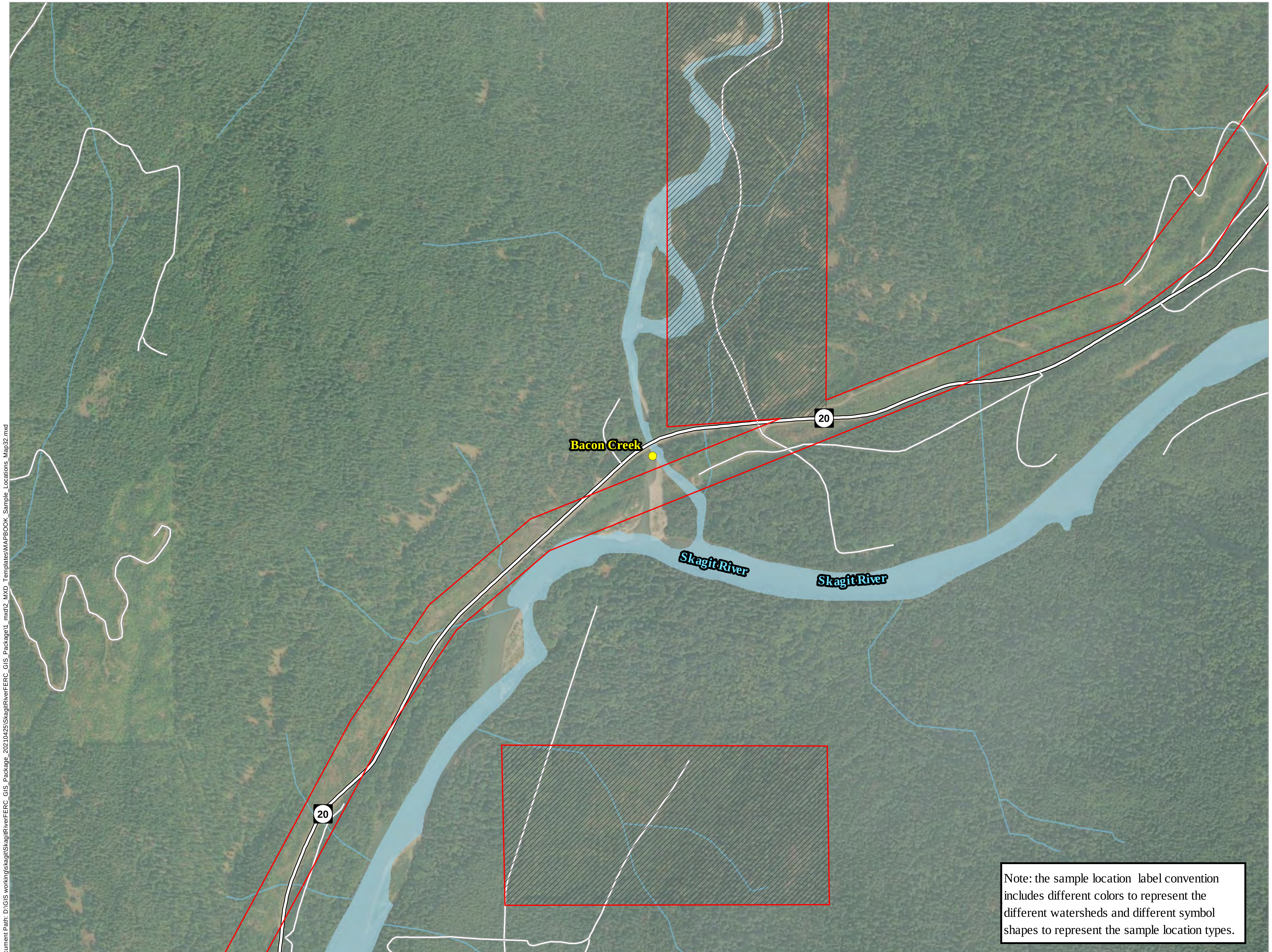

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MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary
Mitigation Parcel

Watershed

Diablo
Gorge
Ross
Skagit

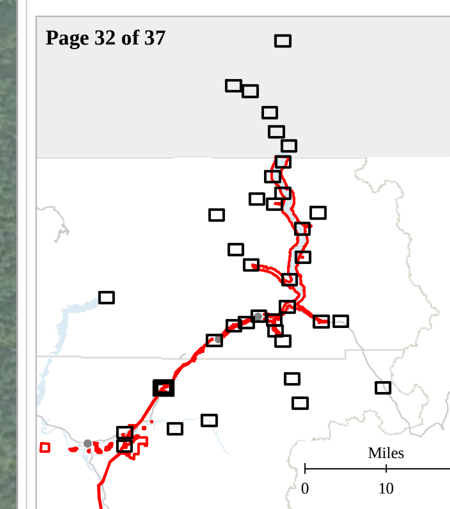
Site Type

Lake
Tributary
Downstream
Upstream

Waterbodies

Estuary
Ice Mass
Lake/Pond
Reservoir
Swamp/Marsh
Stream/River
Streams

0 410 820 Feet



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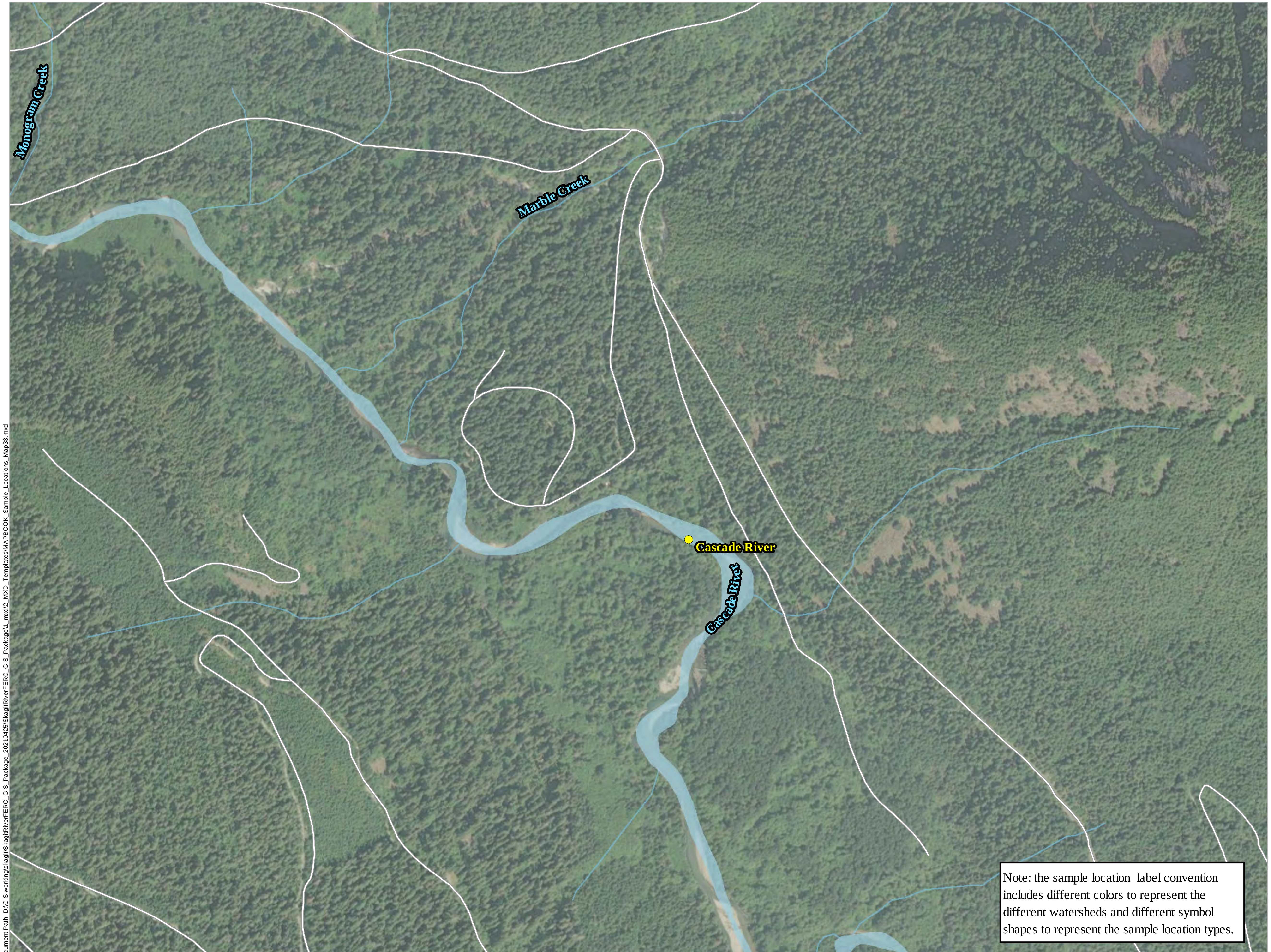


MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

Diablo

Gorge

Ross

Skagit

Site Type

Lake

Tributary

Downstream

Upstream

Waterbodies

Estuary

Ice Mass

Lake/Pond

Reservoir

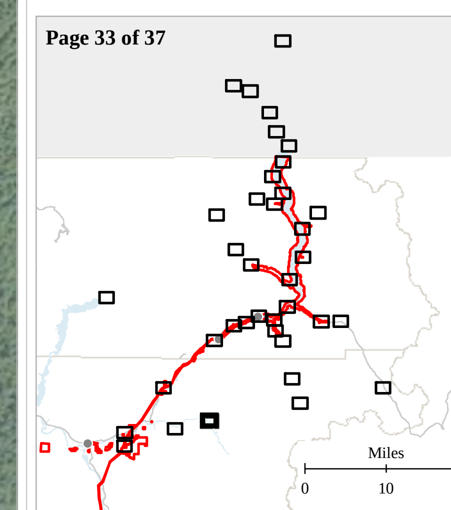
Swamp/Marsh

Stream/River

Streams

N

0 360 720 Feet



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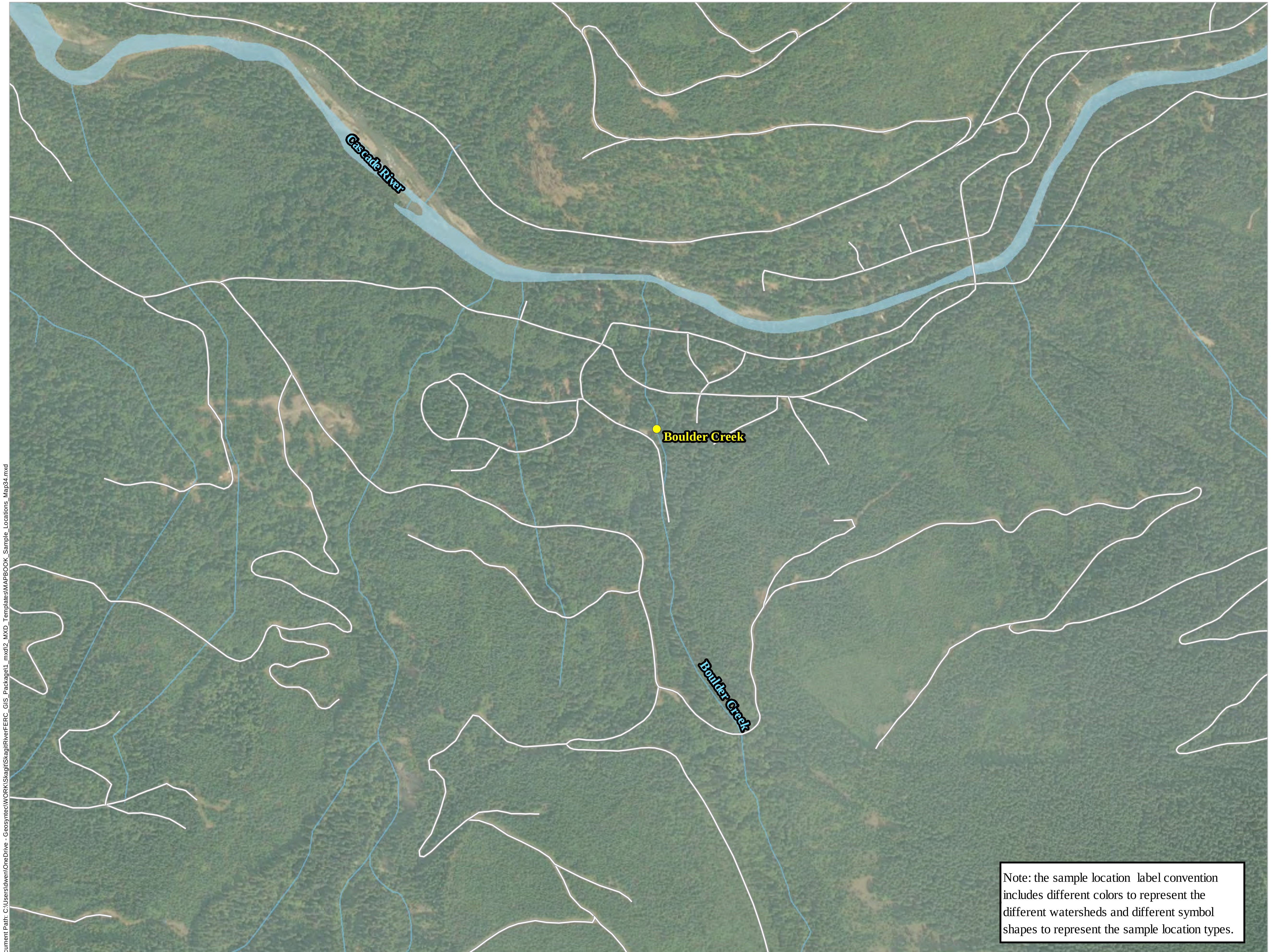
MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA



Note: the sample location label convention includes different colors to represent the different watersheds and different symbol shapes to represent the sample location types.

FERC Project Boundary

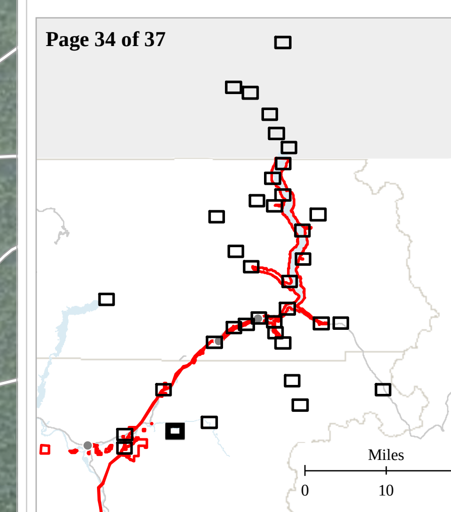
Watershed
- Diablo
- Gorge
- Ross
- Skagit

Site Type
- Lake
- Tributary
- Downstream
- Upstream

Waterbodies
- Estuary
- Ice Mass
- Lake/Pond
- Reservoir
- Swamp/Marsh
- Stream/River
- Streams

N

0 360 720 Feet



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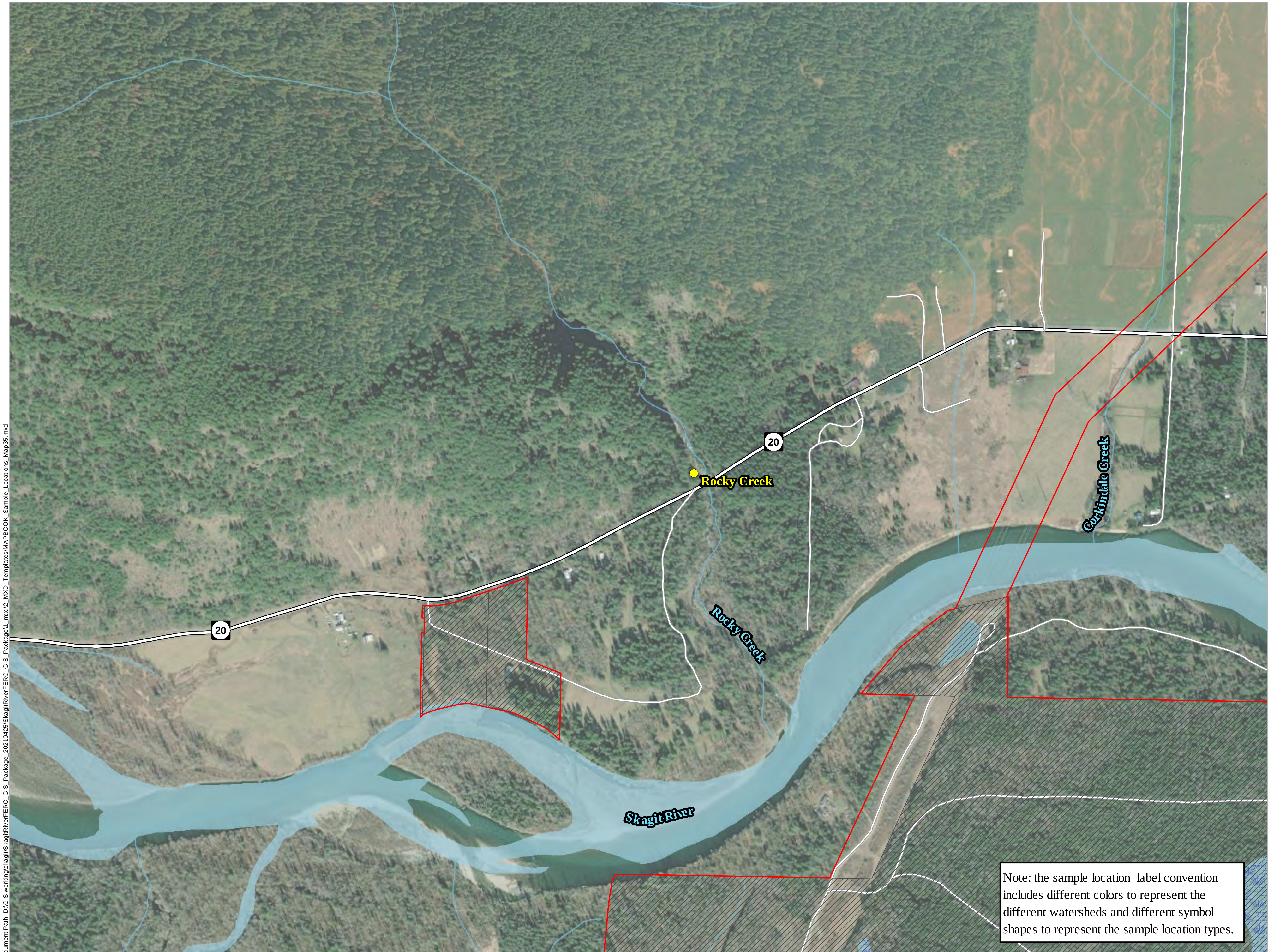


MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

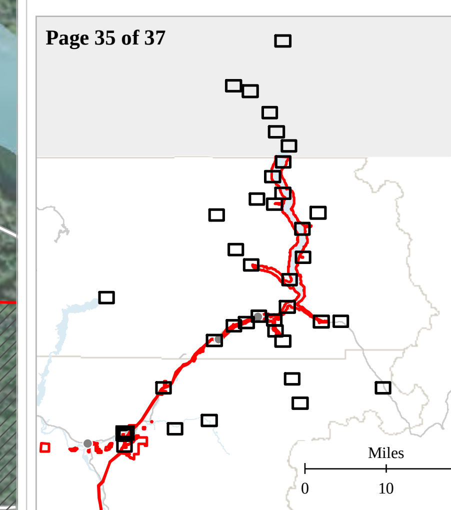
FERC Project Boundary
Mitigation Parcel

Watershed
Diablo
Gorge
Ross
Skagit

Site Type
Lake
Tributary
Downstream
Upstream

Waterbodies
Estuary
Ice Mass
Lake/Pond
Reservoir
Swamp/Marsh
Stream/River
Streams

N
0 360 720 Feet



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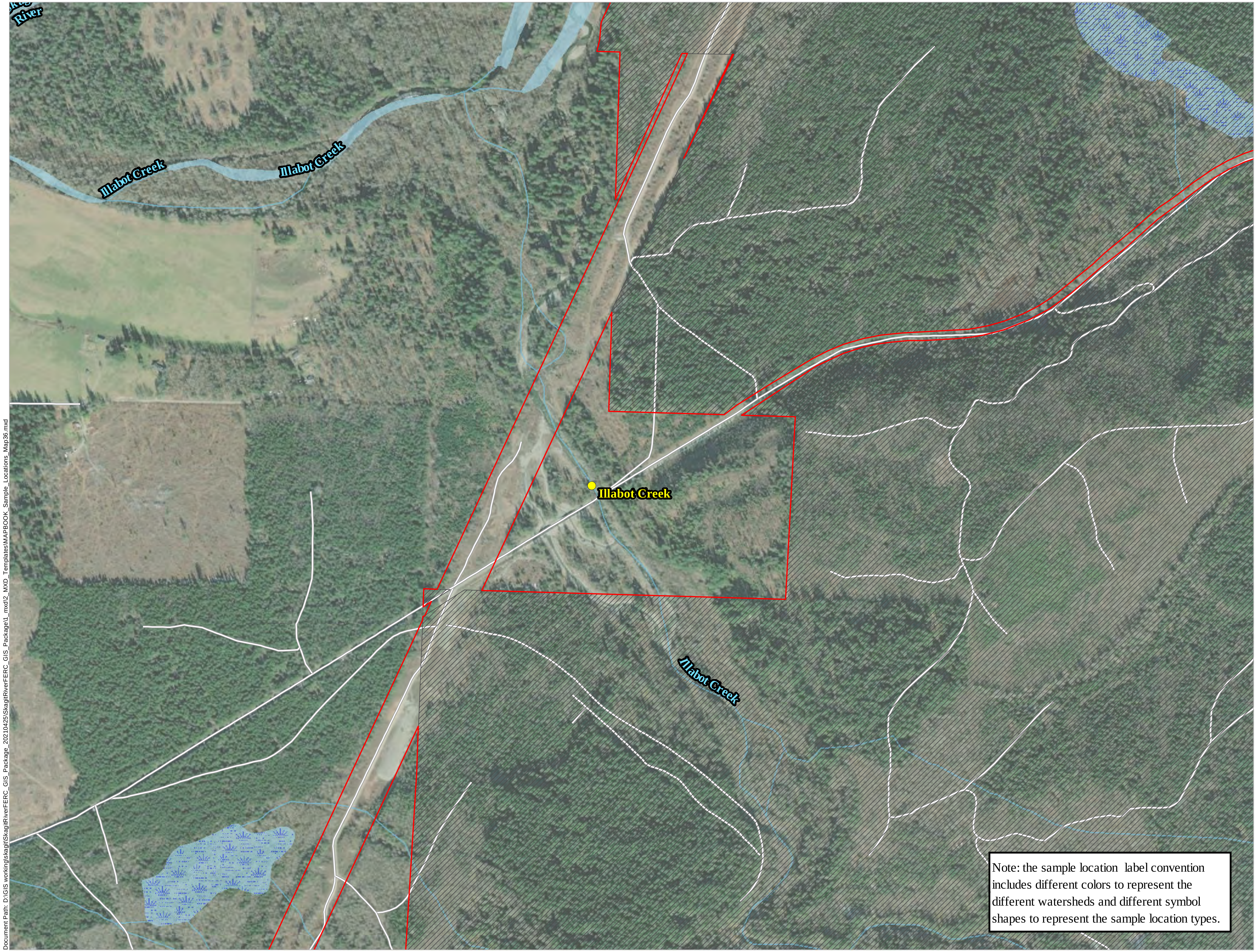


MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

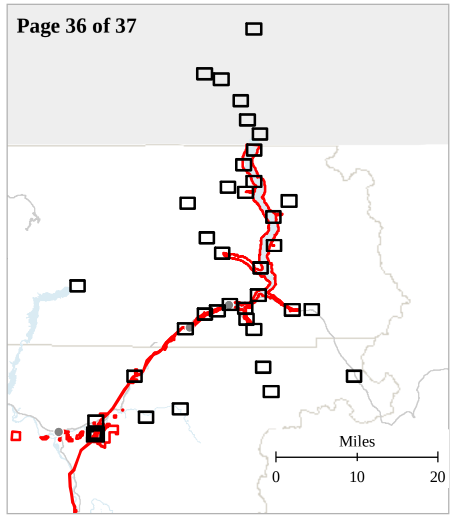
FERC Project Boundary
Mitigation Parcel

Watershed
Diablo
Gorge
Ross
Skagit

Site Type
Lake
Tributary
Downstream
Upstream

Waterbodies
Estuary
Ice Mass
Lake/Pond
Reservoir
Swamp/Marsh
Stream/River
Streams

N
0 360 720 Feet



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MEASUREMENT AND SAMPLING LOCATIONS OF EXISTING WQ DATA

FERC Project Boundary

Watershed

Diablo

Gorge

Ross

Skagit

Site Type

Lake

Tributary

Downstream

Upstream

Waterbodies

Estuary

Ice Mass

Lake/Pond

Reservoir

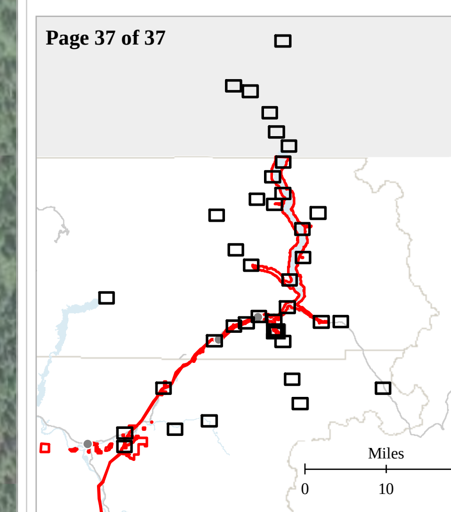
Swamp/Marsh

Stream/River

Streams

N

0 360 720 Feet



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MANAGEMENT AND EVALUATION OF EXISTING WATER QUALITY DATA DRAFT REPORT

APPENDIX 3

DATA INVENTORIES

The data collected by City Light and other entities were inventoried to create a clear picture of the data available for analysis and interpretation. Separate data inventories were created for separate variables or groups of variables. Inventories were created for the following:

- Continuous temperature measurements;
- Water quality sonde deployments; and
- Grab samples.

Each of these is presented separately in the following sections.

Continuous Temperature Data Inventory

Continuous temperature data constitute the vast majority of data inventoried. Data exist from August 2000 through October 2020.[1] When locations were sampled separately yet near each other by NPS and City Light (i.e., in Big Beaver Creek, Lightning Creek, and Little Beaver Creek), these were combined when creating the data inventory.

Thermistor chain data exist near Ross Dam in a long, mostly complete, record at the Log Boom location (Table A3-1; Figure A3-1). This is supplemented by monitoring in four lacustrine locations called Hozomeen, Little Beaver, Skymo, and Pumpkin Mountain (abbreviated "Pump" in monitoring data) that occurred in 2017-2018. At these locations, three temperature sensors were deployed from spring to fall at three depths to form a low-resolution thermistor chain: 3.28 ft from the surface, 3.28 ft from the bottom, and an intermediate depth (Archambault 2019b; Archambault 2021). Vertical profiles were also collected at Little Beaver, Skymo, and Pumpkin Mountain in 2015-2018; these appear in the inventory alongside thermistor chain data (Table A3-1; Figure A3-1). Few data were qualified and removed from analyses at these reservoir locations.

Continuous temperature monitoring of tributaries to Ross Lake began in 2000 with the deployment of sensors in Big Beaver Creek, Devil's Creek, Lightning Creek, and Ruby Creek (Table A3-1; Figure A3-1). Canyon Creek and Granite Creek were added in 2004, and upstream Big Beaver, Panther, Perry, Little Beaver, and Silver Creek locations were added in 2014. A Hozomeen Creek location was added in 2019; this location, Granite Creek, Silver Creek, and Big Beaver Creek have data that continue through late 2020. After removal of erroneous data, data continuity (i.e., the number of days with useable observations out of the total number of days within the timespan of a useable record) varied because of gaps in the deployment of some sensors. Of the data recorded by stream sensors, between 0 and 59 percent were qualified and removed from analysis due to concerns about quality.

Continuous temperature data were collected with a water quality sonde at 15-minute intervals at the USGS Border Station from August 2019 through November 2020.

Thermistor chain data in Diablo Lake begin in fall 2005 at the Log Boom location, and data there are mostly continuous (Table A3-2; Figure A3-2). These data are supplemented by additional

[1] Data exist through late 2020 in the data sets evaluated for this study. Data collection has continued in several active locations. The ending dates of data availability in several monitoring locations is a result of the last retrieval of data from those sites, not necessarily a discontinuation of data collection at those sites.

thermistor chains deployed near the dam from 2014-2016 and 2019 and at the Diablo Continuous Temperature Station in 2018-2019. Individual thermistors were deployed at the Ross Powerhouse, the State Route (SR) 20 bridge over the Thunder Creek Arm, and Buster Brown Bay in 2014, 2016, and 2018, respectively. Monitoring of tributary creeks began in late 2014, with sensor deployments in McAllister Creek, Fisher Creek, and West Fork Creek. Few data from reservoir locations were qualified and removed from analysis, but 0 to 54 percent of data from tributary locations were judged to be erroneous based on the methods described in the main text of this report.

Gorge Lake data begin in 2013 with the commencement of records at the Diablo Powerhouse, Upstream-of-Stetattle Creek (also called “Dolly Hole”), Boat Launch, and Log Boom locations (Table A3-3; Figure A3-3). The Boat Launch data end <1 year later, but they restart in summer 2017 along with data from the Powerline and Midway locations. Data at the Reflector Bar location, which is upstream of the Diablo Dam Powerhouse, begin in June 2019. Of these, only the Log Boom data are thermistor chain data. Tributary monitoring in Stetattle Creek starts in 2005, predating records in Gorge Lake by several years. Data continuity in Gorge Lake and its tributary was generally excellent, and few data required qualification and removal from analyses.

Temperature in the Skagit River has been monitored extensively upstream of Ross Lake (Table A3-4; Figure A3-4). Monitoring at the 26-Mile Bridge and Nepopekum locations began in 2001, along with monitoring on the Klesilkwa River. The Swing Bridge location just upstream of Ross Lake was added in 2002, and the Brown Sign location and the Sumallo River were added in 2003. In 2014, data for the Foot Bridge location begin. These data records end in late 2019. However, most of these locations are expected to be active to the present, with data download impaired by border crossing restrictions associated with the coronavirus pandemic. Data continuity tended to be excellent in these locations, although measurements at the Skagit River location near the Sumallo confluence were sufficiently intermittent to be omitted from analyses. Data quality varied, with 20 percent or fewer of observations removed except at the location called “Right Dry Channel,” which did not yield any useable data.

Downstream of the Project, temperature monitoring in the Skagit River began at the Newhalem location in summer 2013 (Table A3-4; Figure A3-4). In 2014, data begin at three Skagit River tributaries, the Cascade River, Boulder Creek, and Illabot Creek, and Bacon Creek was added in 2015. The Baker River and Hidden Creek, which flow to Baker Lake, also begin in 2014. Data continuity was >75 percent except in Bacon Creek and Boulder Creek, where it was >50 percent.

Table A3-1. Continuous temperature data inventory, Ross Lake and related tributaries.

Location	Data Start	Data End	Total Days	Useable Data Start[1]	Useable Data End[1]	Useable Days[1]	Useability	Observations Omitted
Lake Locations								
USGS Border Station	8/14/2019	11/8/2020	453	8/14/2019	11/8/2020	0	100%	0%
Hozomeen (Lake)	6/15/2017	10/15/2018	488	6/15/2017	10/15/2018	252	52%	0%
Little Beaver (Lake)	6/16/2015	11/19/2018	1,253	6/16/2015	11/19/2018	382	30%	0%
Skymo	6/16/2015	11/19/2018	1,253	6/16/2015	11/19/2018	382	30%	0%
Pumpkin Mountain	5/14/2015	2/14/2019	1,373	5/14/2015	2/14/2019	481	35%	0%
Log Boom	8/30/2001	10/16/2018	6,257	8/30/2001	10/16/2018	5,188	83%	1%
Tributary Locations								
Hozomeen Creek	10/24/2019	10/21/2020	364	10/27/2019	10/16/2020	321	88%	28%
Silver Creek	10/20/2014	10/27/2020	2,200	10/23/2014	9/30/2017	971	44%	52%
Perry Creek	10/20/2014	9/17/2019	1,794	10/23/2014	9/16/2019	1,506	84%	27%
Little Beaver Creek	8/30/2001	10/10/2019	6,616	8/30/2001	10/7/2019	1,086	16%	55%
Lightning Creek	8/11/2000	9/6/2017	6,236	8/28/2000	9/6/2017	2,485	40%	19%
Devil’s Creek	8/23/2000	2/14/2002	541	8/23/2000	2/14/2002	384	71%	0%
Big Beaver Creek Downstream	8/11/2000	10/26/2020	7,382	8/23/2000	10/19/2020	5,113	69%	12%
Big Beaver Creek Upstream	10/22/2014	10/26/2020	2,197	10/24/2014	10/19/2020	1,600	73%	42%
Ruby Creek	8/11/2000	10/15/2018	6,640	8/25/2000	10/11/2018	4,014	60%	7%
Canyon Creek	9/2/2004	8/12/2013	3,267	9/2/2004	8/6/2013	2,414	74%	3%
Granite Creek	9/2/2004	10/29/2020	5,902	9/2/2004	9/30/2019	3,418	58%	36%
Panther Creek	10/14/2014	9/11/2019	1,794	10/17/2014	9/11/2019	1,623	90%	24%

1 Useable days are days with any useable observations. These are equal to the total days, which span from the start date to the end date of the record, minus days with missing observations and days when all observations were qualified due to probable erroneous measurements.

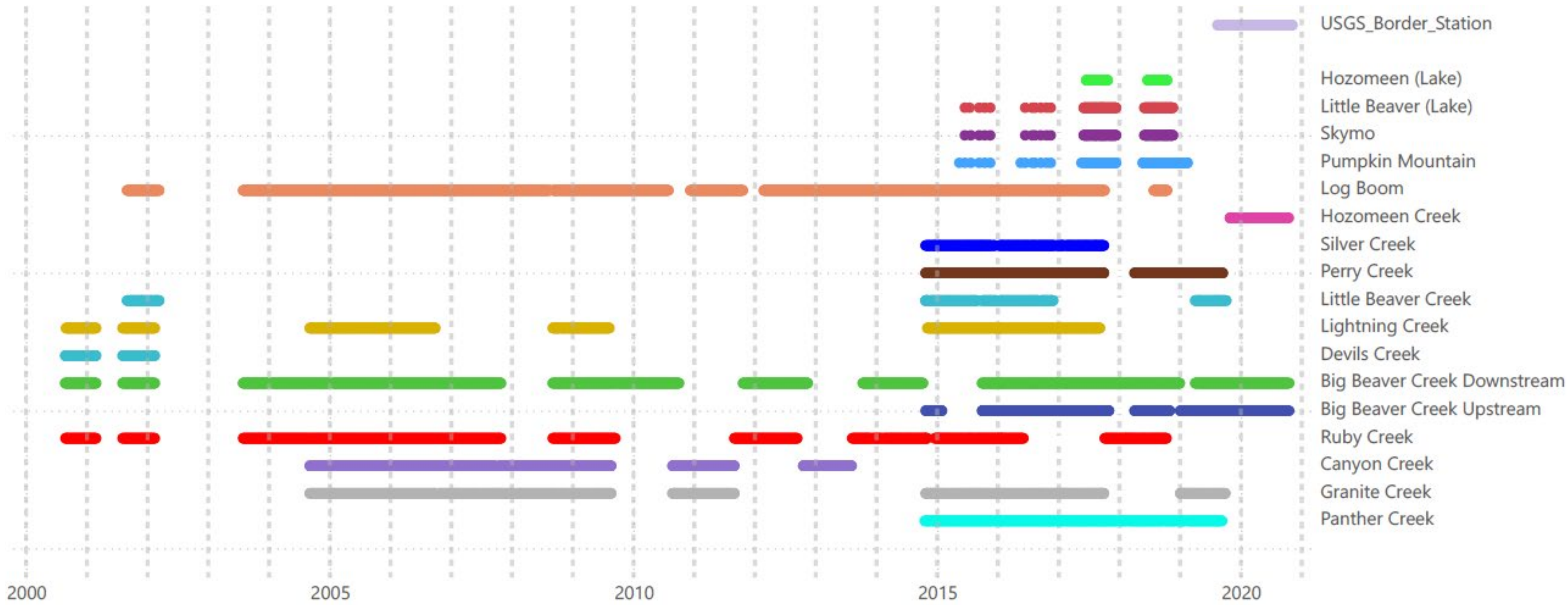

Figure A3-1. Continuous temperature data inventory, Ross Lake (top 6 locations) and Ross tributaries (bottom 12 locations). Time spans of useable data are shown.

Table A3-2. Continuous temperature data inventory, Diablo Lake and related tributaries.

Location	Data Start	Data End	Total Days	Useable Data Start[1]	Useable Data End[1]	Useable Days[1]	Useability	Observations Omitted
Lake Locations								
Ross Powerhouse	2/25/2014	1/6/2020	2142	2/26/2014	12/17/2019	2121	99%	1%
Buster Brown Bay	8/27/2018	1/7/2020	499	8/28/2018	12/17/2019	477	96%	5%
Thunder Arm Nav. Boom	6/21/2018	12/15/2019	543	6/21/2018	12/15/2019	203	37%	0%
Thunder Creek (Bridge)	10/26/2016	12/16/2019	1147	10/27/2016	12/16/2019	1131	99%	3%
Continuous Temperature Station	6/7/2018	10/17/2019	498	6/7/2018	10/17/2019	436	88%	0%
Log Boom	9/16/2005	1/7/2020	5227	9/16/2005	12/17/2019	4398	84%	1%
Dam or Dam Face	11/13/2014	12/13/2019	1857	11/13/2014	12/13/2019	540	29%	0%
Tributary Locations								
Thunder Creek (Mouth)	11/1/2019	10/18/2020	353	11/1/2019	10/10/2020	292	83%	34%
Thunder Creek (Lower)	8/3/2017	8/22/2018	385	8/3/2017	8/22/2018	385	100%	0%
McAllister	10/27/2014	9/22/2017	1062	11/7/2014	9/22/2017	737	69%	38%
Fisher Creek	10/27/2014	10/31/2019	1831	11/7/2014	9/22/2017	913	50%	54%
West Fork Creek	11/11/2014	9/22/2017	1047	11/11/2014	8/28/2017	793	76%	41%

1 Useable days are days with any useable observations. These are equal to the total days, which span from the start date to the end date of the record, minus days with missing observations and days when all observations were qualified due to probable erroneous measurements.

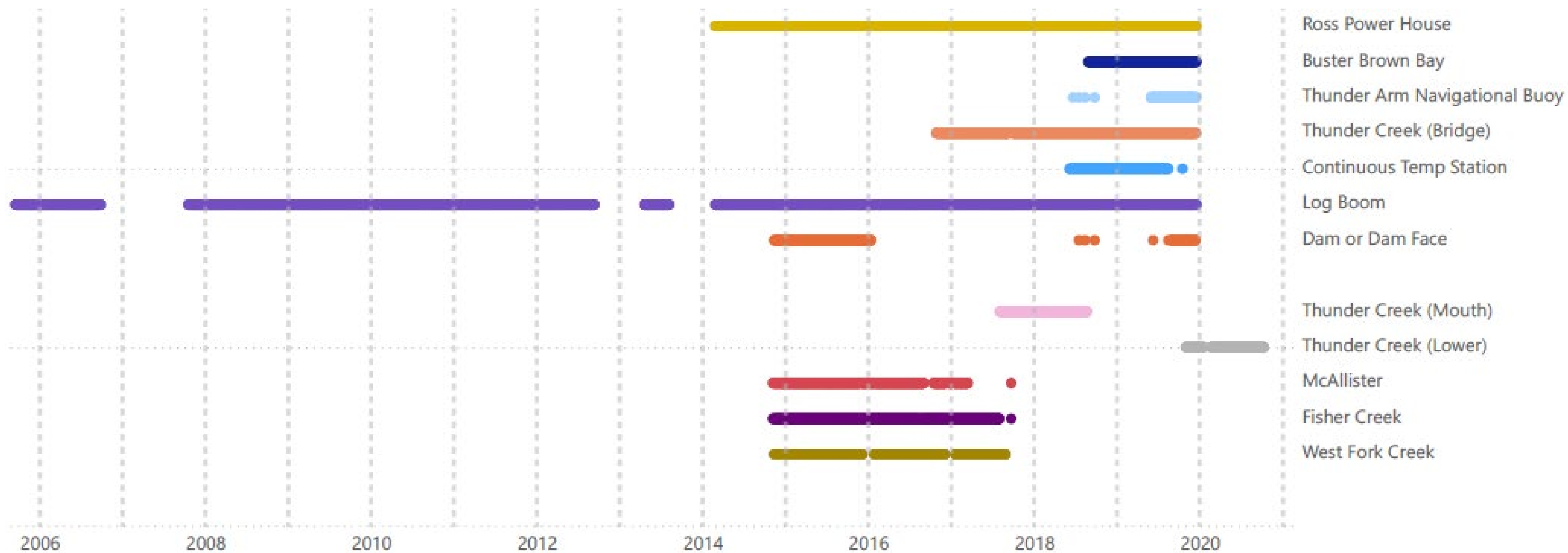

Figure A3-2. **Continuous temperature data inventory, Diablo Lake (top 7 locations) and Diablo tributaries (bottom 5 locations). Time spans of useable data are shown.**

Table A3-3. Continuous temperature data inventory, Gorge Lake and related tributaries.

Location	Data Start	Data End	Total Days	Useable Data Start[1]	Useable Data End[1]	Useable Days[1]	Useability	Observations Omitted
Lake Locations								
Reflector Bar	5/30/2019	1/7/2020	223	5/31/2019	12/16/2019	200	90%	10%
Diablo Powerhouse	8/6/2013	1/7/2020	2,346	8/6/2013	12/20/2019	2,328	99%	1%
Upstream of Stetattle Creek	8/6/2013	1/7/2020	2,346	8/6/2013	12/16/2019	2,262	96%	1%
Powerline	8/1/2017	1/7/2020	890	8/4/2017	12/16/2019	859	97%	4%
Midway	8/1/2017	1/7/2020	890	8/4/2017	12/16/2019	859	97%	5%
Log Boom	12/5/2013	1/7/2021	2,591	12/5/2013	1/7/2021	2,538	98%	0%
Boat Launch	4/18/2013	1/7/2020	2,456	4/19/2013	12/18/2019	1,230	50%	3%
Tributary Locations								
Stetattle Creek	9/14/2005	1/7/2020	5,229	9/16/2005	12/20/2019	4,571	87%	1%

1 Useable days are days with any useable observations. These are equal to the total days, which span from the start date to the end date of the record, minus days with missing observations and days when all observations were qualified due to probable erroneous measurements.

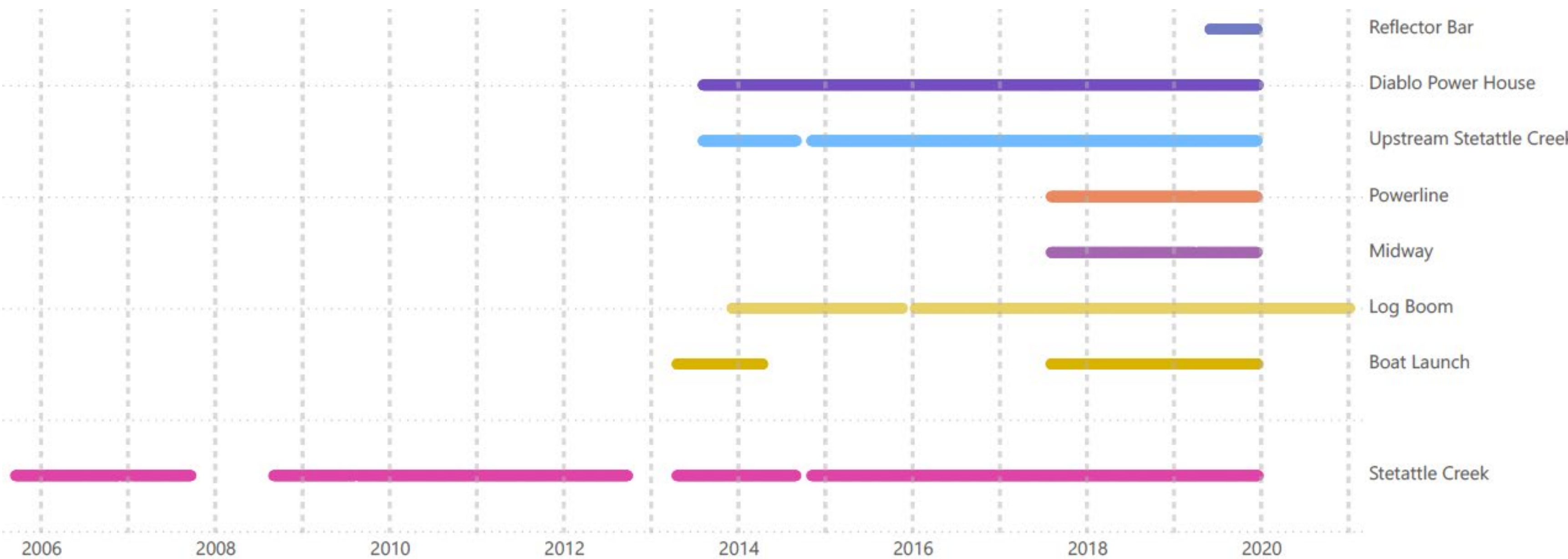

Figure A3-3. **Continuous temperature data inventory, Gorge Lake (top 7 locations) and Gorge tributary Stetattle Creek. Time spans of useable data are shown.**

Table A3-4. Continuous temperature data inventory, Skagit River and Skagit tributaries.

Location	Data Start	Data End	Total Days	Useable Data Start[1]	Useable Data End[1]	Useable Days[1]	Useability	Observations Omitted
Skagit River Locations Upstream of Ross Lake								
Near Sumallo Confluence	7/17/2003	8/13/2019	5,872	7/17/2003	8/13/2019	940	16%	9%
Foot Bridge	11/21/2014	8/7/2017	991	11/28/2014	8/2/2017	885	89%	13%
Right Dry Channel	7/27/2011	8/7/2017	2,204	none	none	0	0%	100%
Left Wet Channel	8/14/2008	11/25/2014	2,295	8/14/2008	11/24/2014	1,929	84%	20%
26 Mile Bridge	8/15/2001	8/13/2019	6,573	8/16/2001	8/13/2019	5,023	76%	10%
Brown Sign	7/17/2003	8/13/2019	5,872	7/17/2003	8/13/2019	5,177	88%	9%
Nepopekum	8/15/2001	8/13/2019	6,573	8/15/2001	8/13/2019	5,703	87%	10%
Swing Bridge	8/26/2002	8/13/2019	6,197	8/26/2002	8/13/2019	4,887	79%	9%
Skagit River Tributaries Upstream of Ross Lake								
Sumallo River	7/17/2003	7/24/2018	5,487	7/17/2003	7/23/2018	4,728	86%	11%
Klesilkwa River	8/15/2001	8/13/2019	6,573	8/16/2001	8/13/2019	5,414	82%	11%
Skagit River Location Downstream of Gorge Dam								
Newhalem	8/4/2013	6/7/2019	2,134	8/6/2013	5/27/2019	1,686	79%	8%
Skagit River Tributaries Downstream of Gorge Dam								
Bacon Creek	8/13/2015	9/28/2020	1,874	8/14/2015	9/28/2020	927	49%	15%
Cascade River	10/13/2014	10/8/2020	2,188	10/24/2014	10/8/2020	1,105	51%	55%
Boulder Creek	10/15/2014	10/9/2020	2,187	10/24/2014	10/8/2020	1,044	48%	30%
Rocky Creek	10/24/2019	10/21/2020	364	10/27/2019	10/16/2020	321	88%	28%
Illabot Creek	10/15/2014	3/3/2021	2,332	10/24/2014	3/3/2021	1,864	80%	31%
Baker River	10/13/2014	10/9/2020	2,189	10/23/2014	10/9/2020	2,069	95%	27%
Hidden Creek	10/10/2014	10/9/2020	2,192	10/23/2014	10/9/2020	1,453	66%	25%

1 Useable days are days with any useable observations. These are equal to the total days, which span from the start date to the end date of the record, minus days with missing observations and days when all observations were qualified due to probable erroneous measurements.

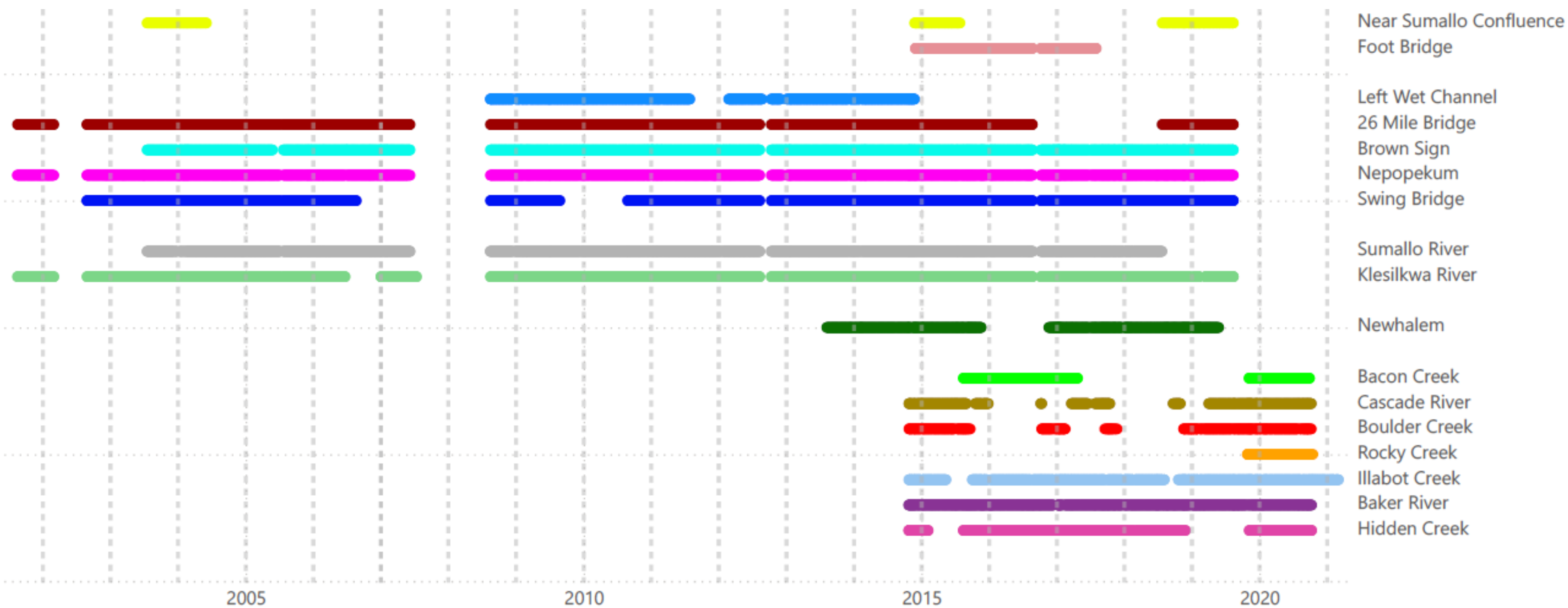

Figure A3-4. Continuous temperature data inventory: Skagit River upstream of Ross Lake (top 7 locations); Skagit River Tributaries Upstream of Ross Lake (Sumallo and Klesilkwa Rivers); Skagit River downstream of Gorge Dam at the Newhalem Location; and Skagit River tributaries downstream of Gorge Dam (bottom 7 locations). Time spans of useable data are shown.

Water Quality Sonde Deployments

Vertical profiles of T, SC, pH, and DO were collected by the NCCN in three locations in each of Ross and Diablo Lakes in 2015-2018 and 2018-2019, respectively (Table A3-5). The water quality sonde that collected temperature data at the USGS Border Station from August 2019 through November 2020 also measured SC, pH, DO, turbidity, and fDOM in 15-minute intervals.

Table A3-5. Vertical profile collection in Ross and Diablo Lakes.

Month	Ross Lake			Diablo Lake		
	Little Beaver	Skymo	Pumpkin Mtn.	Nav. Buoy	Dam	Thunder Arm
May 2015			x			
June 2015	x	x	x			
July 2015	x	x	x			
Sep. 2015	x	x	x			
Oct. 2015	x	x	x			
Nov. 2015	x	x	x			
May 2016			x			
June 2016	x	x	x			
July 2016	x	x	x			
Aug. 2016	x	x	x			
Sep. 2016	x	x	x			
Oct. 2016	x	x	x			
Nov. 2016	x	x				
May 2017			x			
June 2017	x	x	x			
July 2017	x	x	x			
Aug. 2017	x	x	x			
Sep. 2017	x	x	x			
Oct. 2017	x	x	x			
Nov. 2017	x	x	x			
May 2018			x			
June 2018	x	x	x			x
July 2018	x	x	x	x	x	x
Aug. 2018	x	x	x	x	x	x
Sep. 2018	x	x	x	x	x	x
Oct. 2018	x	x	x			
Nov. 2018	x	x	x			
June 2019				x	x	x
Aug. 2019				x	x	x
Oct. 2019				x	x	x

Grab Samples

Grab samples were collected at the same locations and times in Ross Lake as the vertical profiles described in Section 2 of this appendix. The depth of these samples was not specified. Anions, cations, nutrients, biological markers, and zooplankton were measured (Table A3-6).

Table A3-6. Analytes for grab samples collected in Ross Lake, 2015-2018.

Analyte Group	Analyte
General Chemistry	acid neutralizing capacity dissolved organic carbon total dissolved solids
Anions	chloride sulfate
Cations	calcium potassium magnesium sodium
Nutrients	ammonia nitrate nitrate plus nitrite total dissolved nitrogen phosphate total dissolved phosphorus
Biological Markers	Chlorophyll *a* uridine triphosphate
Zooplankton	zooplankton concentration zooplankton species zooplankton density

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APPENDIX 4

ASSESSMENT OF DATA QUALITY

Continuous Temperature Data

Deployment of continuous temperature sensors in reservoir tributaries was documented by NPS (2020). This documentation is broadly consistent with the calibration and deployment requirements described in Ecology EAP080 (Ecology 2018). Specifically, sensors were calibrated with a reference thermometer to within 0.2 °C, data collected before and after deployment were deleted from data records, and internal NPS deployment protocols were followed. Data were plotted and examined with respect to six years of Stream Sensor Monitoring Reports (NPS 2015; 2016; 2017; 2018; 2019; 2020). Data were qualified in the database and removed from analyses and interpretation when documentation noted data quality issues relating to compromised field deployments (usually sensors spending time out of water). Other outliers that were similar to those that occurred during documented occurrences of poor field conditions were also qualified and removed from further analyses. The fraction of observations qualified in a given measurement location varied between locations (Appendix 3). After these QC steps were taken, remaining data were deemed reliable.

Similar practices for collection of continuous temperature data by NPS were documented for 2017-2018 in Ross Lake and 2018-2019 in Diablo Lake (Archambault 2019a; 2019b), and thus these data were deemed reliable. Data collected in Ross Lake in 2015-2016 were collected by the same methods (Archambault 2021) and thus were also deemed reliable.

No documentation was available for temperature sensors deployed in the Skagit River and tributaries upstream of the Project, in tributaries to Ross Lake prior to 2012, in thermistor chains near the dams (i.e., Log Boom and Dam Face locations), and in tributaries downstream of Diablo Dam. These data were qualified in the database, evaluated for obviously poor data in the same manner as for the NPS data described above, and interpreted (see Section 3.4 for details regarding data qualification).

Water Quality Sonde Deployments

Water quality sonde deployments in Diablo Lake and Ross Lake followed internal NPS documentation (Archambault 2019a; Archambault 2019b). Deployments included pre- and post-deployment screenings, calibration according to the manufacturer specification, and other activities consistent with internal NPS protocols, and so field activities associated with these data were deemed reliable, although documentation describing consistency with Ecology EAP129 (Ecology, 2019a) was not found. No documentation was available for the water quality sonde deployment in the inflow to Ross Lake by the USGS. This agency is known for its consistent and reputable field methodologies, and thus these data were deemed reliable yet qualified in the database (see Section 3.4 for details regarding data qualification).

Depth data from water quality sondes deployed in Diablo Lake and Ross Lake by NCCN were plotted with respect to time. These data showed that, in nearly all deployments, sondes were lowered to discrete depths and allowed to equilibrate there for 30-60 seconds. This field procedure is consistent with EAP130 (Ecology 2019b). Vertical profile data were plotted and examined for outliers consistent with EAP130 (Ecology 2019b). Occasional outliers that existed in the raw data were qualified in the database as erroneous data (see Section 3.4). To create plots in this report (see Section 5 and Appendix 6), the conversion of time series data for depth, T, SC, pH, and DO to data expressing T, SC, pH, and DO performed by the NCCN, which was available in data files, was used. When these processed data were plotted, remaining outliers, which comprised a fraction of a percent of the sonde data, were removed from analyses. Profiles in November 2016 at the Pumpkin Mountain location and August 2019 at the Thunder Arm location were noted by NCCN to be compromised due to sonde malfunction. The former contained too little data to be used; the valid data from the latter were included in the analysis. Remaining data (>99.5 percent) were regarded as acceptable for analysis and interpretation.

Data from the water quality sonde placed in the Skagit River inflow to Ross Lake in 2019-2020 were plotted against time to assess the presence of outliers. Extrema in the different sensors on the sonde (T, SC, pH, DO, turbidity, and fDOM) were evaluated based on the presence or absence of other extrema. No obvious errors were observed, and so data were retained and used for analysis.

Data pertaining to field QC samples to assess the quality of data from water quality sondes were not available, and data from pre- and post-deployment checks that were reported complete by NCCN (Archambault 2019a; 2019b) were not available. Thus, additional QC assessments consistent with EAP130 (Ecology 2019b) were not possible.

Grab Samples

Grab sample data were accepted based on documentation by Archambault (2019a, 2019b) and the analysis of water samples under the established Quality Assurance Plan at the Water Analysis Laboratory of the College of Forestry Cooperative Chemical Analytical Laboratory at Oregon State University. Grab samples were considered separately for the following groups of analytes:

- TDS;
- ANC and DOC;
- Nutrients;
- Anions;
- Cations;
- Chlorophyll *a*; and
- Zooplankton.

Total Dissolved Solids

Four pairs of field replicates for TDS were collected from 2015 to 2018, and concentrations within replicate pairs differed by no more than 4 mg/L in replicate samples whose concentrations ranged from 45-56 mg/L. Field blanks were nondetects. These data were judged as suitable for analysis and interpretation.

Acid Neutralizing Capacity and Dissolved Organic Carbon

ANC sample sets included field blanks and field replicates. Blanks had concentrations of 0 μeq/L. Field replicates are summarized in Table A4-1. Given the range of potential uncertainty in 2017, ANC data were summarized and analyzed for broad trends.

Table A4-1. Replicate samples collected with ANC data, from NCCN grab samples.

Year	Error, Replicate 1	Error, Replicate 1	RSD[1] of All Data
2015	-2%	4%	15%
2016	None	None	12%
2017	28%	29%	17%
2018	2%	0%	25%

1 RSD: Relative standard deviation, the arithmetic standard deviation divided by the arithmetic mean, expressed as a percentage.

For DOC, 45 sets of field replicates were collected across the four sampling years and three Ross Lake locations. The relative standard deviation (RSD, calculated relative to the arithmetic mean) was calculated for each set of replicates. The median RSD was 3 percent; five replicate sets had an RSD of >20 percent. One of these was a triplicate set, and so the value that obviously differed from the other two values was excluded from analyses. The median value of all samples was 1.4 (mg C)/L, and two blanks collected in 2017 and 2018 had concentrations of 0.17 (mg C)/L and 0.75 (mg C)/L, suggesting possible contamination of samples. These data may be appropriate only for analysis of broad trends.

Nutrients

Nearly all (83 of 85) ammonia observations were below detection limit (BDL); detection limit (DL) = 0.003 (mg N)/L, so these data were not evaluated for quality. When nitrate, nitrate+nitrite, and TDN replicates were above detection limit, they were within 2 µg/L of each other. The nitrogen blanks were BDL. Thus, nitrogen data above detection were judged to be useable for analysis.

Nearly all (85 of 88) TDP observations were BDL (DL ≈ 0.002 (mg P)/L), so these data were not evaluated for quality. For PO_4-P and UTP observations, replicate samples agreed within 1 (mg P)/L. However, 1 of 3 blank samples analyzed had a concentration on par with that of other samples. Additionally, 34 of 88 PO_4-P samples and 25 of 91 UTP samples had concentrations above the detection limit (DL ≈ 0.002 (mg P)/L), thus exceeding concentrations of total dissolved phosphorus (TDP). Concentrations of samples were universally low, and so this suggests that few robust conclusions can be drawn from PO_4-P or UTP data.

Across eight field replicate pairs, sulfate concentrations differed by no more than 2 mg/L and concentrations of the one blank sample analyzed were BDL. Sulfate data were judged to be useable for analysis.

Anions

Chloride was the only anion measured. It was not measurable in two field blanks analyzed. Across nine replicate pairs, a difference of no more than 0.05 mg/L was observed. Thus, these data were judged to be useful for analysis.

Cations

Cations analyzed were sodium, magnesium, potassium, and calcium. Differences between replicate samples for were <0.07 mg/L, with one exception where two calcium replicates differed by 0.55 mg/L. Two field blanks were measured for each of sodium, magnesium, potassium, and calcium, and all were BDL except for one sodium sample, which had a concentration of 0.03 mg/L. Sodium, magnesium, and potassium observations were judged as appropriate for analysis, and detailed variations in calcium were interpreted with caution.

Chlorophyll *a* and Zooplankton

One chlorophyll *a* blank sample was available, and its reported concentration was 0.000 µg/L. A detection limit for this measurement method was not reported. No field replicates were collected, so further assessment of the quality of chlorophyll data was not possible.

To prevent contamination of zooplankton samples, the net, collecting, cup, and line were rinsed thoroughly between sampling locations and dried thoroughly between sampling events. Duplicate samples were collected at each location during each sampling event. Additionally, the nylon lines were routinely checked for stretching and recalibrated if needed. Chain of custody and proper handling procedures were used from the collection of the sample through the delivery of the data. Based on the sampling methodology, it was assumed that a lack of observation of a species within a sample indicates that there were zero organisms of that species present. Species identification and counting was completed by a contractor retained by the NCCN; information pertaining to these measurements is pending.

MANAGEMENT AND EVALUATION OF EXISTING WATER QUALITY DATA DRAFT REPORT

APPENDIX 5

TEMPERATURE AND RELATIVE THERMAL RESISTANCE TO MIXING IN THERMISTOR CHAINS

As a further analysis of the continuous thermistor chain temperature data presented in Section 5.1 of the existing data report, time-depth contour plots were created (Figures A5-1 through A5-5).

Ross Lake exhibited a pattern of summer stratification, fall overturn, and a vertically mixed period in the winter that is typical of deep, temperate lakes (Figure A5-1). In summer, the thermocline often extended over a large range of depth below the water surface; often, water at the bottom of the thermistor chain was not isothermal below a well-defined thermocline (e.g., 2014 in Figure A5-1). Maximum surface water temperatures were about 20-22 °C in most years. Minimum surface water temperatures were 3-6 °C.

Water level varies by nearly 100 ft annually in Ross Lake, with lowest water levels coinciding with vertically mixed conditions in the late winter. When water level was low in winter, water temperature was the same at all depths, so the depth at which the penstocks (i.e., the pipes leading through the dam that connect the reservoir to the hydroelectric power plant) withdrew water was irrelevant for water temperature downstream. When water level was high in summer, water temperature was much warmer on the surface than at depth. The penstock openings are at approximately 1,446 ft North American Vertical Datum of 1988 (NAVD 88) (1,440 ft City of Seattle datum [CoSD][1]), and therefore, when the water level was high in summer, the dam released water downstream that was 9-14 °C colder than the water at the surface of the reservoir.

Thermal stratification began around April in most years and ended with autumn overturn in November of most years. During early 2017, winter stratification occurred at the Log Boom location, but this did not occur in other winters as shown in January to March 2017 (Figure A5-1).

At its Log Boom location, Diablo Lake showed a similar seasonal stratification pattern to Ross Lake, although its warmest surface temperatures were cooler (about 15-17 °C), and stratification began in June (Figure A5-4). Unlike Ross Lake, the water surface elevation in Diablo Lake was relatively consistent over the year.

Gorge Lake showed only occasional, short-lived, and minor stratification (Figure A5-5), likely due to its short residence time of <1 day (City Light 2021). Diablo Dam releases water from about 104 ft deep (City Light 2020). When the Diablo thermistor chain measured water temperature at this depth (late 2018 onward), temperature in Gorge Lake downstream matched this depth, suggesting that Gorge Lake temperatures follow those of Diablo Dam releases closely. Gorge Lake was the coldest of the three reservoirs, with temperatures rarely exceeding 13 °C. The weak stratification in Diablo Lake and negligible stratification in Gorge Lake were also shown in RTRM plots (Figure A5-8 through Figure A5-11). Data from Gorge Lake show an effect of the Goodell Fire in August 2015. During this time, City Light shut down hydroelectric generation at the Project from August 19-29, 2015, instead discharging water from the spillways of each of the three dams. Warm surface water from Ross Lake moved downstream and warmed Gorge Lake significantly during this time.

Temperature measurements in thermistor chains were used to calculate RTRM, a simple, unitless statistic that can be used to understand and compare the strength of stratification present in a water

[1] Conversion factors between CoSD and NAVD 88 at different locations within the Project are specified in Appendix A of the RSP.

column at or among locations (i.e., the resistance to wind-driven mixing on a given day).[2] It is calculated at discrete depths such that:

$$RTRM_{(z1+z2)/2} = \frac{\rho_{z2} - \rho_{z1}}{\rho_{5^\circ C} - \rho_{4^\circ C}}$$

Where	RTRM	=	relative thermal resistance to mixing;
	z1, z2	=	any two consecutive depths in a vertical profile (e.g., 9 ft and 10 ft);
	ρ	=	density, based on temperature at a given depth (salinity contributions to density were neglected).

RTRM values can be assembled into a vertical profile that can be plotted along with a temperature profile (plotted as a three-ft moving average in Figure A5-6, which shows examples of summer 2015, autumn 2015, and winter 2015-2016, respectively, at the Ross Lake Log Boom). Maxima in an RTRM profile correspond to regions of rapid temperature change (i.e., stratification) in a temperature profile. Time-depth contour plots of RTRM appear in Figure A5-7 through Figure A5-11).

Wind appears to play a minor role in vertical circulation patterns in summer near Ross Dam, as no meaningful surface mixed layer was observed and RTRM values were below 20 (Figure A5-7). This is low compared to RTRM values near 80 in other deep, temperate lakes that exhibited well-defined surface mixed layers and steep thermoclines (Kunz and Wildman 2019). This implies not only that surface water was warmer than it would have been with more wind but also that the thermocline began at the surface. Ross Lake is known to be windy, and this observation does not extend to profiling locations further up the lake (discussed below). In the region near Ross Dam, canyon walls and the dam itself may shield the Log Boom location from wind. Consistent with temperature profiles, RTRM in Diablo Lake was minimal, with nonzero values occurring only briefly in summer of each year at the Log Boom location (Figure A5-10). Values of RTRM were negligible in Gorge Lake, which is continually well-mixed (Figure A5-11).

[2] The Schmidt Stability Index is also sometimes used to describe the strength of vertical stratification, but RTRM is simpler to calculate and to interpret.

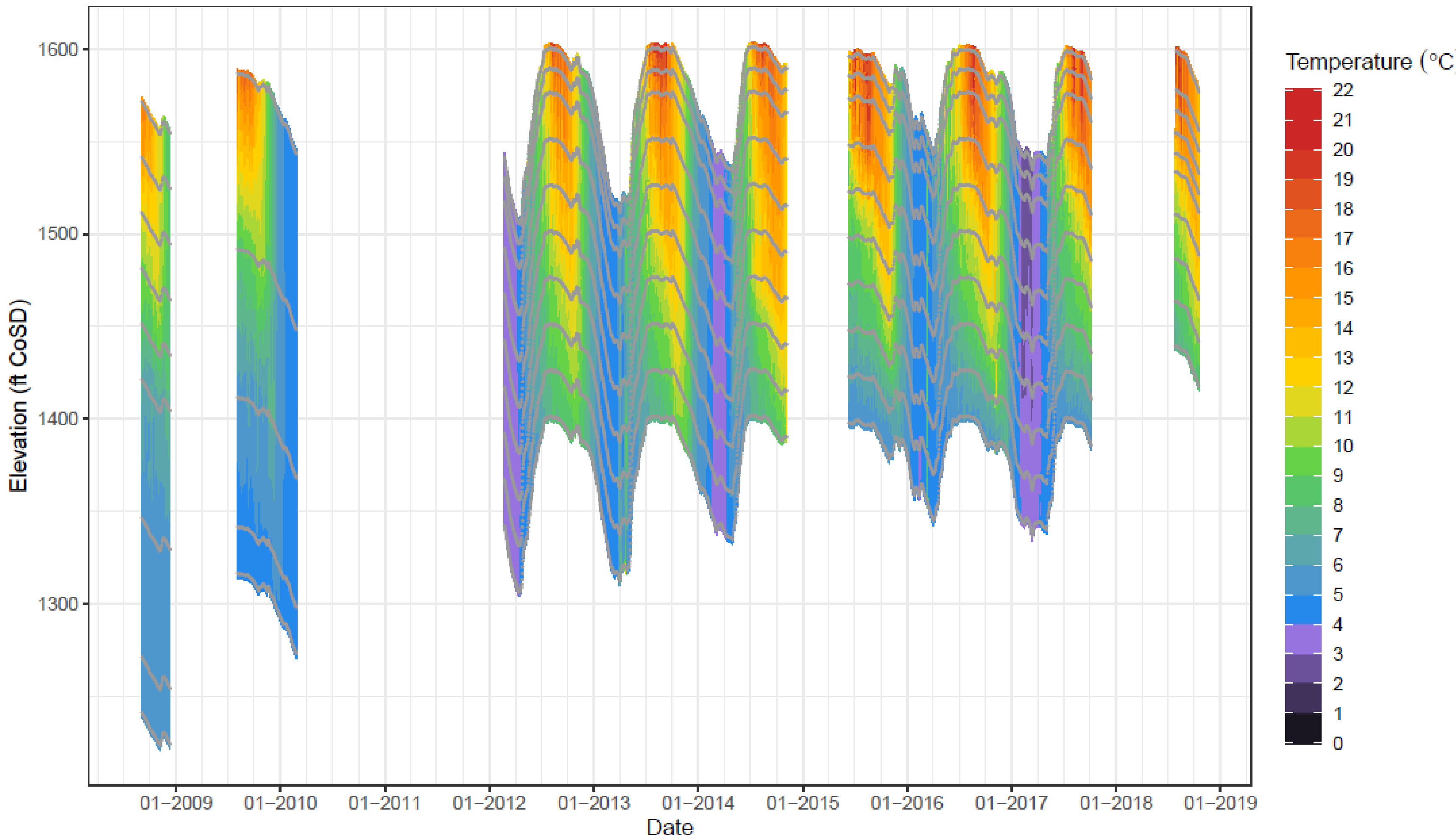


Figure A5-1. **Daily average temperature in Ross Lake at the Log Boom location. Gray lines indicate elevations of thermistors between which temperature was interpolated linearly. The openings of the penstocks of Ross Dam are at approximately 1,440 ft CoSD. Data collected by City Light.**

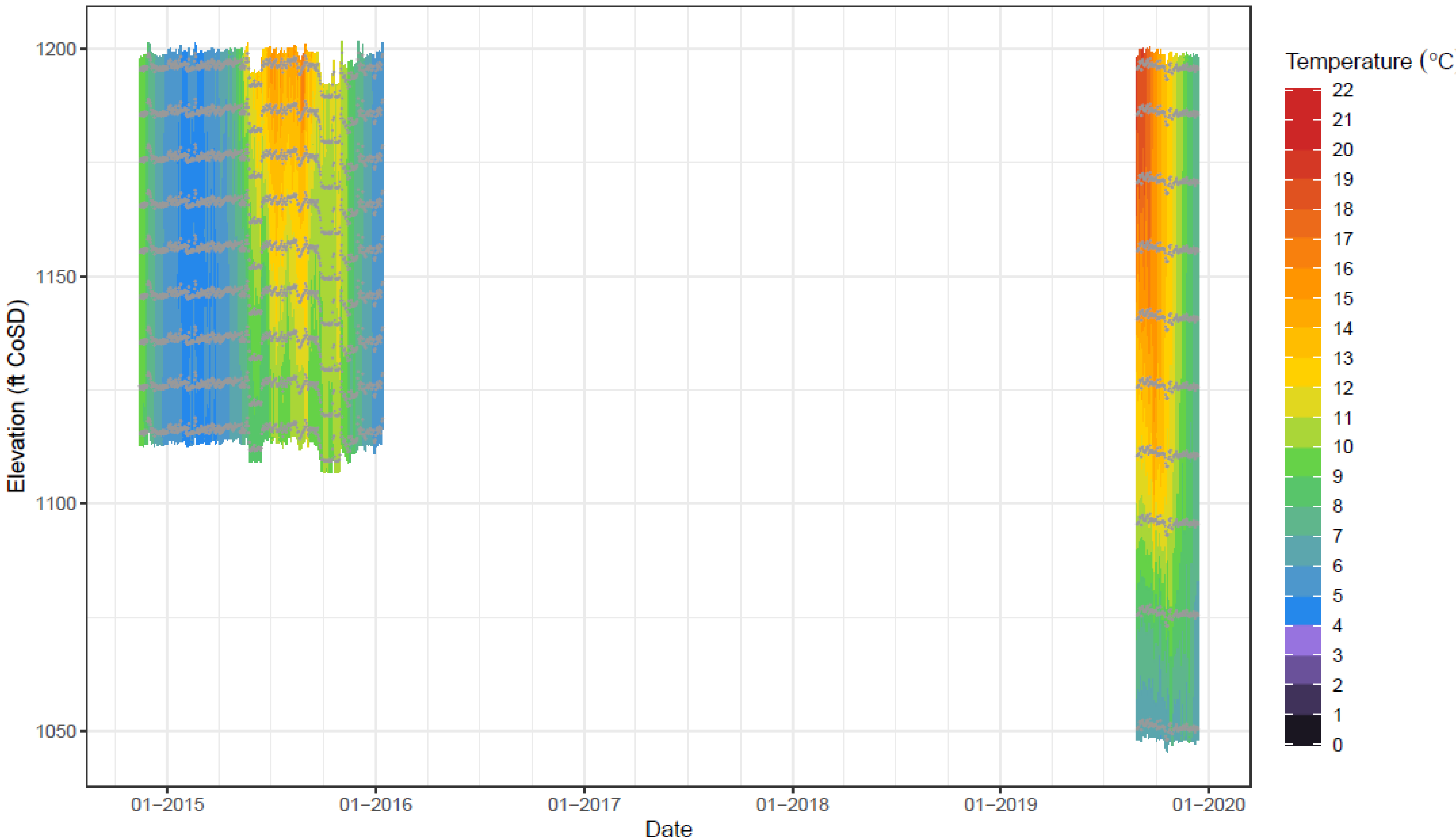


Figure A5-2. Daily average temperature in Diablo Lake at the Dam location. Gray dots indicate elevations of thermistors between which temperature was interpolated linearly. Data collected by City Light.

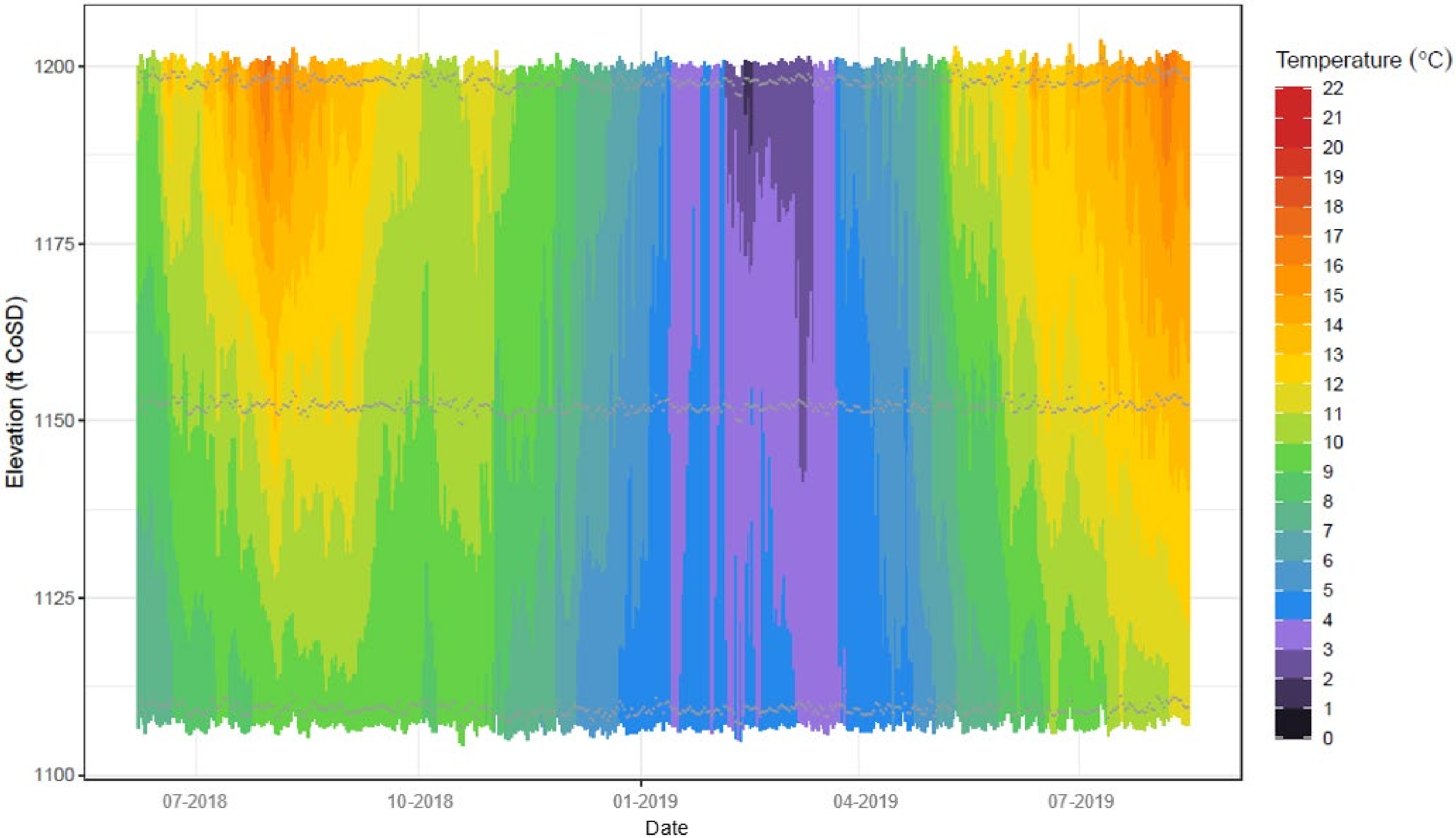


Figure A5-3. Daily average temperature in Diablo Lake at the Continuous Temperature location. Gray dots indicate elevations of thermistors between which temperature was interpolated linearly. Data collected by City Light.

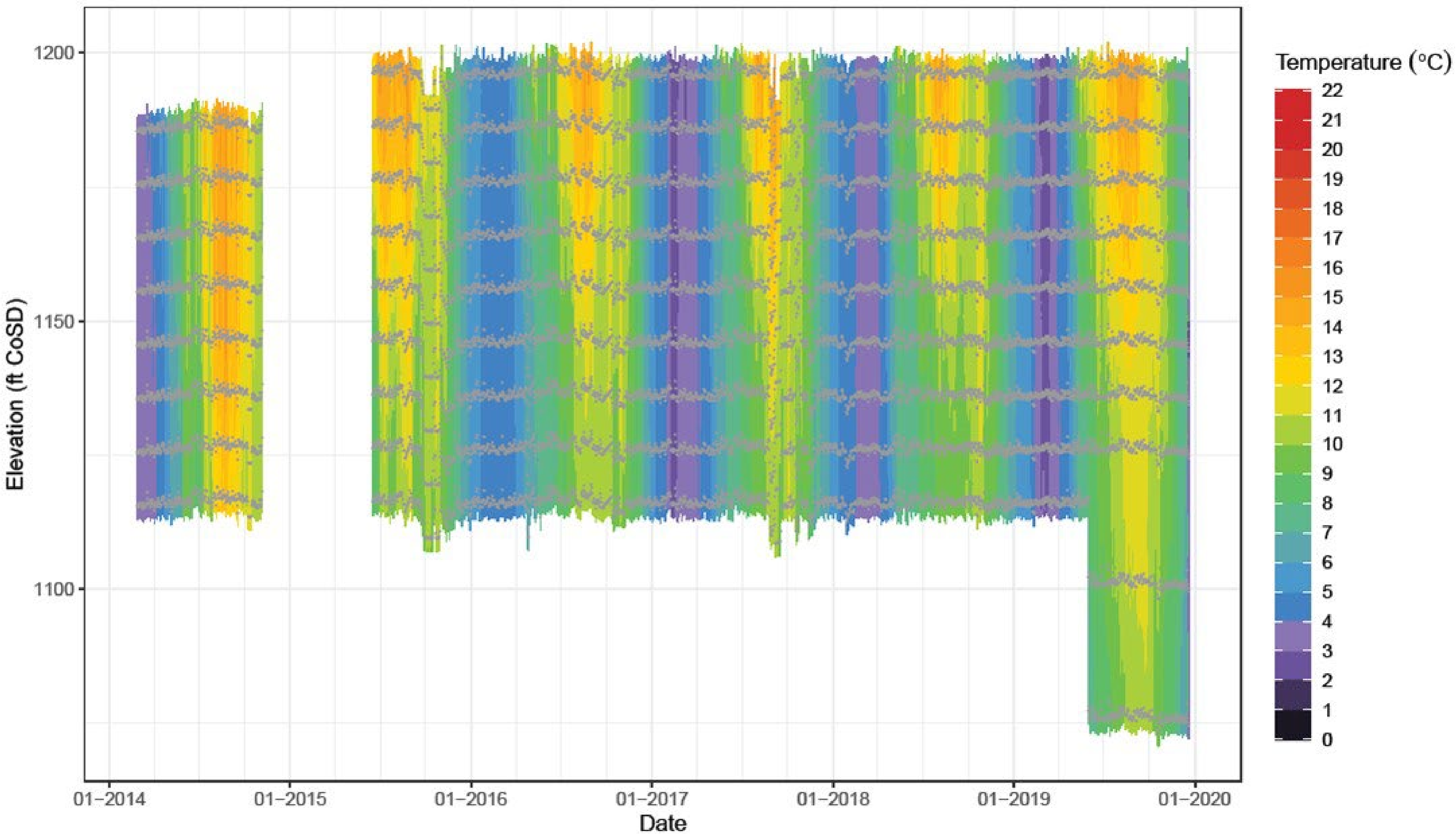


Figure A5-4. Daily average temperature in Diablo Lake at the Log Boom location. Gray dots indicate elevations of thermistors between which temperature was interpolated linearly. The openings of the penstocks of Diablo Dam are at approximately 1,083 ft CoSD. Data collected by City Light.

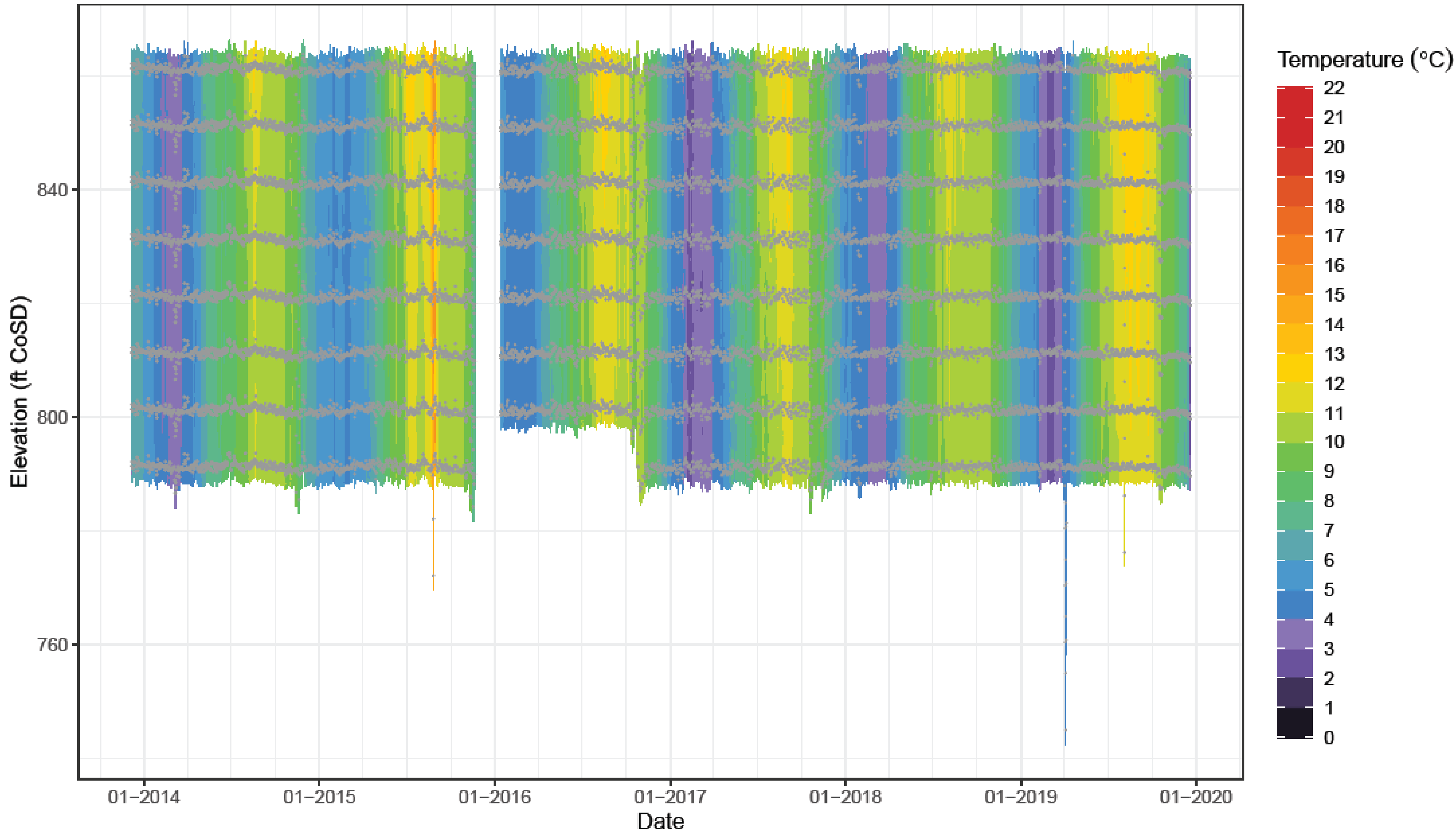


Figure A5-5. Daily average temperature in Gorge Lake at the Log Boom location. Gray dots indicate elevations of thermistors between which temperature was interpolated linearly. Data collected by City Light.

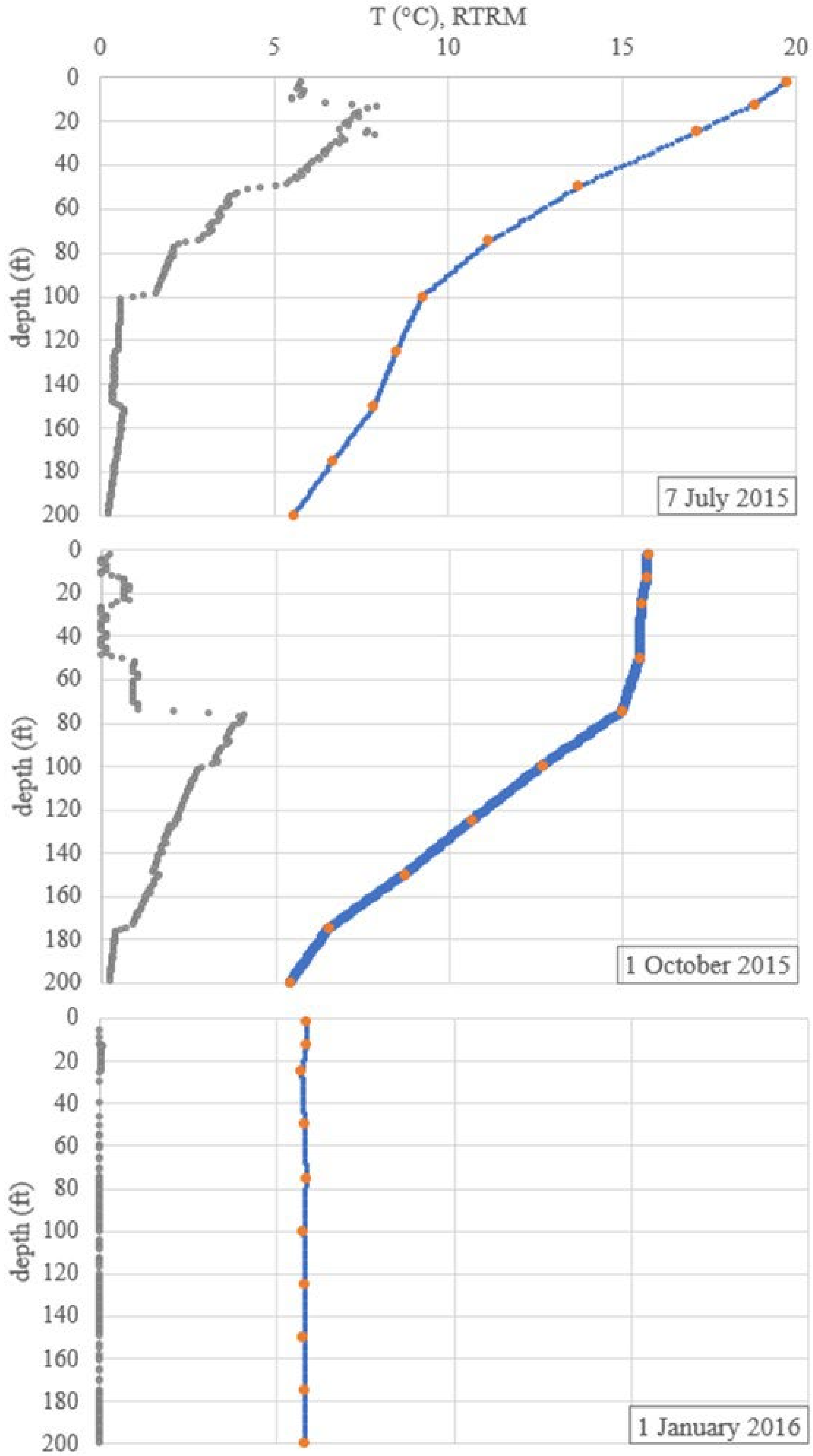


Figure A5-6. **Example vertical profiles of T (blue) and RTRM (gray), Ross Lake Log Boom thermistor chain. Orange dots indicate depth and T of individual sensors.**

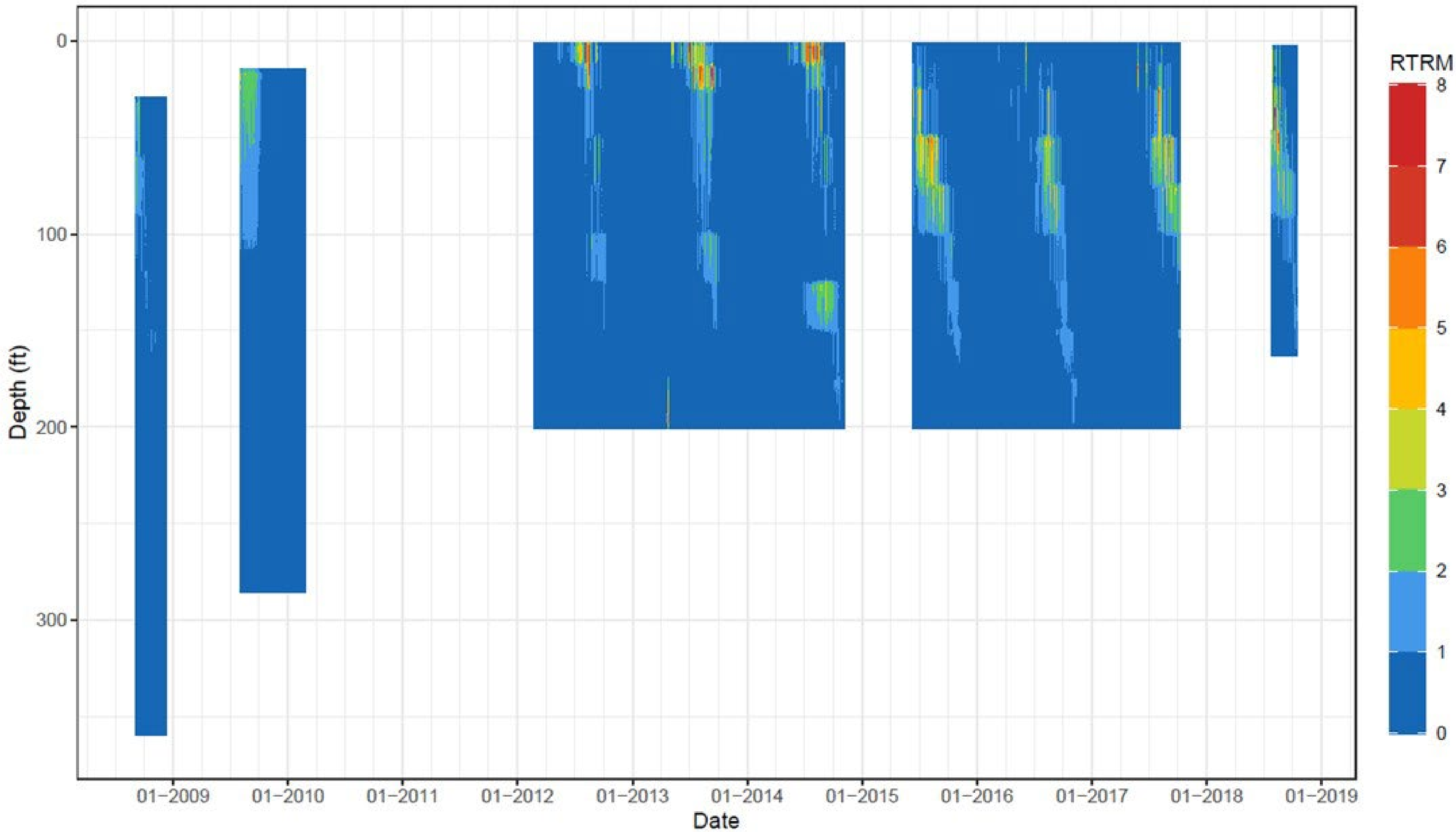


Figure A5-7. Relative thermal resistance to mixing in Ross Lake at the Log Boom location.

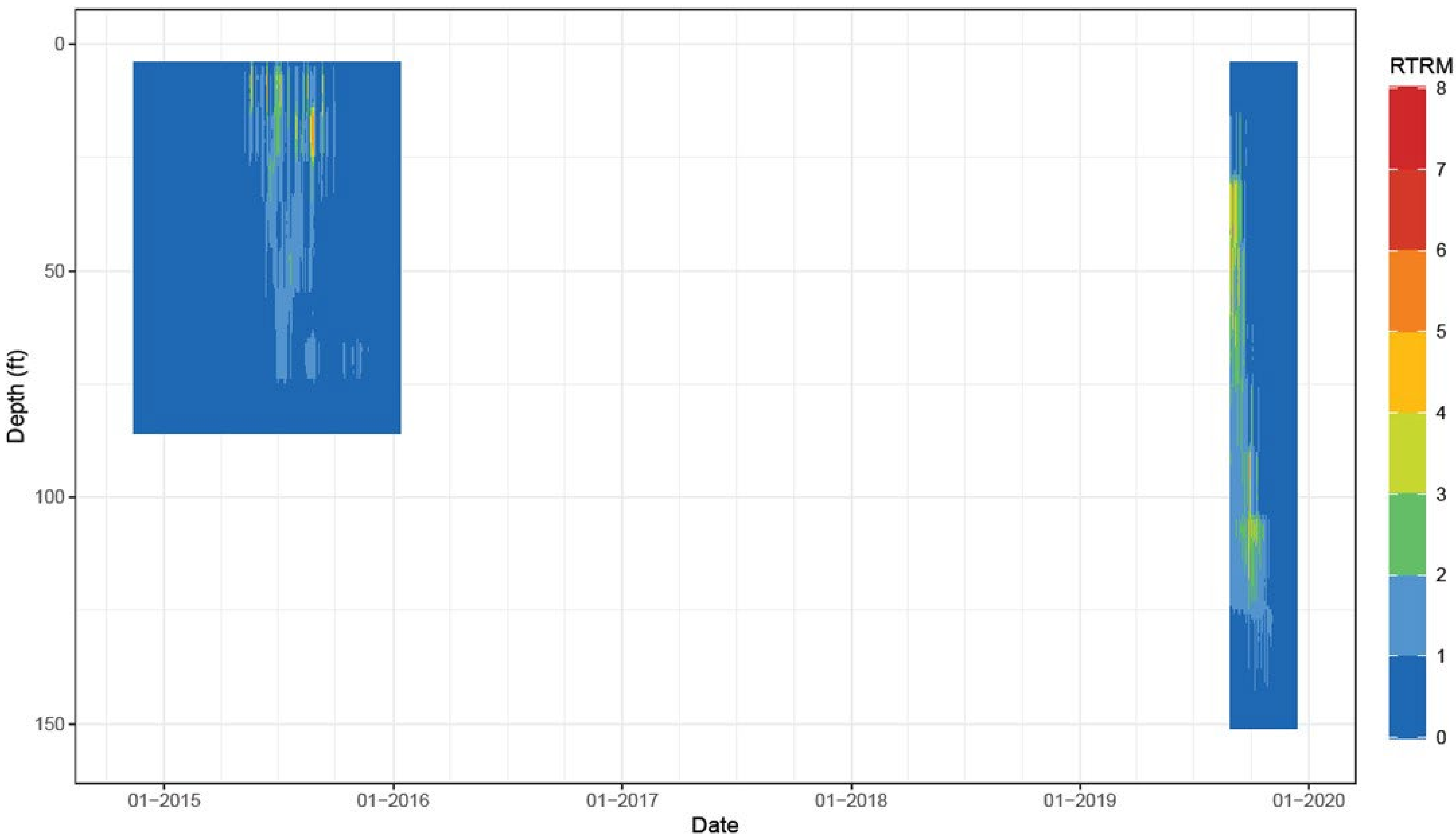


Figure A5-8. Relative thermal resistance to mixing in Diablo Lake at the Dam location.

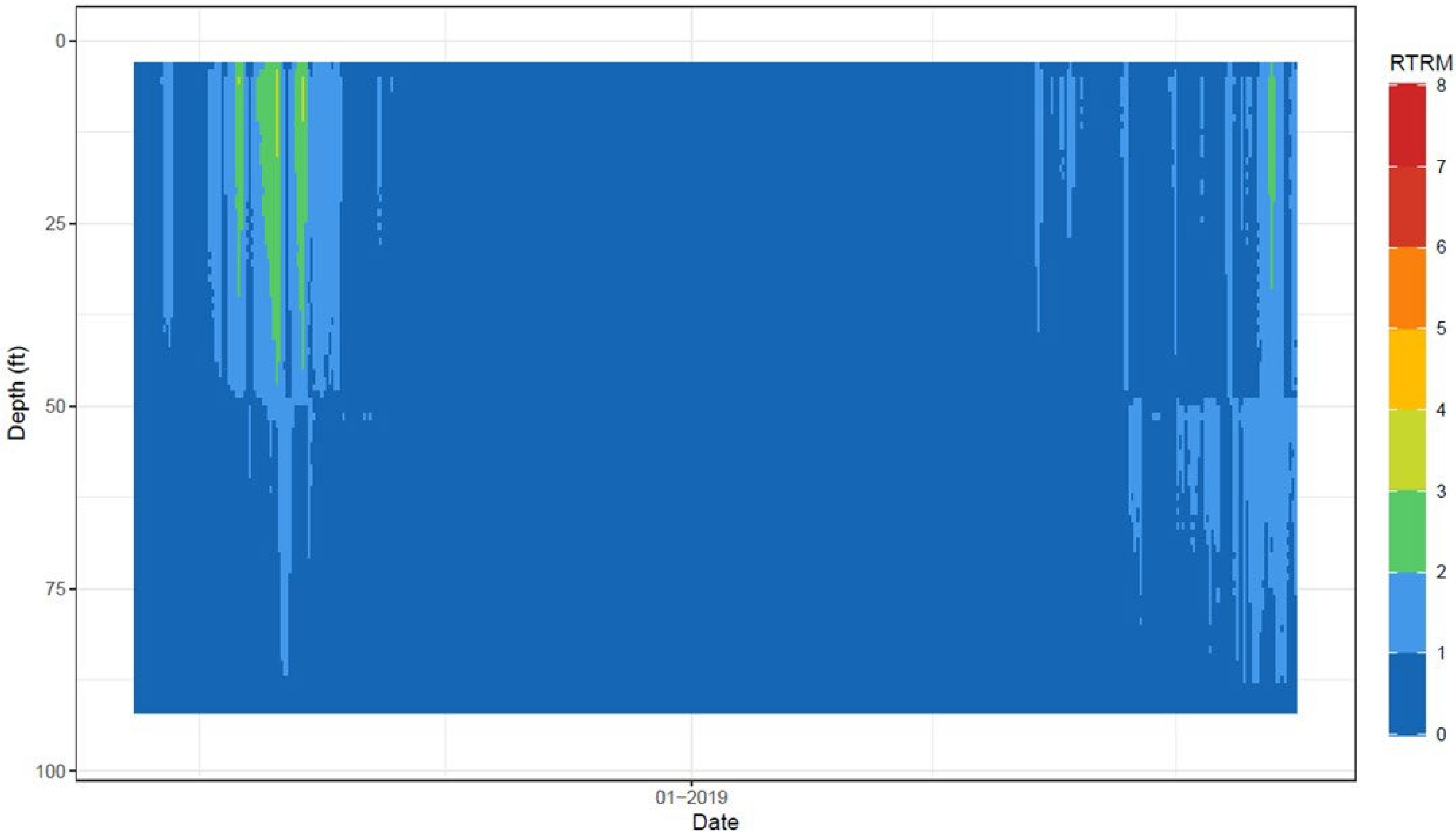


Figure A5-9. Relative thermal resistance to mixing in Diablo Lake at the Continuous Temperature Station.

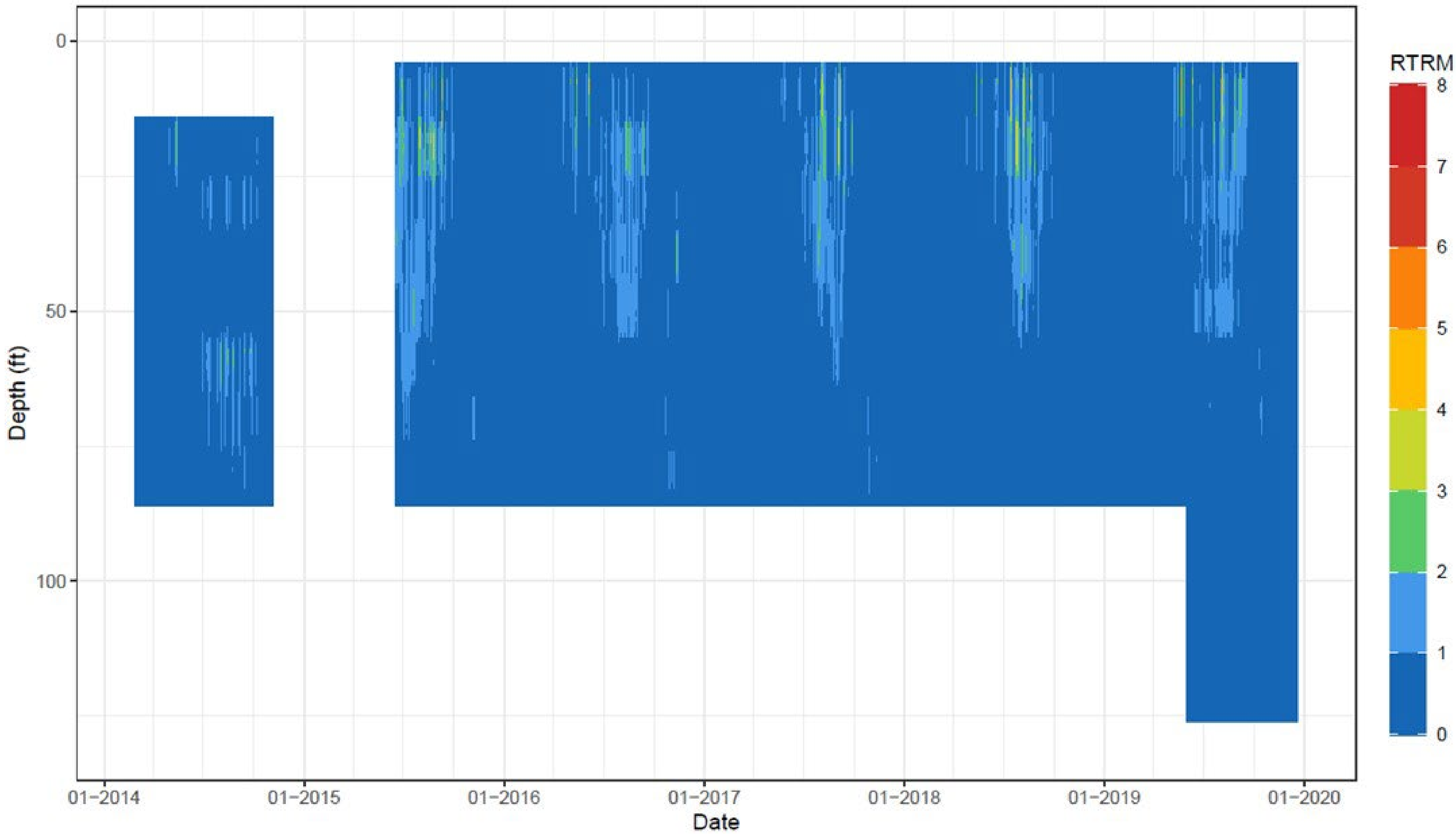


Figure A5-10. Relative thermal resistance to mixing in Diablo Lake at the Log Boom location.

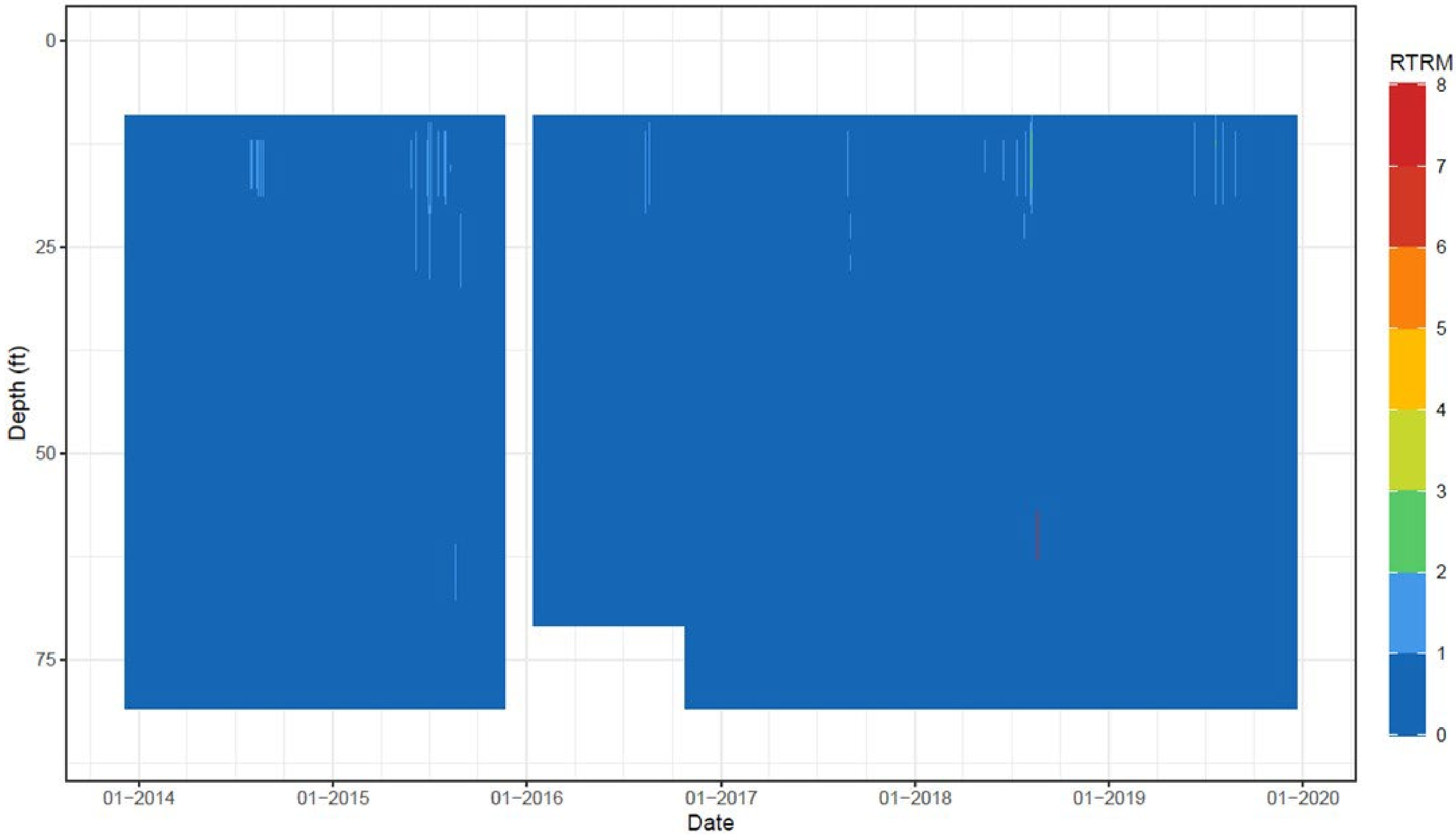


Figure A5-11. Relative thermal resistance to mixing in Gorge Lake at the Log Boom location.

MANAGEMENT AND EVALUATION OF EXISTING WATER QUALITY DATA DRAFT REPORT

APPENDIX 6

VERTICAL PROFILE DATA

This appendix presents the substantial amount of vertical profiling data collected between 2015 and 2018 (inclusive) in the Little Beaver, Skymo, and Pumpkin Mountain locations of Ross Lake and during 2018 and 2019 at the Thunder Arm, Navigation Buoy, and Dam locations of Diablo Lake. Available data are shown; when profiles do not appear, those data were not collected (i.e., Skymo and Little Beaver in May of each year; specific other times and locations compromised by equipment malfunctions). In each profile, T, SC, pH and DO data were collected. Plots show T and SC data together for interpretation related to circulation processes and, separately, pH and DO together to provide insight regarding some water quality implications for these processes. In lakes with high primary productivity, pH and DO can be elevated (e.g., pH > 8 and DO near saturation) in the surface mixed layer while decreasing sharply below it. However, in oligotrophic Ross and Diablo lakes, excursions in pH and DO can also mark variations in inflow characteristics that are moved through the reservoirs consistent with longitudinal circulation patterns. Observations and interpretations of these figures are presented in Section 5.3 of the existing data report.

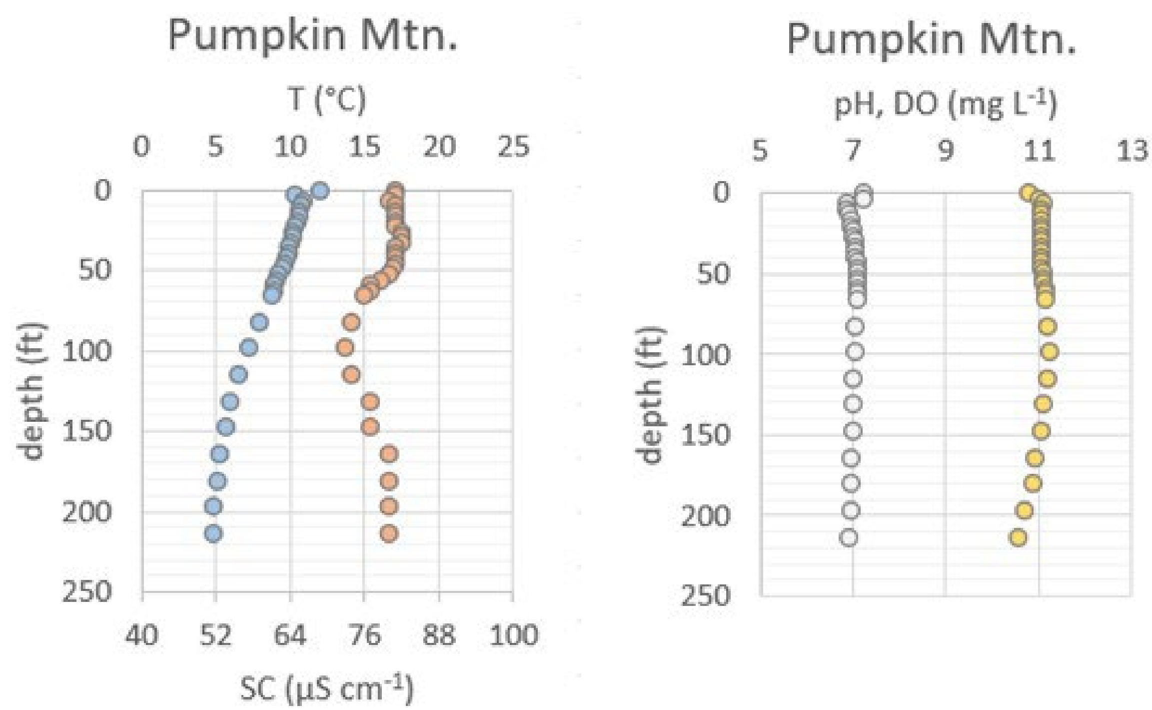


Figure A6-1. **Ross Lake, May 14, 2015. Left Panel: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Right Panel: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

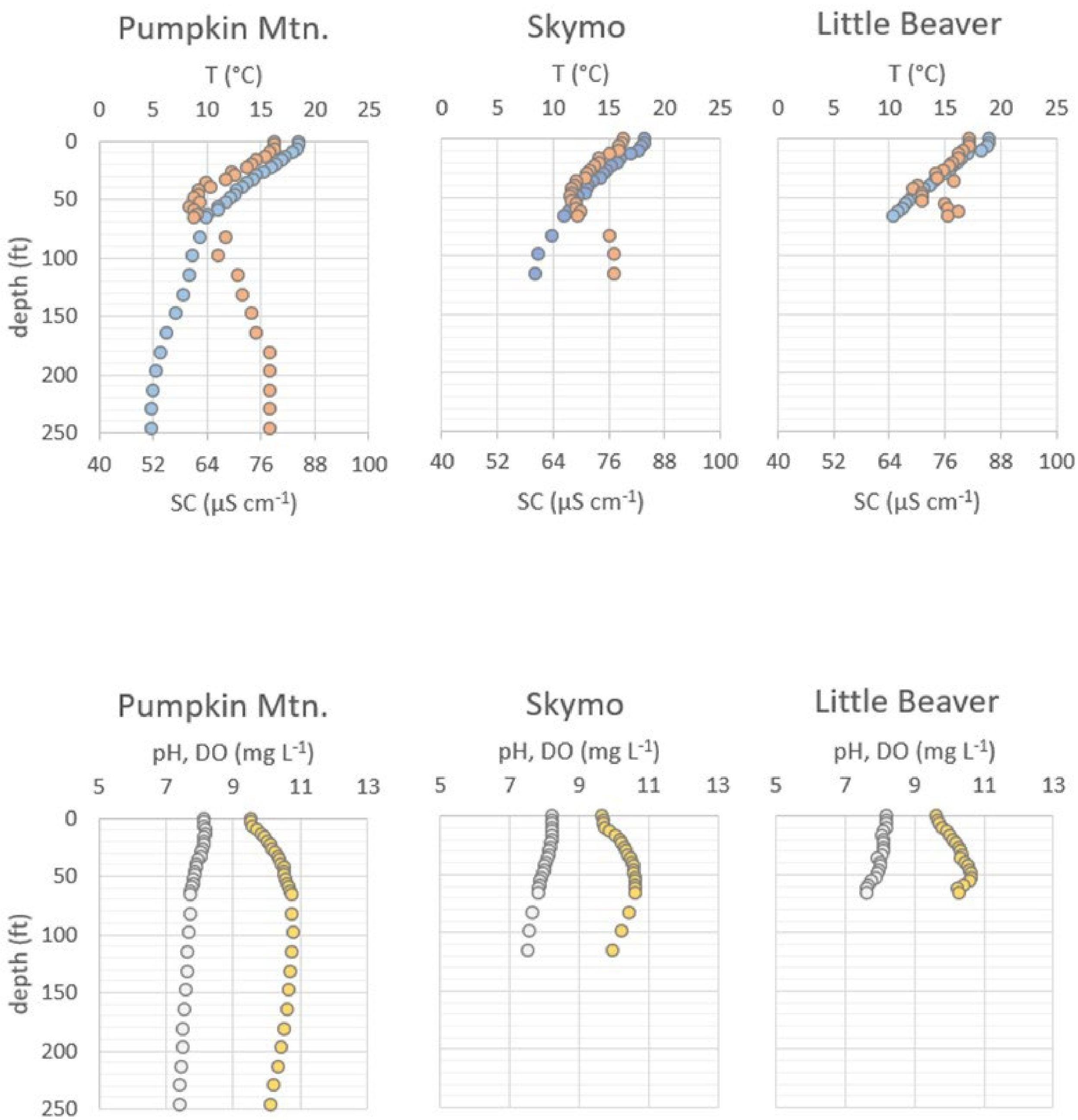
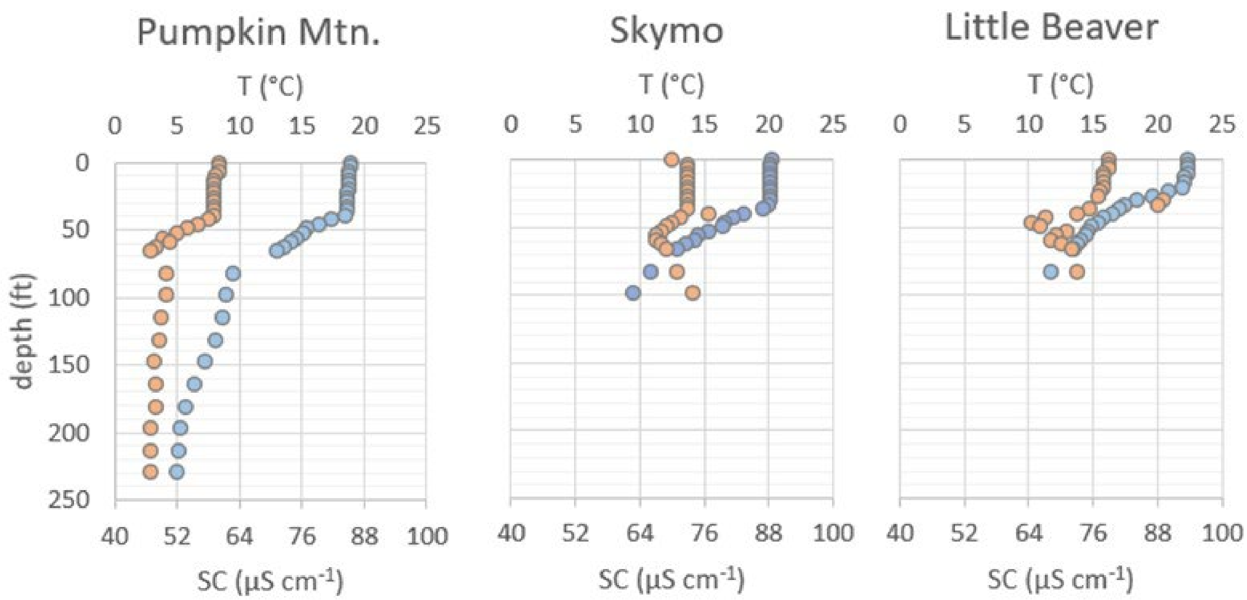


Figure A6.2 **Ross Lake, June 16, 2015. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**



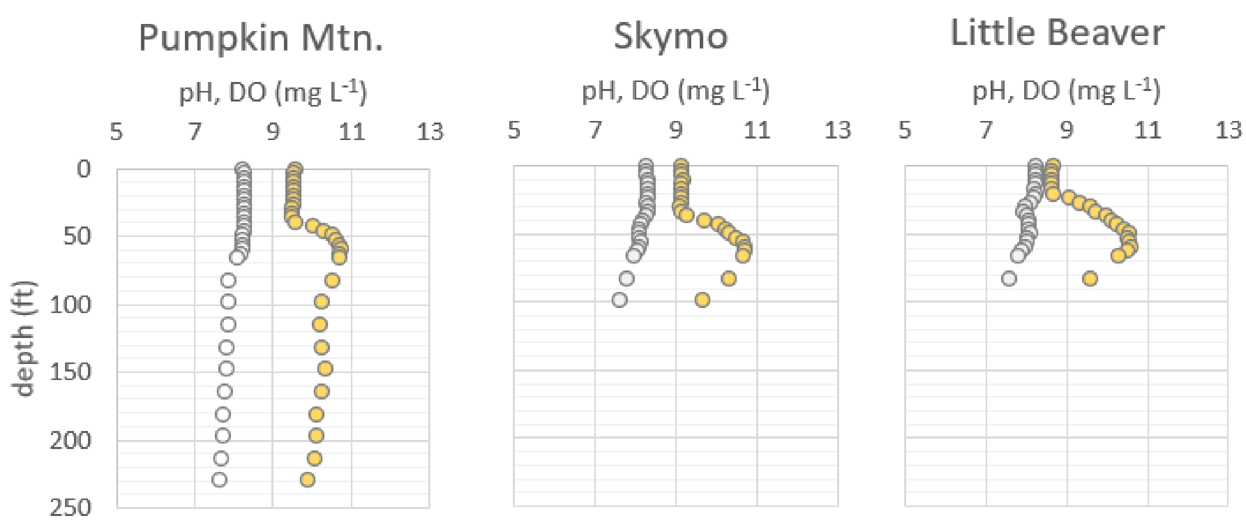


Figure A6-3. Ross Lake, July 22, 2015. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.

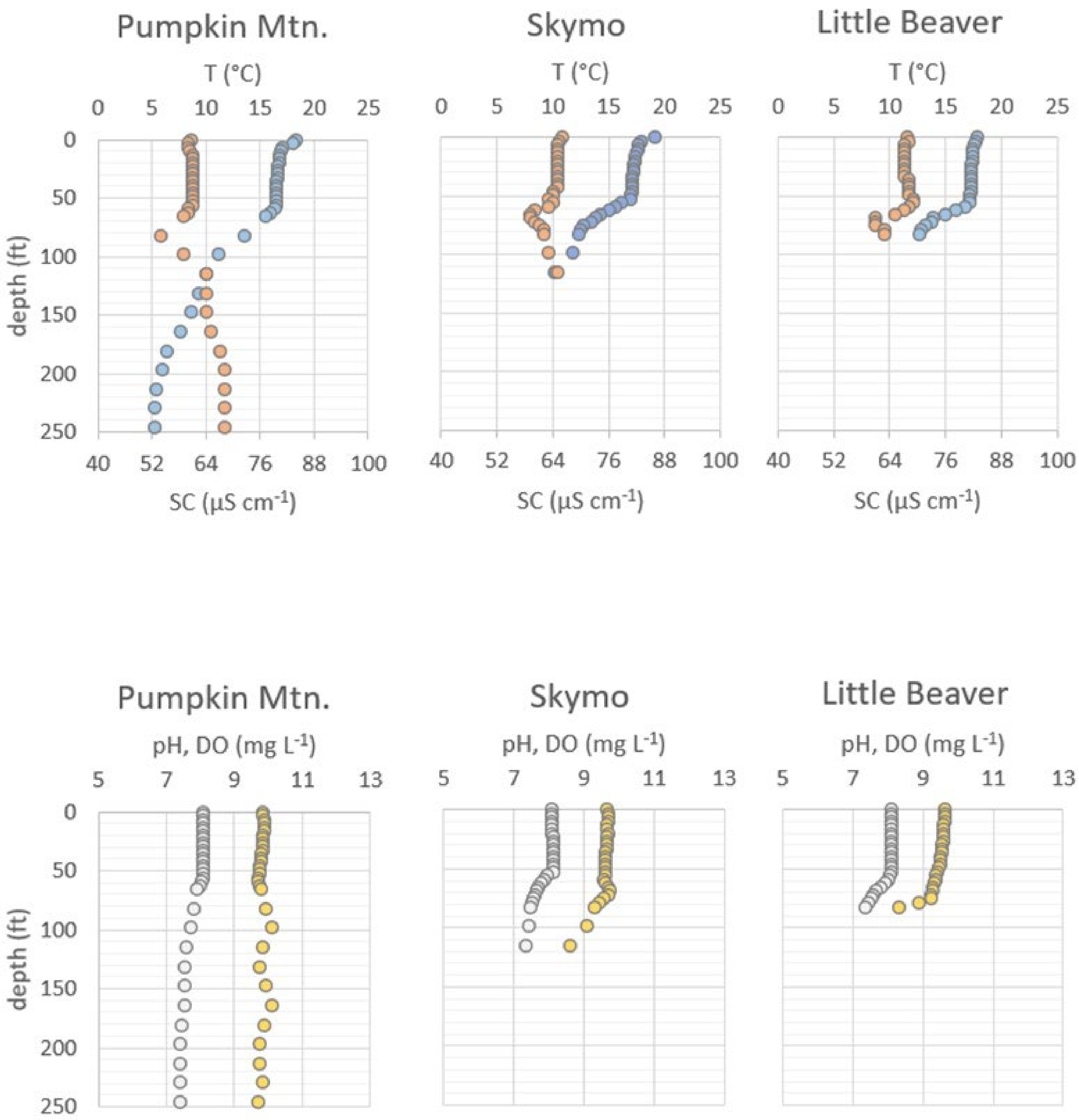


Figure A6-4. **Ross Lake, September 10, 2015. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

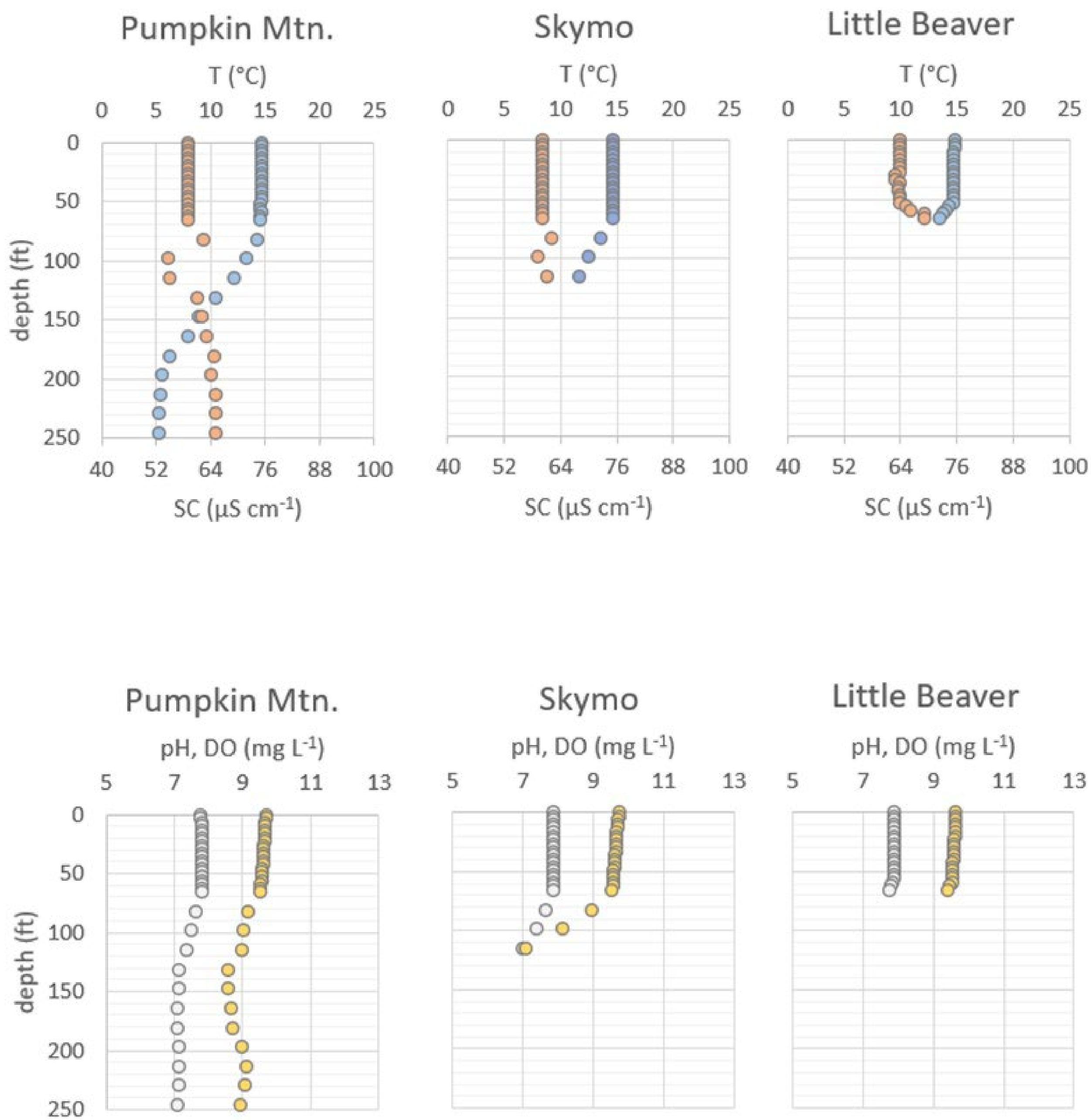


Figure A6-5. **Ross Lake, October 14, 2015. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

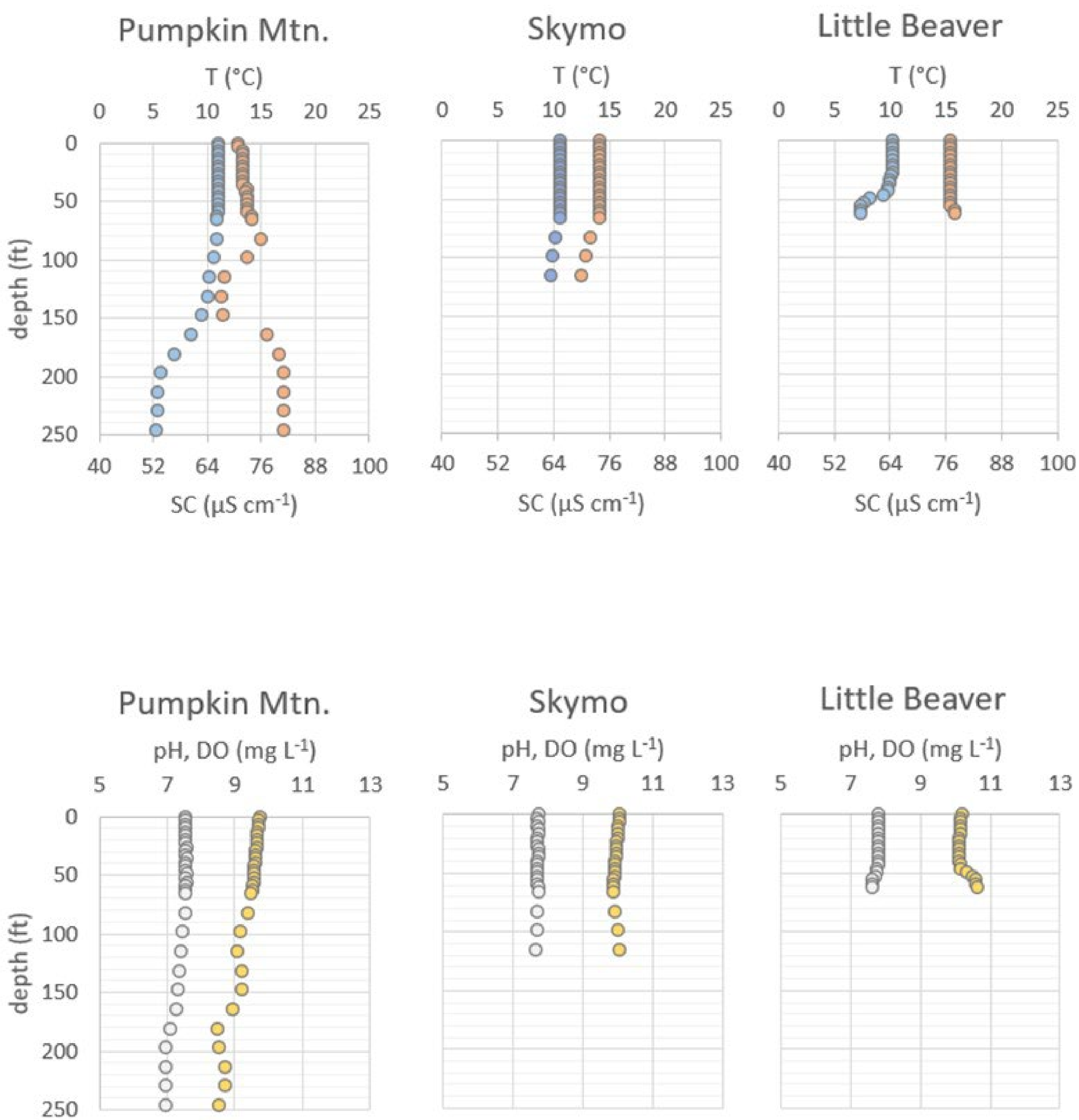


Figure A6-6. **Ross Lake, November 16, 2015. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

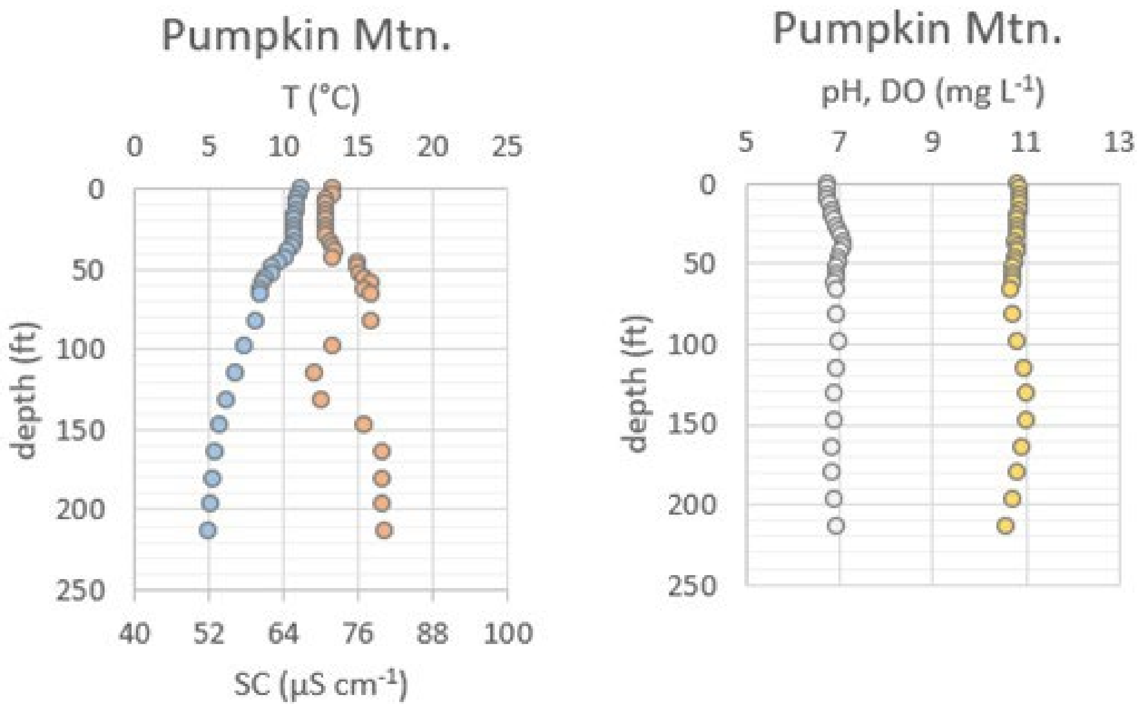


Figure A6-7. **Ross Lake, May 17, 2016. Left Panel: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Right Panel: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

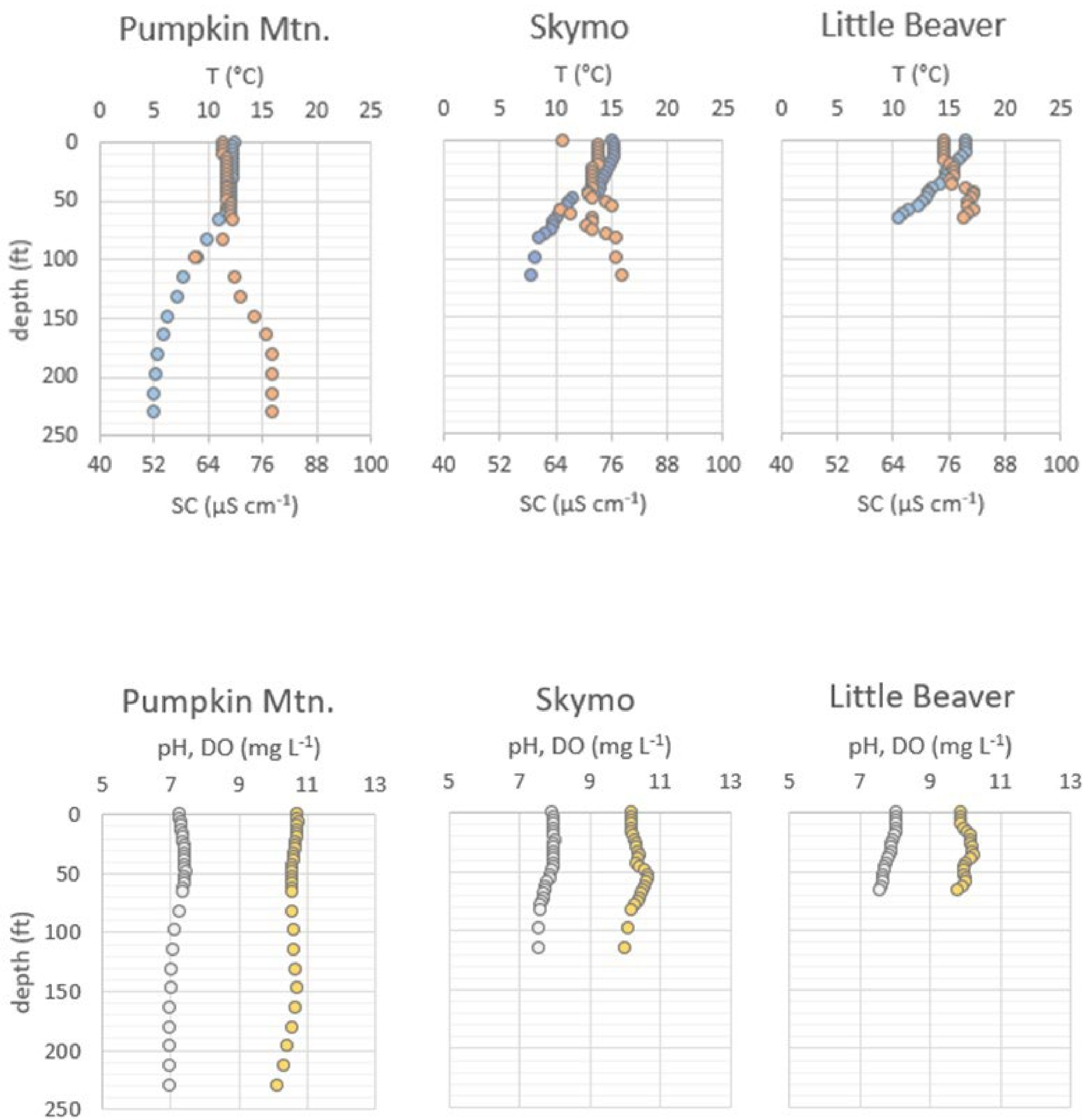


Figure A6-8. **Ross Lake, June 13, 2016. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

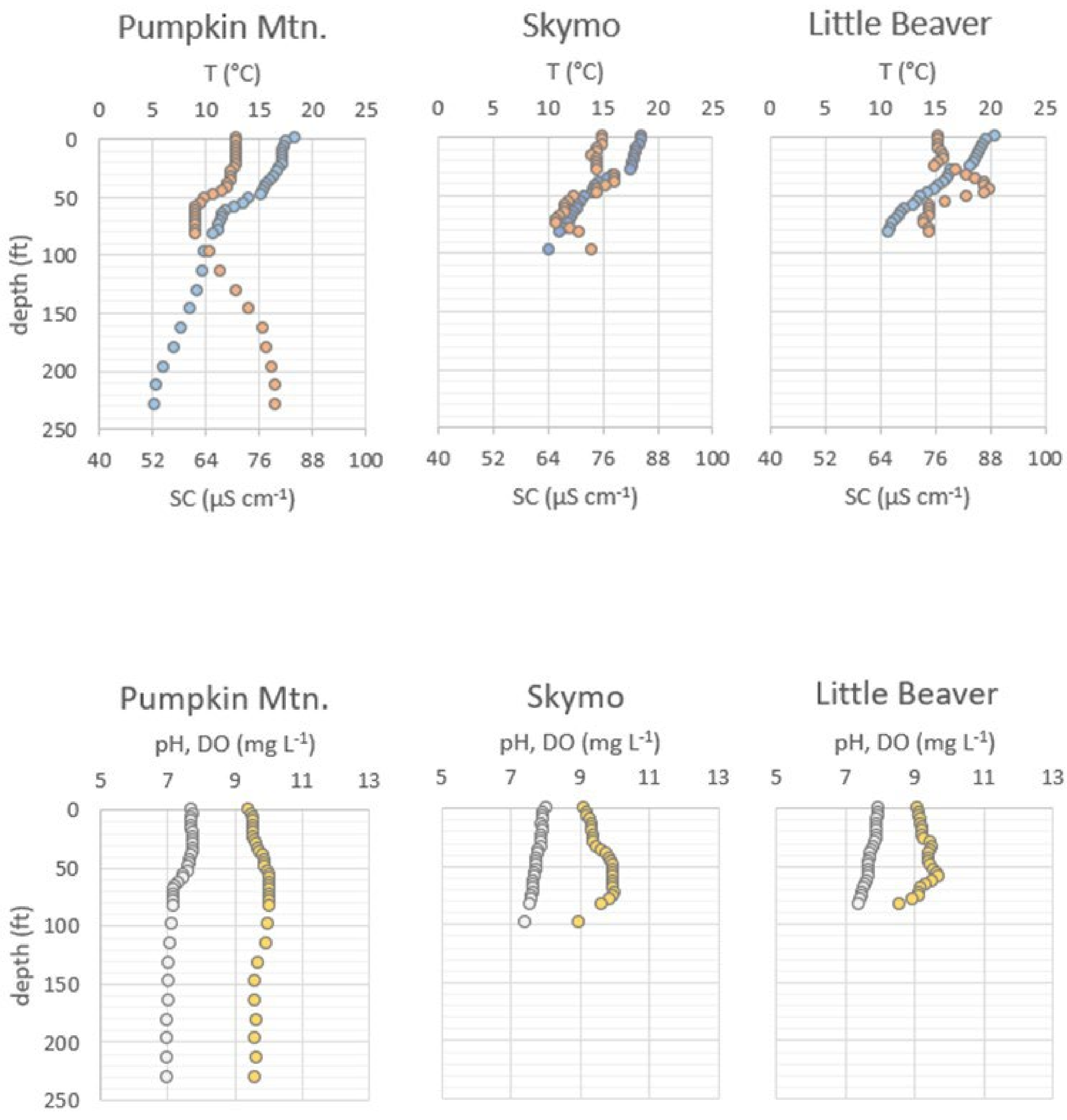


Figure A6-9. **Ross Lake, July 25, 2016. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

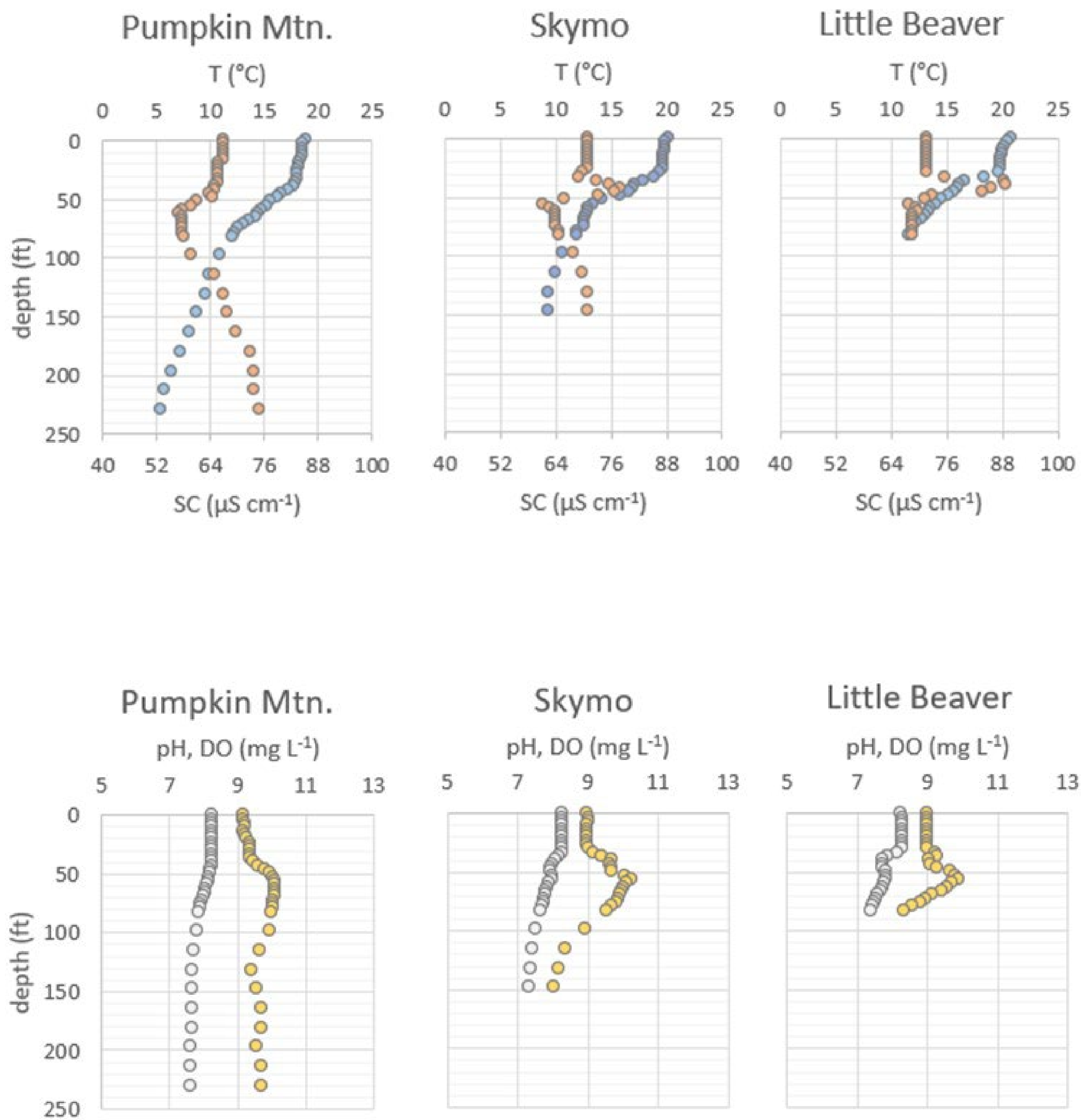


Figure A6-10. **Ross Lake, August 11, 2018. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

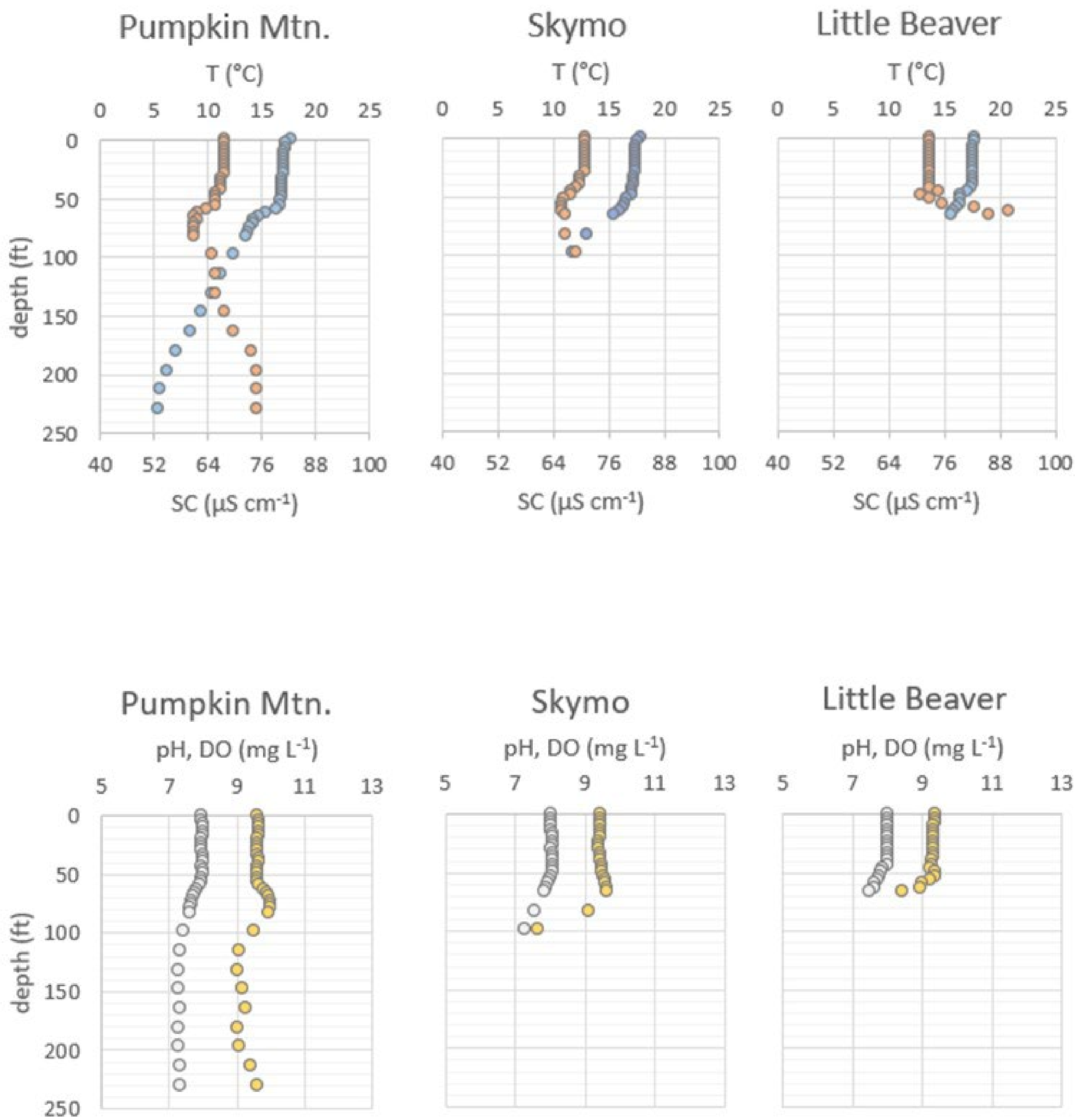


Figure A6-11. Ross Lake, September 15, 2016. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.

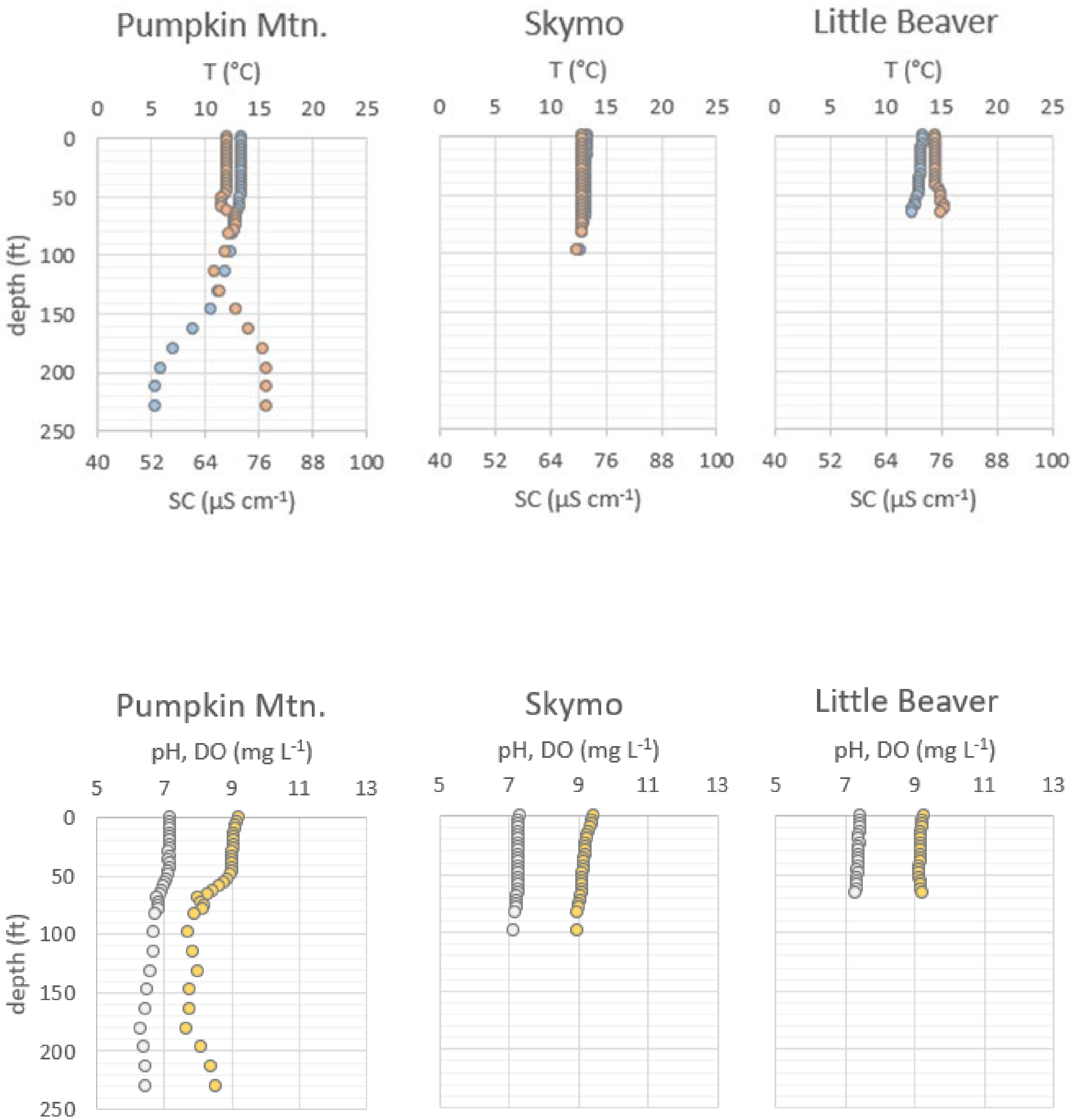
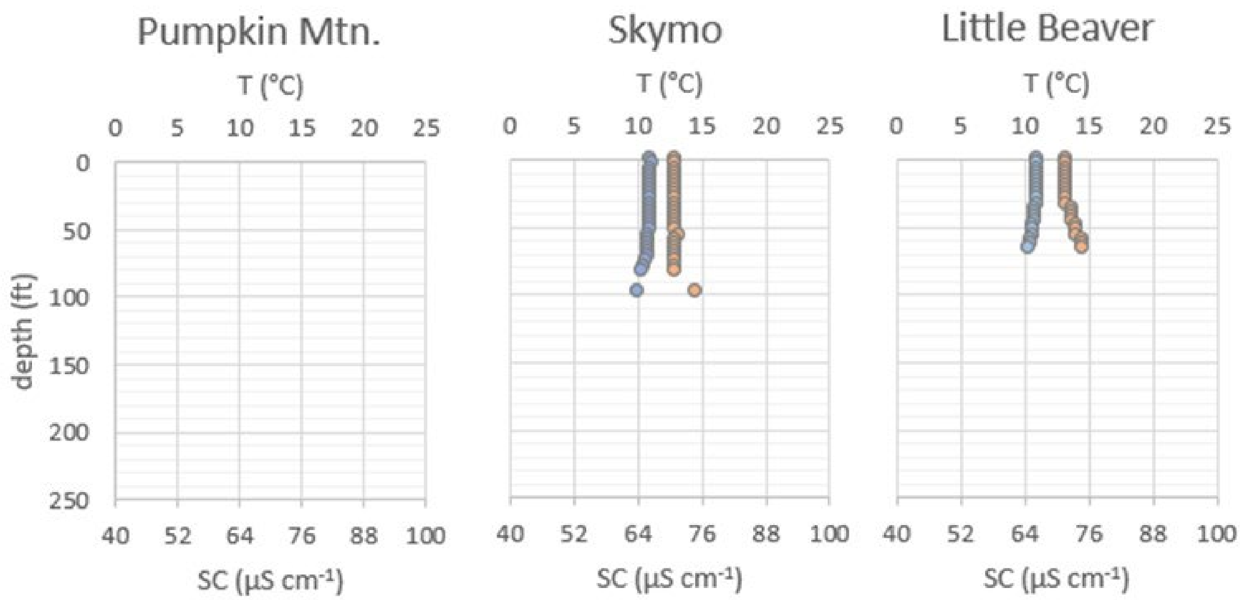


Figure A6-12. **Ross Lake, October 19, 2016. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**



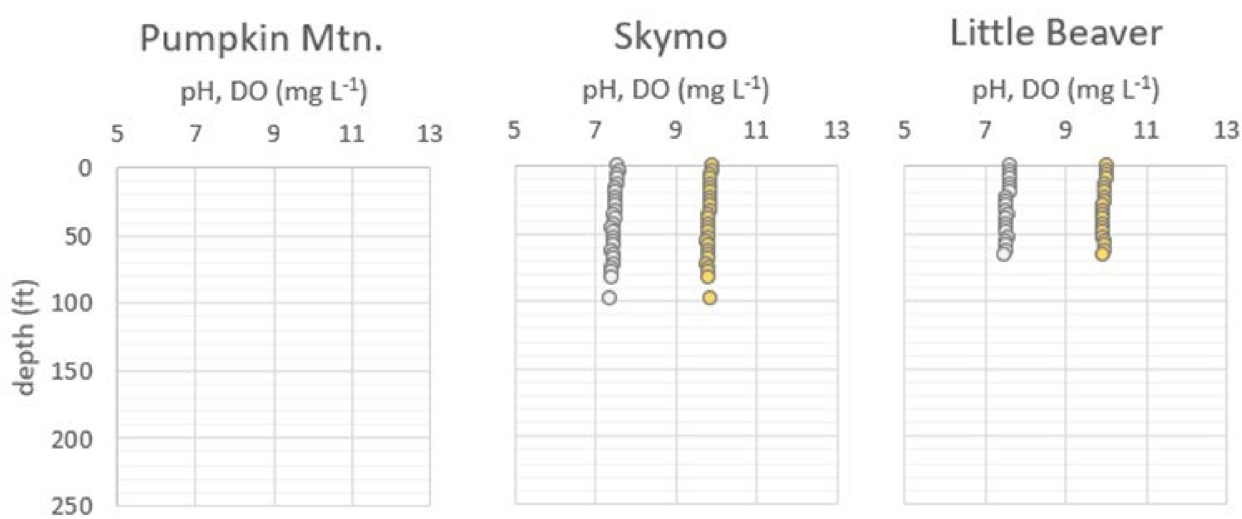
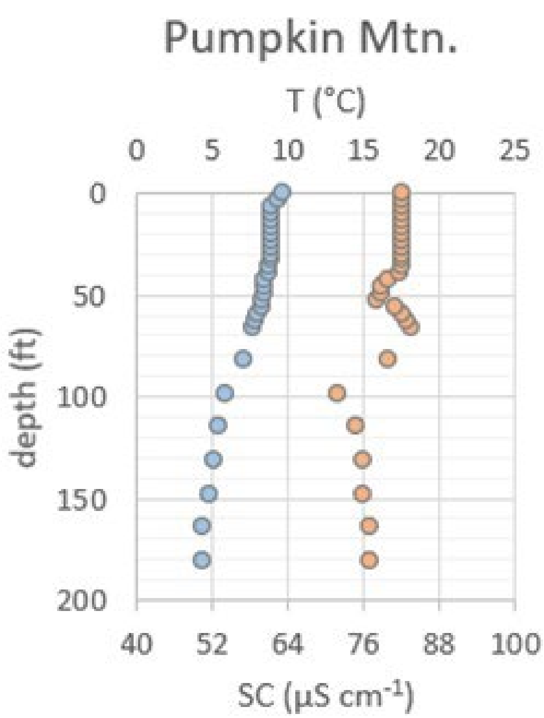


Figure A6-13. **Ross Lake, November 14, 2016. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**



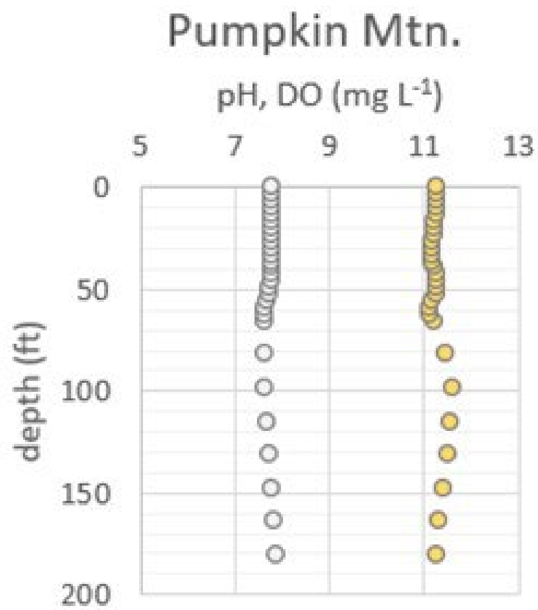


Figure A6-14. **Ross Lake, May 17, 2017. Left Panel: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Right Panel: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

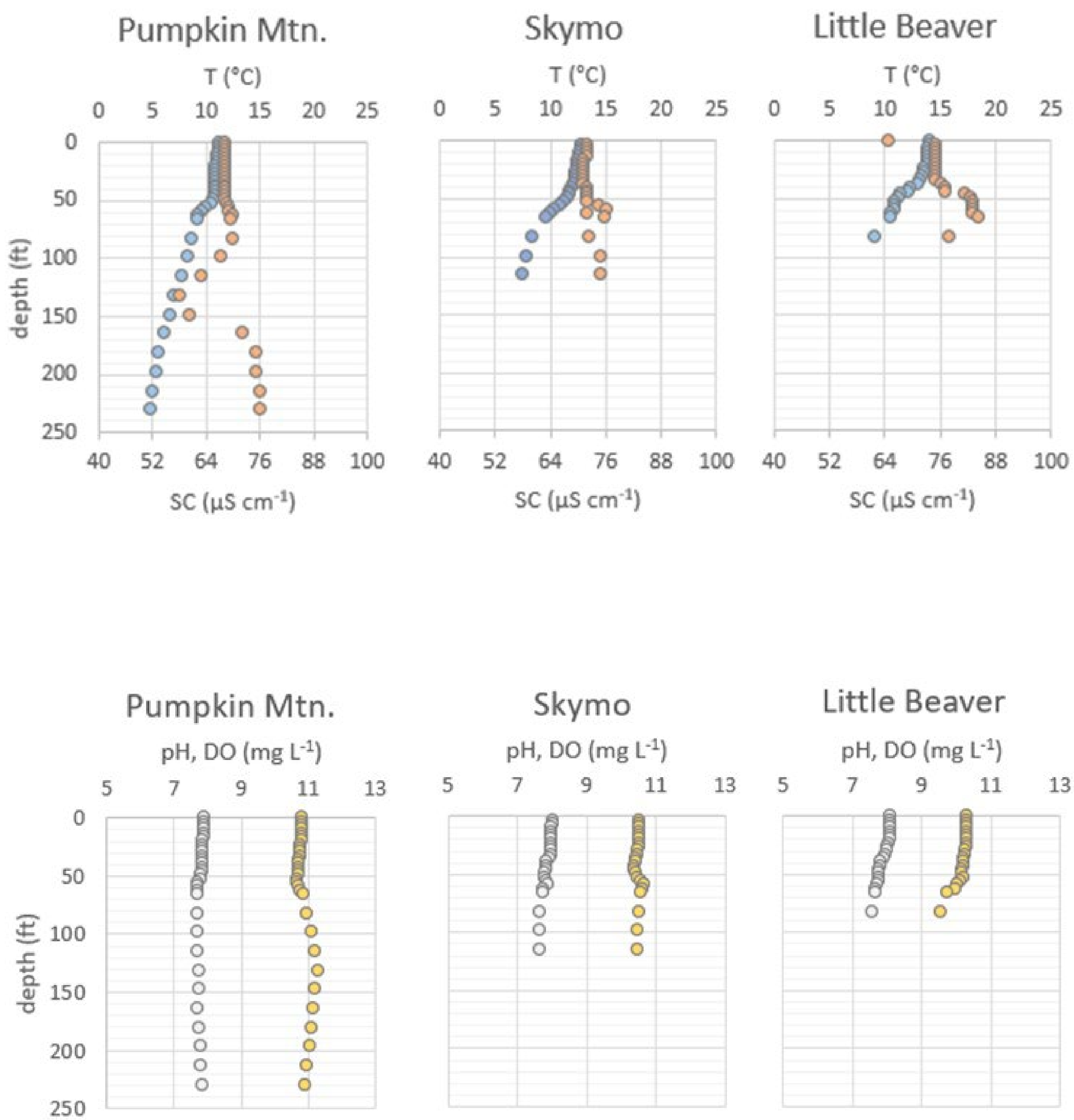


Figure A6-15. **Ross Lake, June 15, 2017. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

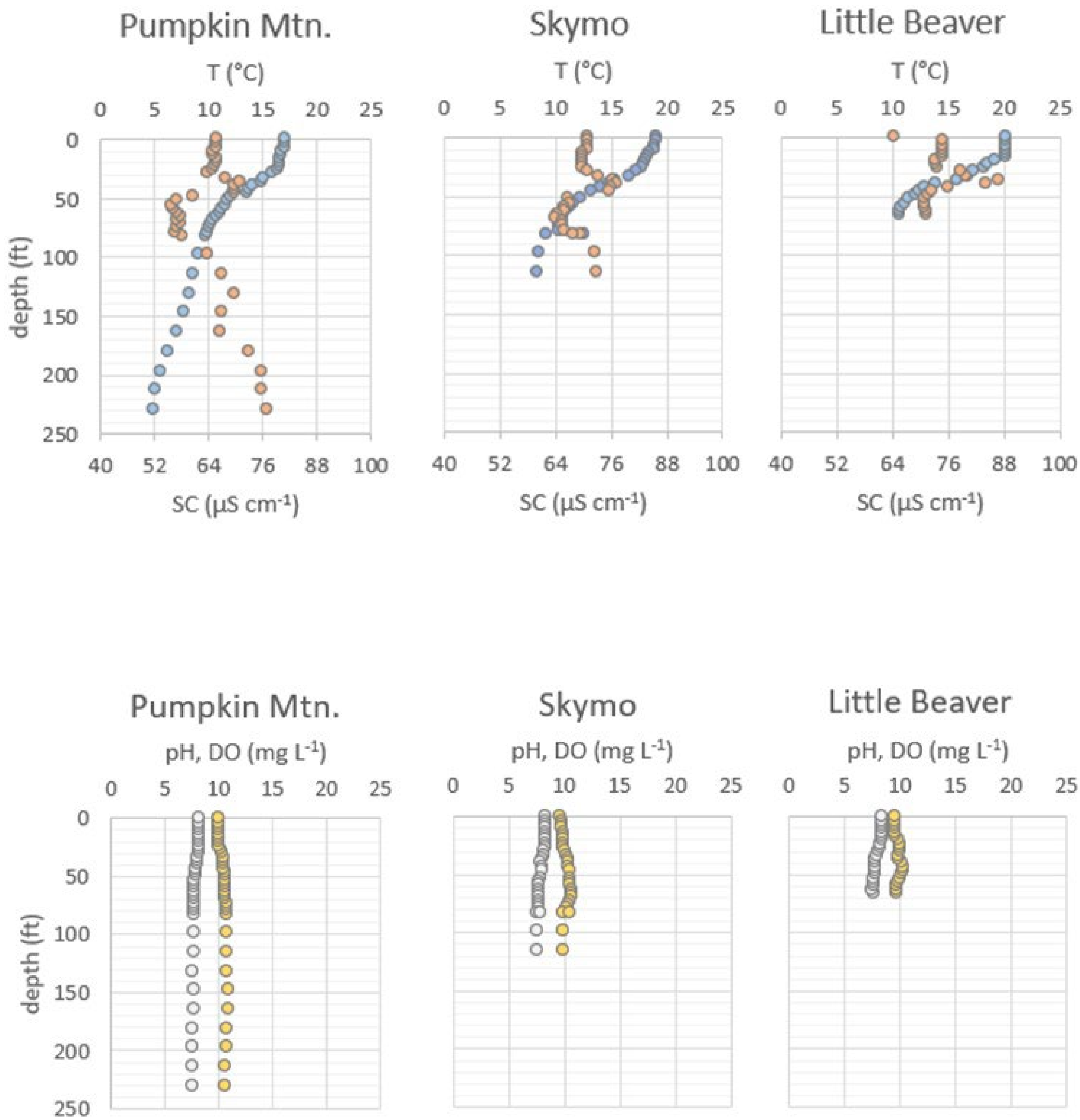
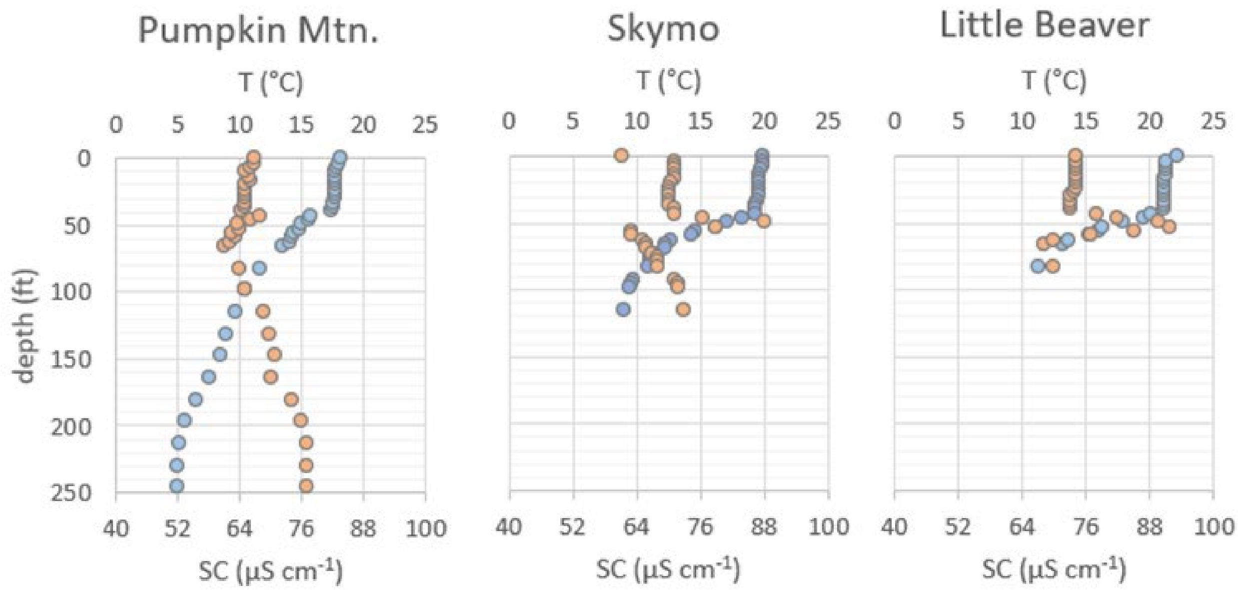


Figure A6-16. **Ross Lake, July 13, 2017. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**



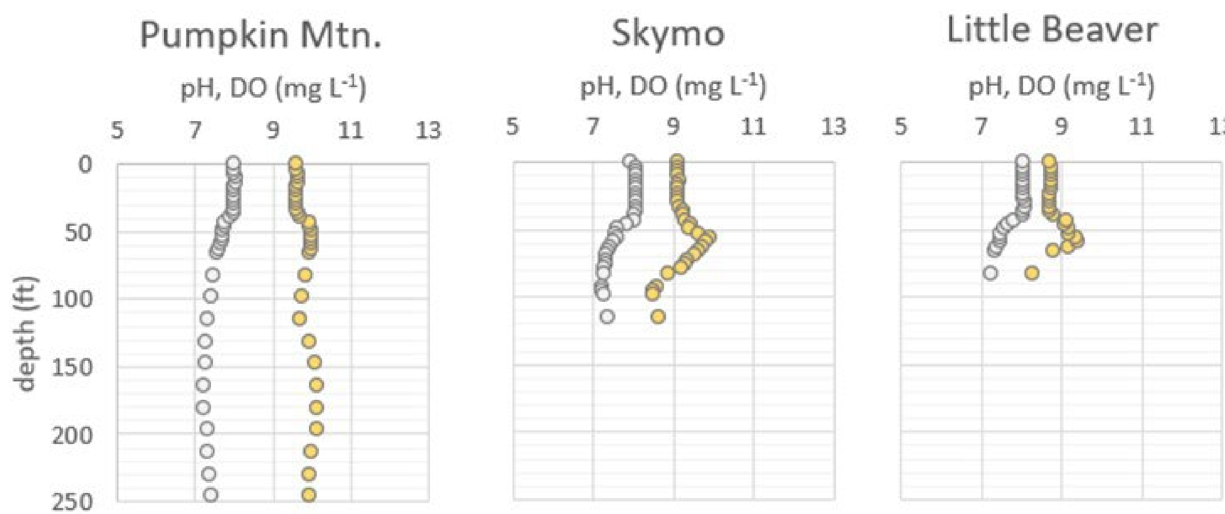


Figure A6-17. **Ross Lake, August 14, 2021. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

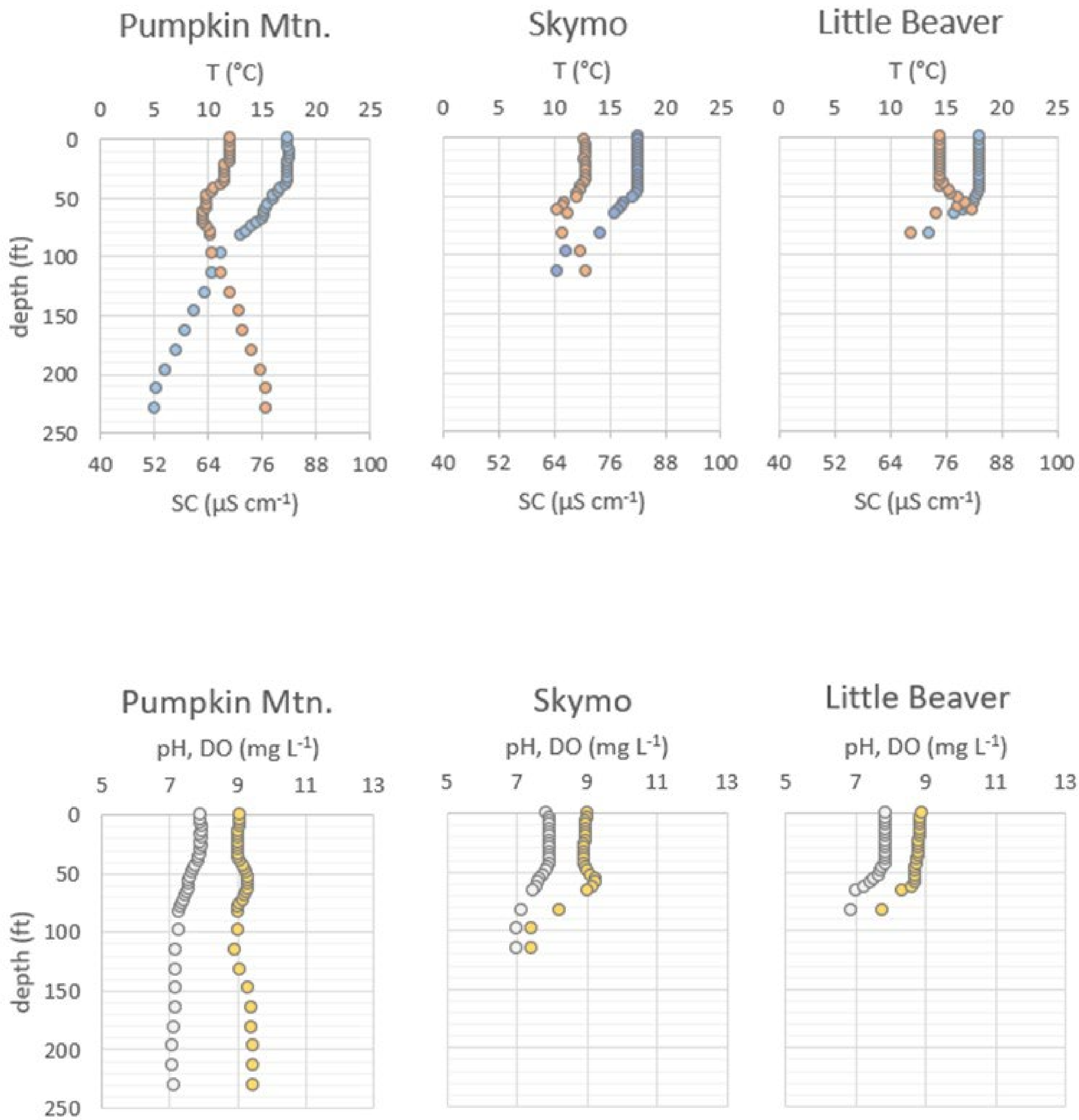


Figure A6-18. **Ross Lake, September 18, 2017. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

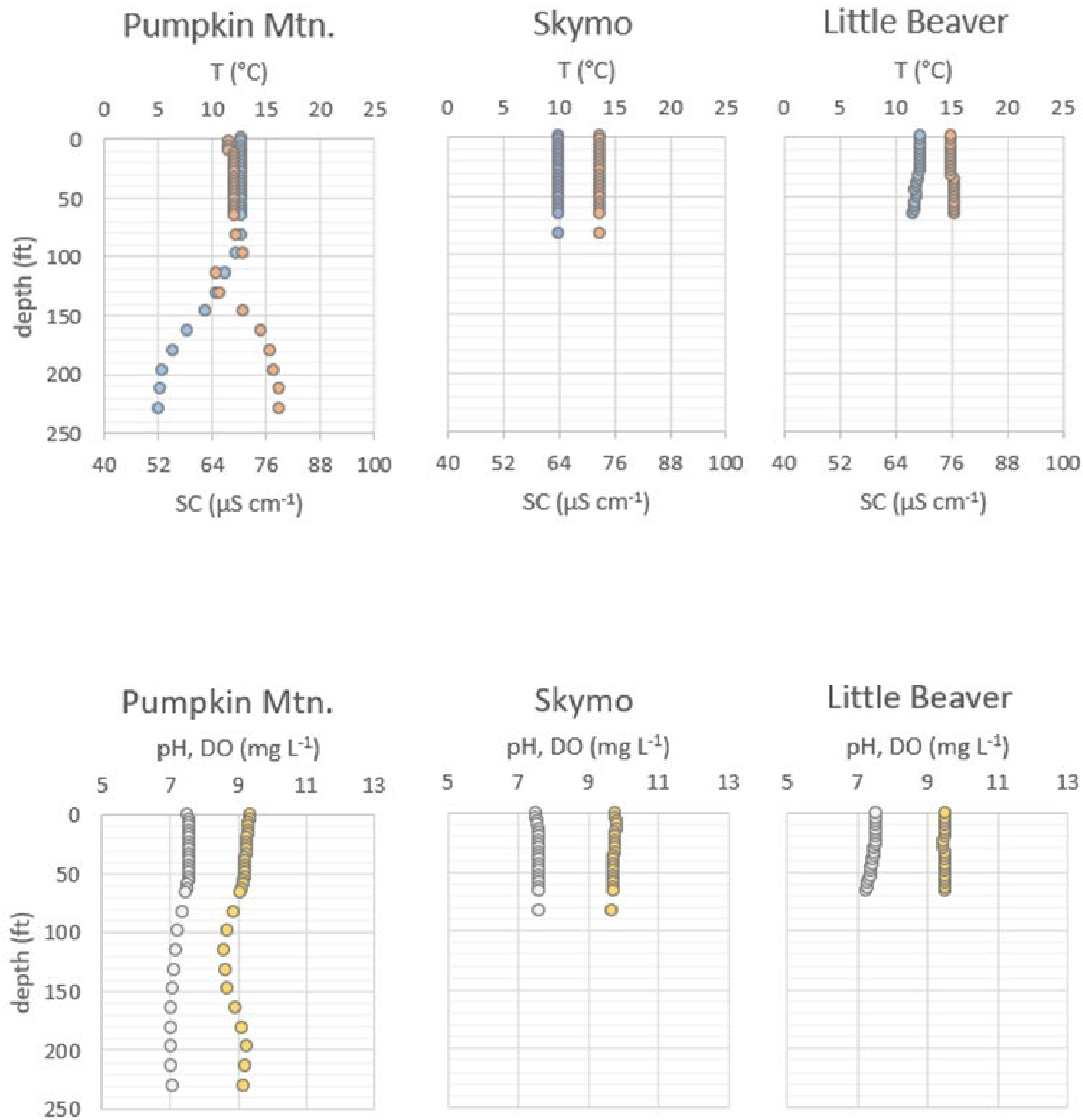


Figure A6-19. **Ross Lake, October 23, 2017. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

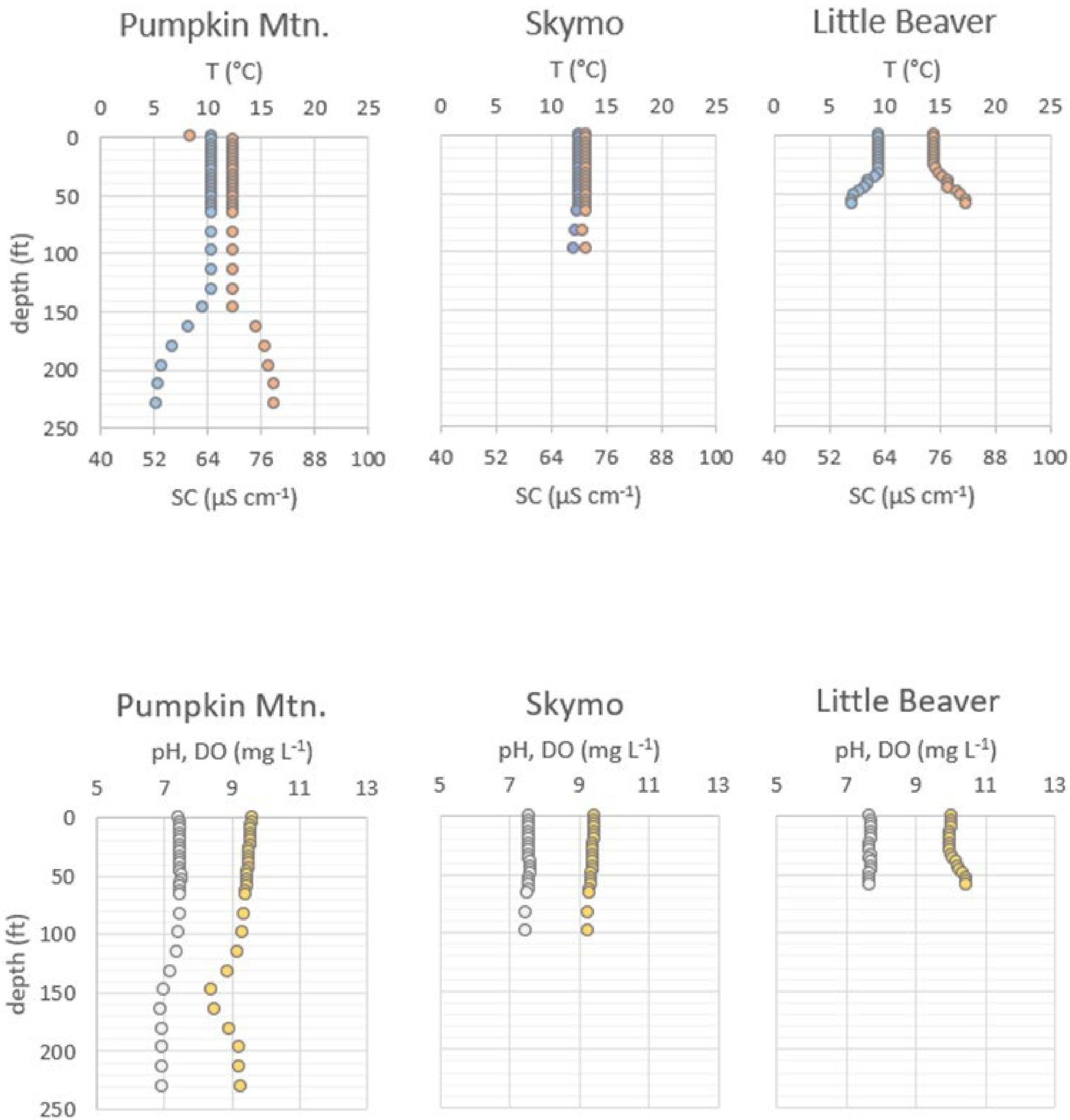
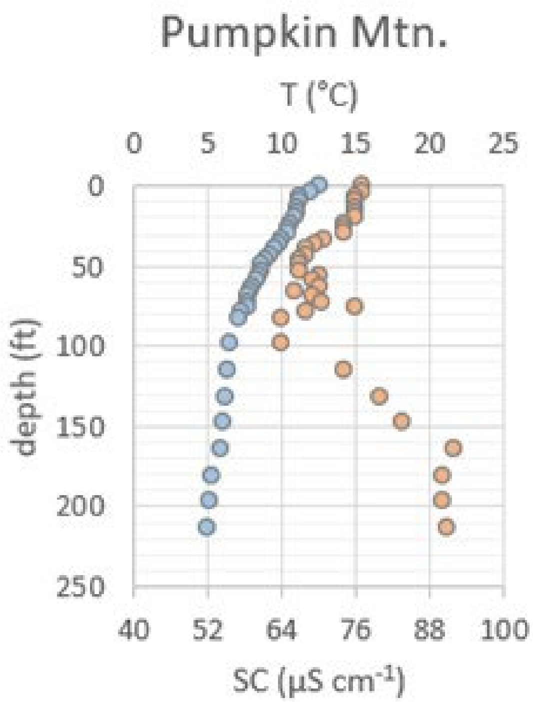


Figure A6-20. **Ross Lake, November 8, 2021. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**



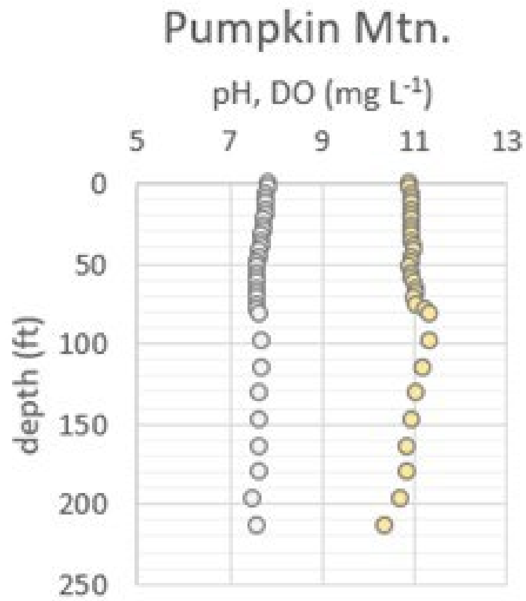


Figure A6-21. **Ross Lake, May 21, 2018. Left Panel: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Right Panel: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

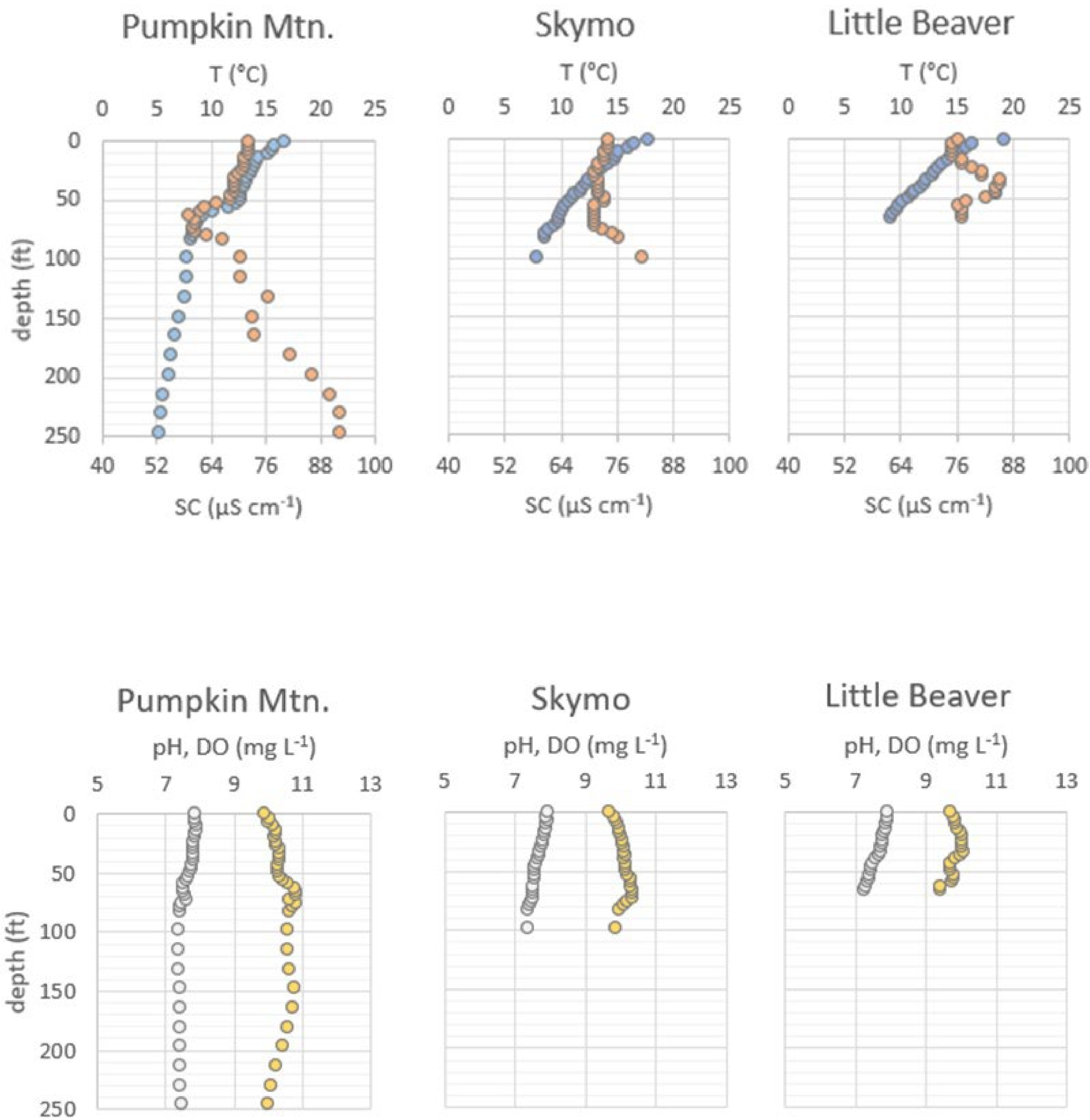


Figure A6-22. **Ross Lake, June 18, 2018. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

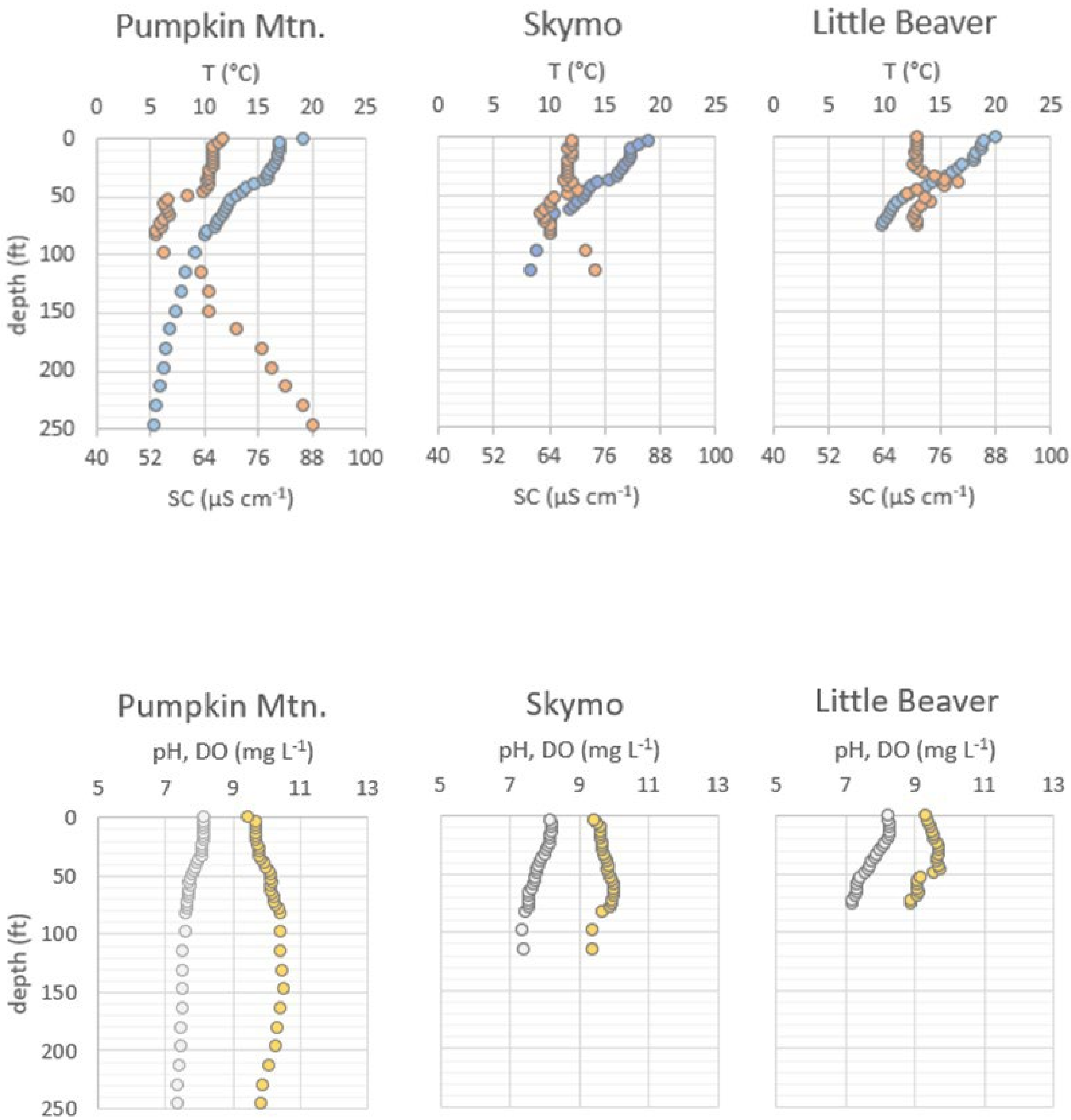


Figure A6-23. **Ross Lake, July 12, 2018. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

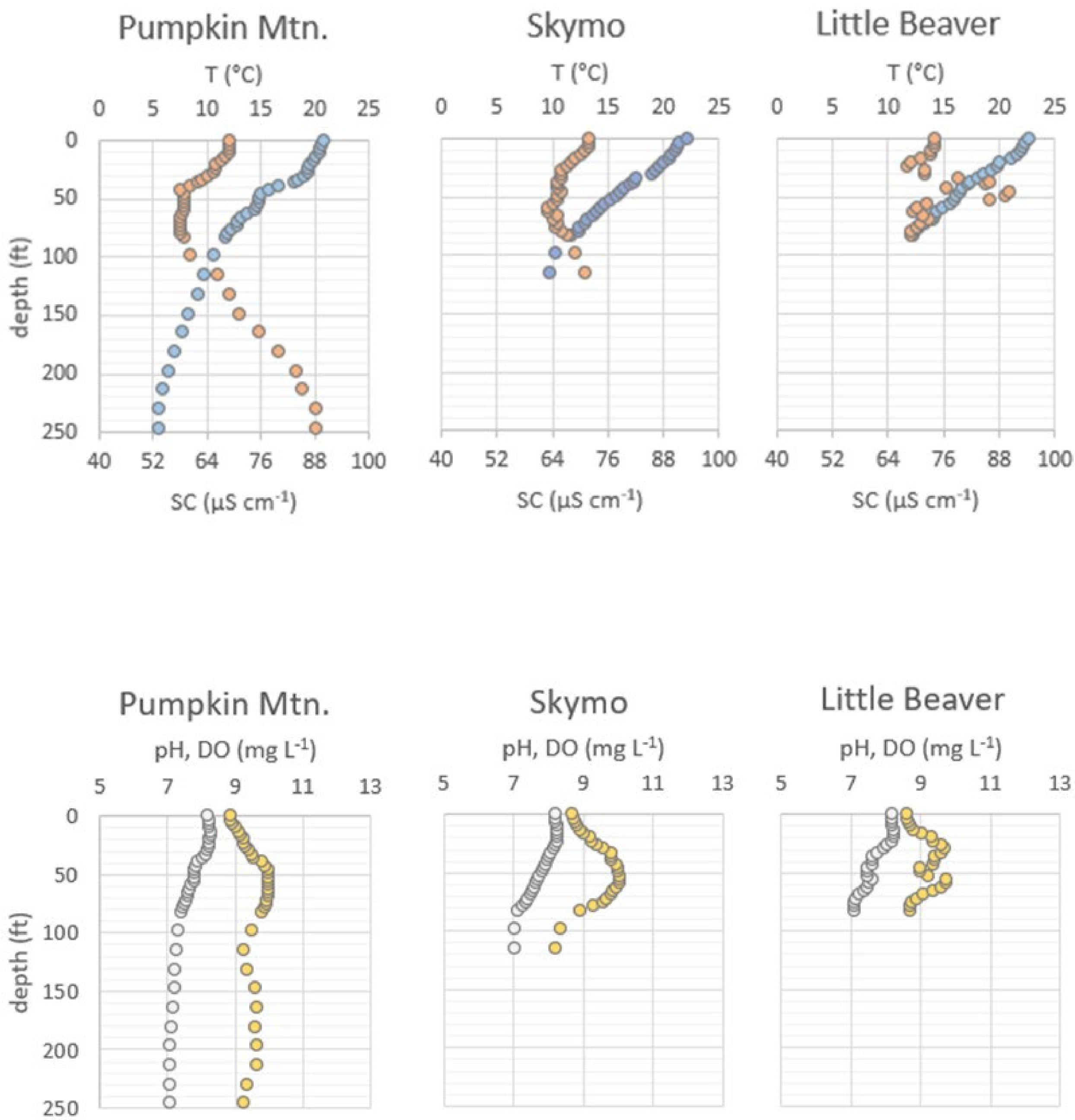


Figure A6-24. **Ross Lake, August 16, 2018. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

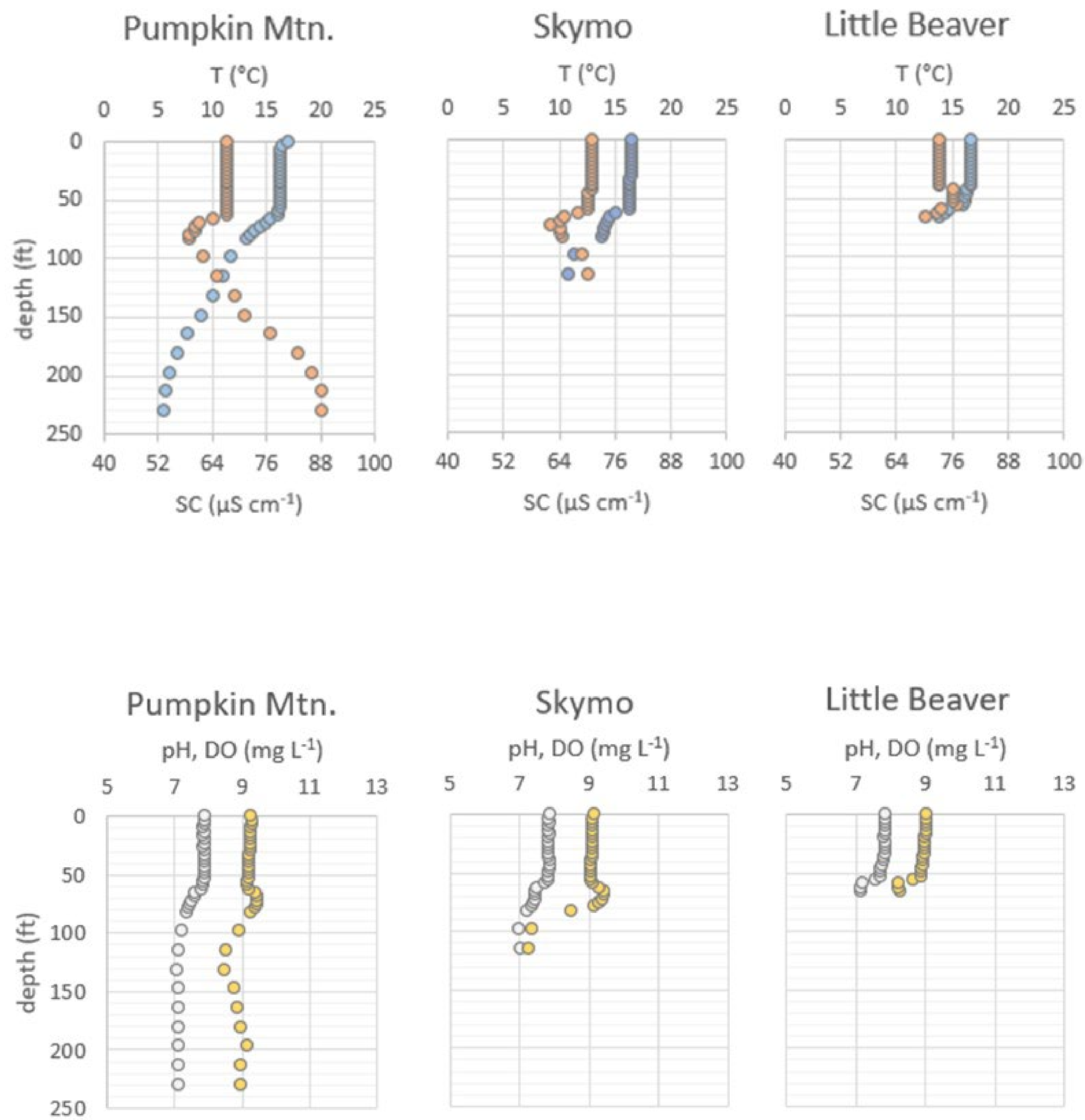


Figure A6-25. **Ross Lake, September 19, 2018. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**

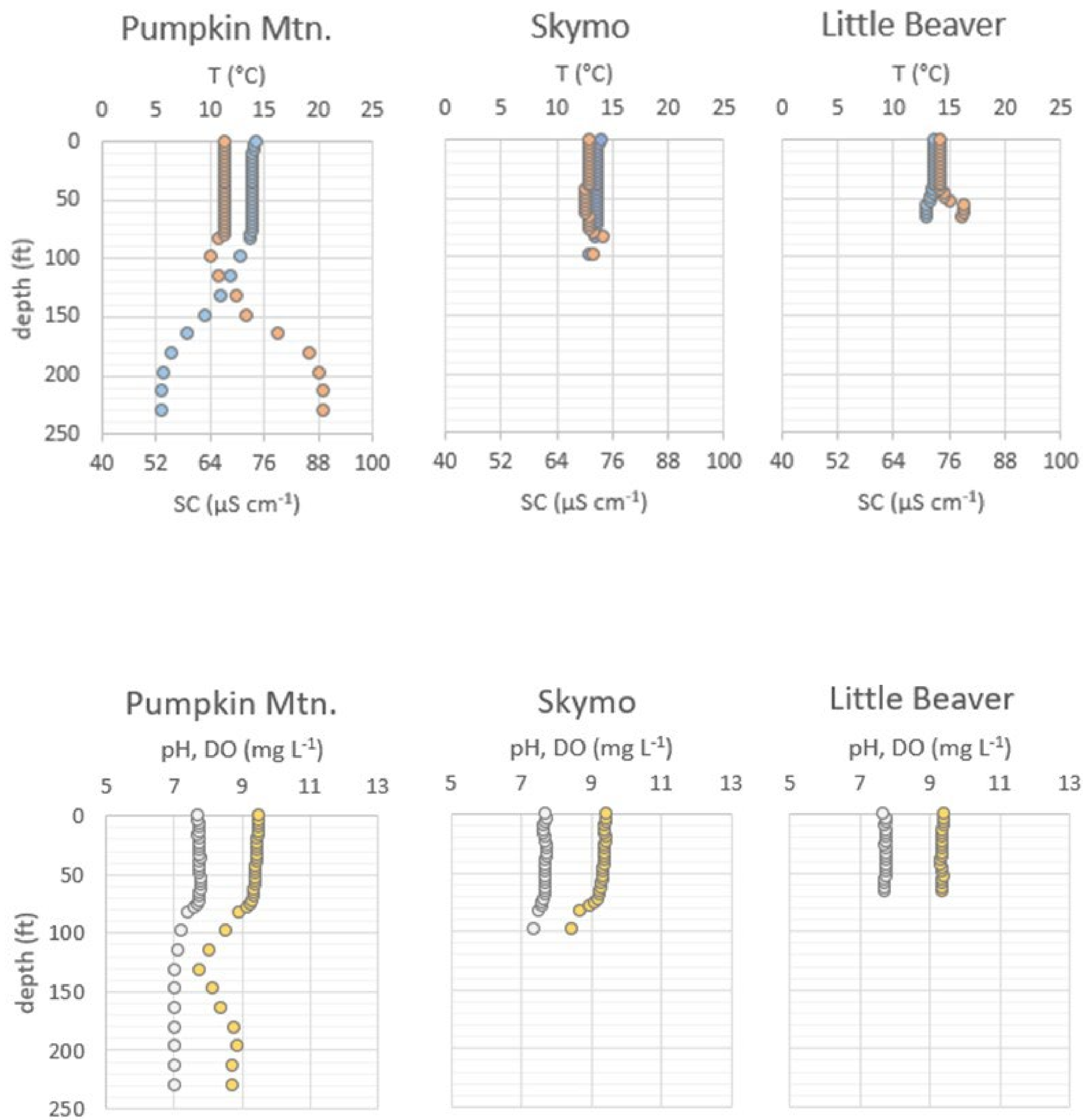
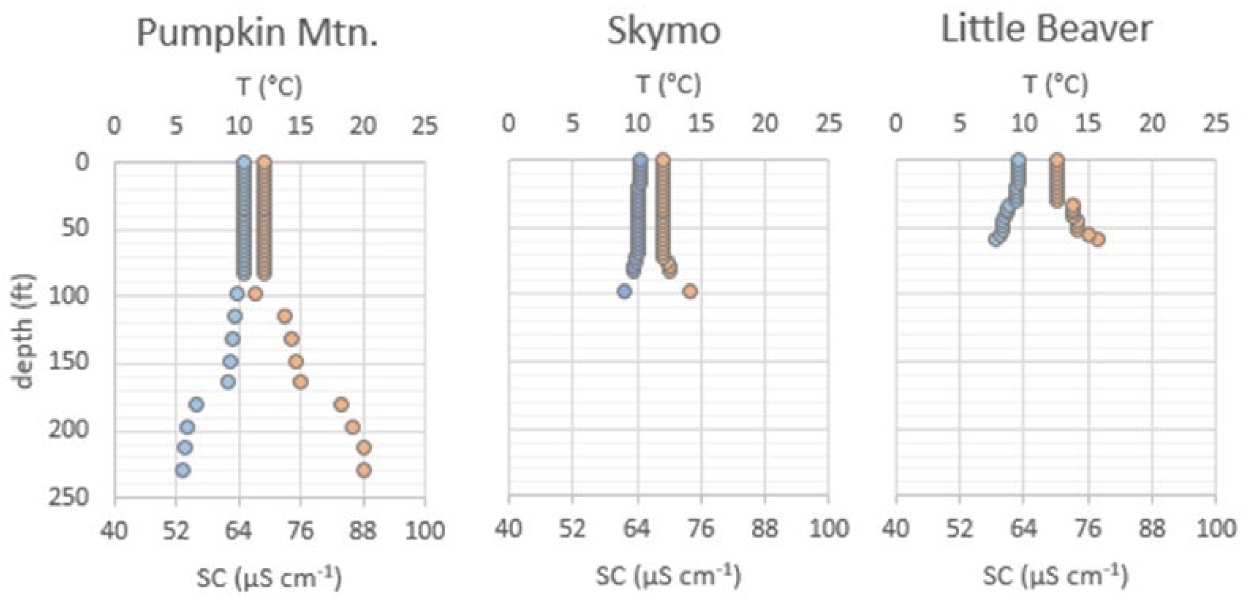


Figure A6-26. **Ross Lake, October 15, 2015. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.**



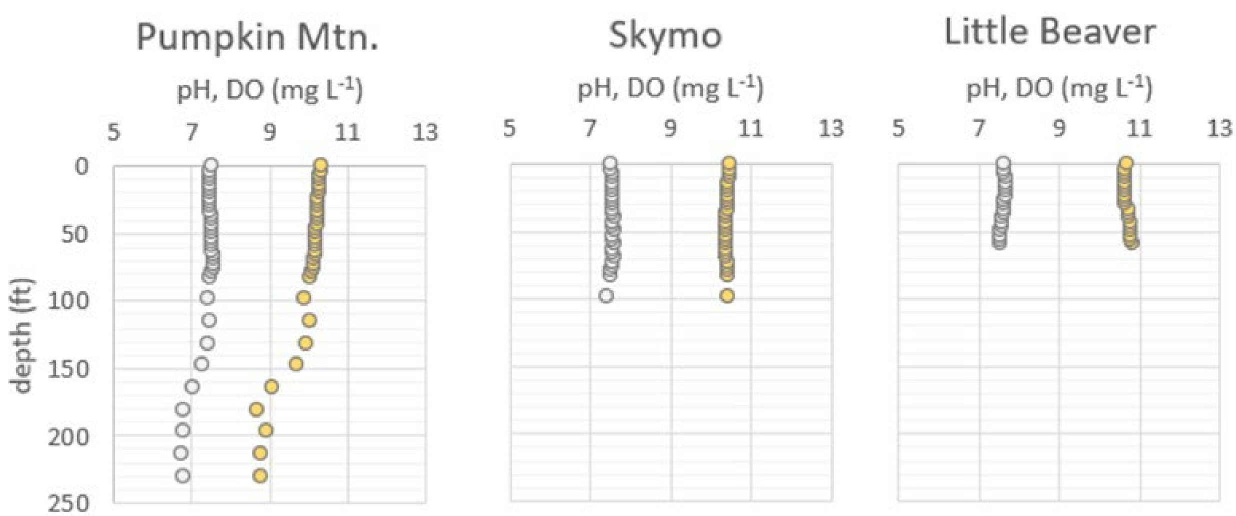


Figure A6-27. Ross Lake, November 19, 2018. Upper Panels: Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. Lower Panels: pH (white) and dissolved oxygen (yellow). See Appendices 1 and 2 for location information.

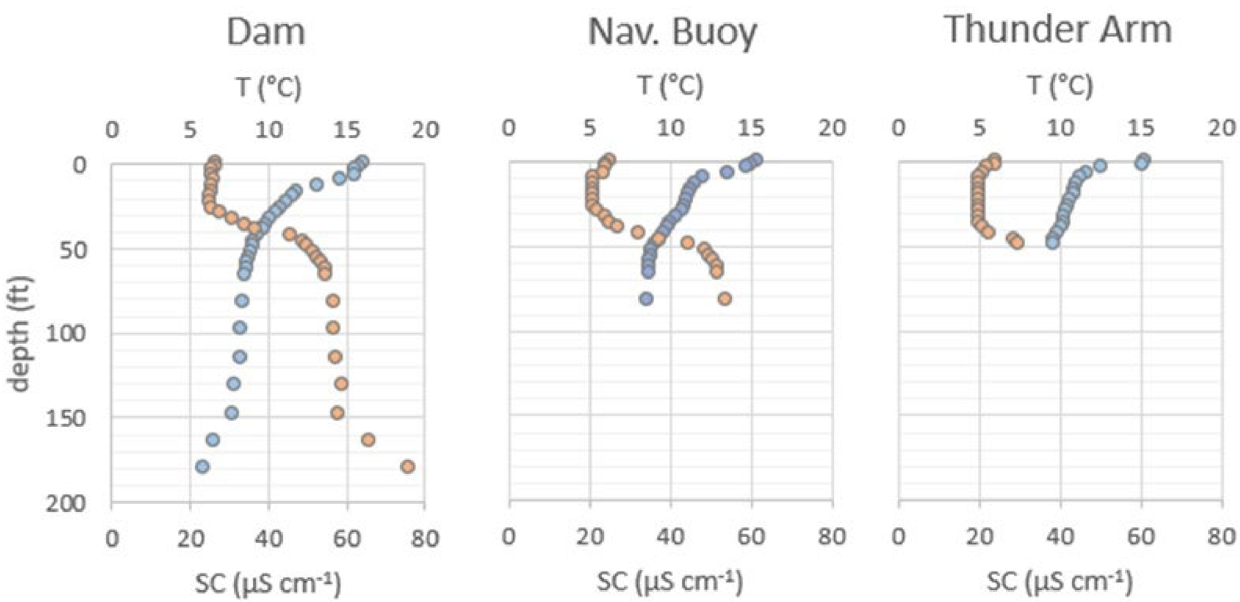


Figure A6-28. **Diablo Lake, July 17, 2018. Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. See Appendices 1 and 2 for location information.**

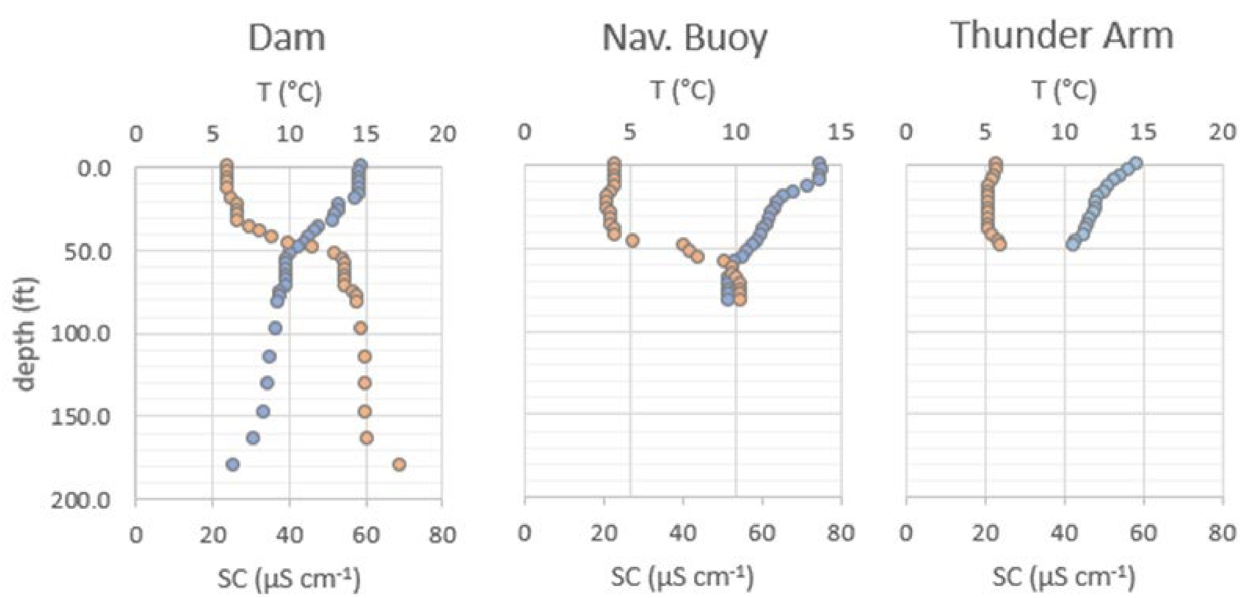


Figure A6-29. **Diablo Lake, August 14, 2018. Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. See Appendices 1 and 2 for location information.**

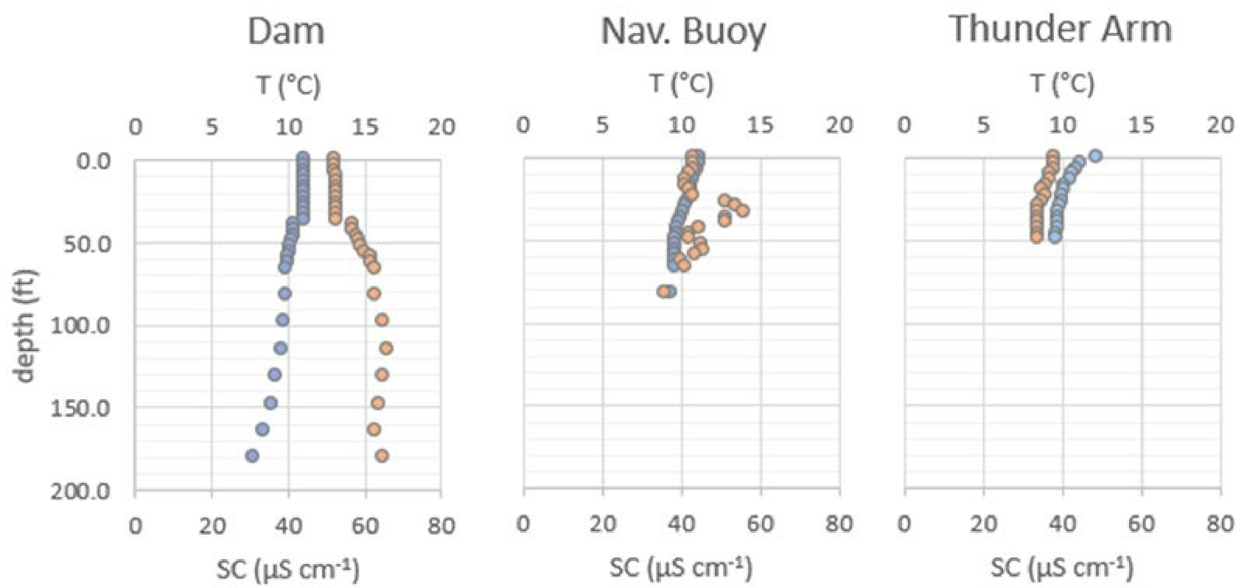


Figure A6-30. **Diablo Lake, September 25, 2018. Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. See Appendices 1 and 2 for location information.**

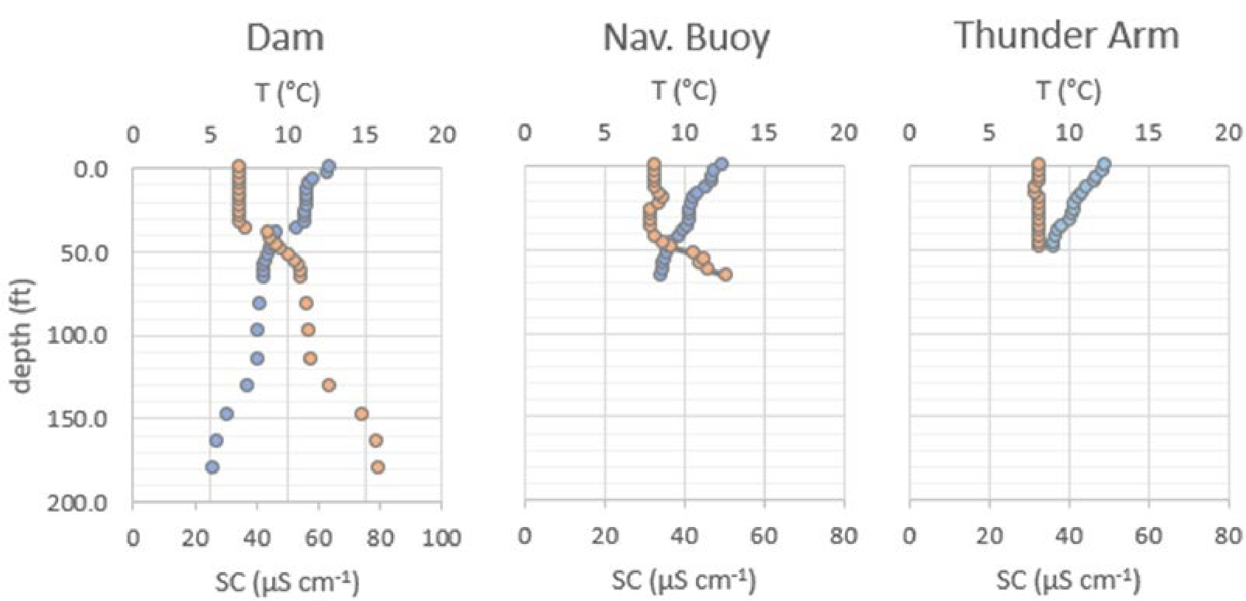


Figure A6-31. **Diablo Lake, June 10, 2019. Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. See Appendices 1 and 2 for location information.**

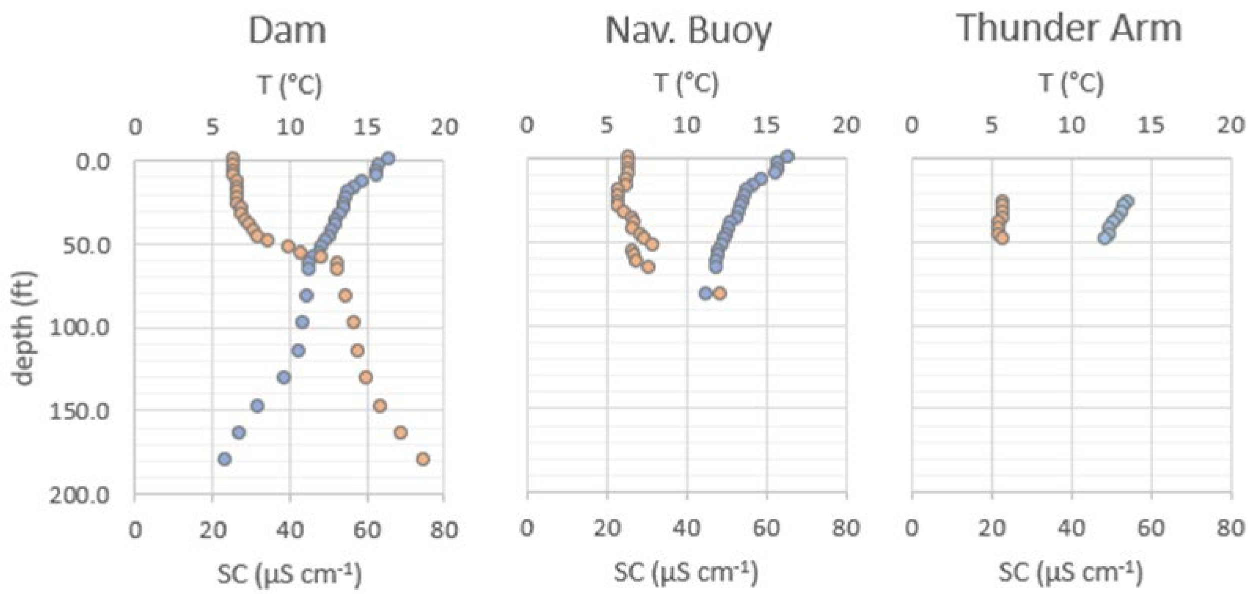


Figure A6-32. **Diablo Lake, August 15, 2019. Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. See Appendices 1 and 2 for location information.**

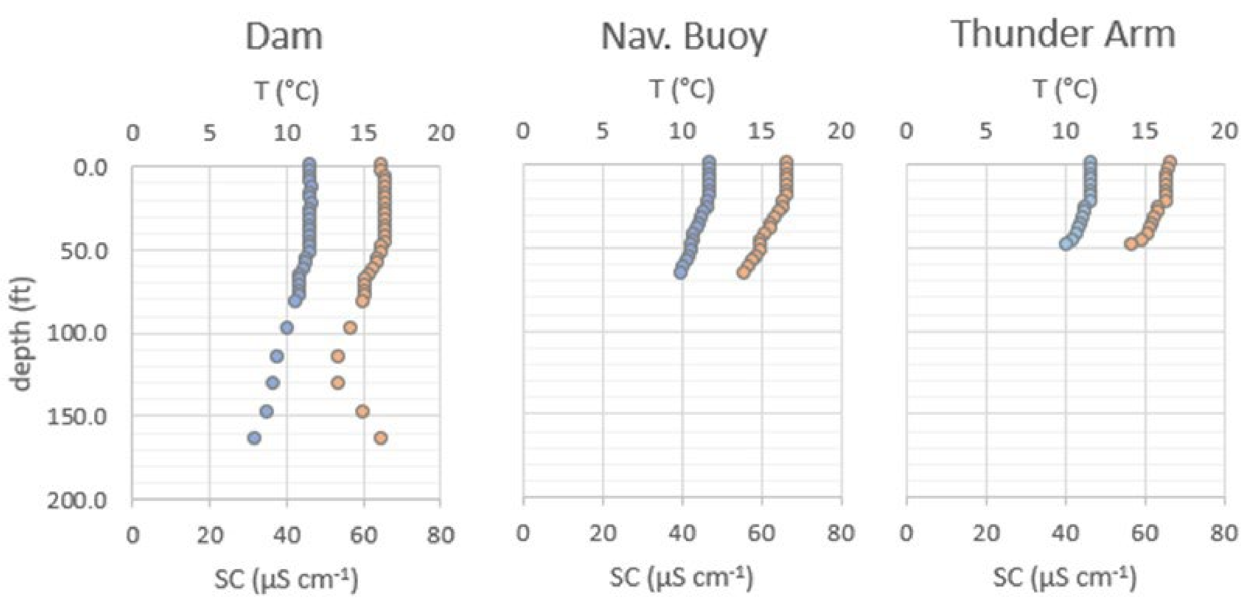


Figure A6-33. **Diablo Lake, October 17, 2019. Temperature (blue, upper horizontal axis) and Specific Conductance (orange, lower horizontal axis. See Appendices 1 and 2 for location information.**